STATE OF COLORADO
MINERAL RESOURCES BOARD

MINERAL RESOURCES of COLORADO

1947

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MINERAL RESOURCES BOARD
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Denver 2, Colorado

MINERAL RESOURCES of COLORADO

Prepared under the supervision of

JOHN W VANDERWILT
Consulting Geologist
Denver, Colorado

1947

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COLORADO MINING ASSOCIATION
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To His Excellency, The Honorable William Lee Knous, Governor of the State of Colorado, and Members of the Thirty-sixth General Assembly:

I have the honor to transmit herewith, the Bulletin of the State Mineral Resources Board on the subject "Mineral Resources of Colorado", by John W Vanderwilt and contributing authors.

It is hoped that this work will serve to stimulate increased activity in the mining industry, and that, this will be the first of many publications by the State Mineral Resources Board, to promote the welfare of Colorado's Mining Industry.

Colorado State Mineral Resources Board

Robert S. Palmer
Executive Director

204 State Office Building

1947

STATE OF COLORADO
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MINERAL RESOURCES OF COLORADO

PART I.

METALS, NONMETALS, AND FUELS

By John W Vanderwilt
Consulting Geologist
Denver, Colorado

PART II.

SUMMARIES OF MINING DISTRICTS AND MINERAL DEPOSITS

Prepared by the United States Geological Survey,
under the general supervision of
W. S. Burbank

PART III.

INVESTIGATIONS OF STRATEGIC MINERAL RESOURCES

By W. M. Traver, Jr.
United States Bureau of Mines

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By W. M. Traver, Jr.

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FOREWORD

The Colorado State Mineral Resources Board was created by Legislation enacted by the Thirty-first General Assembly of the State of Colorado through the passage of H. B. No. 1020 (Chapter 217, Session Laws of 1937). This Act created an agency through which cooperative programs between federal and state governments can be secured.

The Board consists of nine members, appointed by the Governor of the State of Colorado, and an Executive Director who is also Executive Director of the Colorado State Board of Directors of the Metal Mining Fund. The Governor is Ex-Officio Chairman of the Board.

The Board was created during the period in which the federal government was active in a Public Works' Program, and was designed to be a cooperative agency between the State of Colorado and the Federal Government. It was specifically created to plan and develop drainage tunnels, tailing disposal and milling projects, and in line with these general objectives it is quite possible for the Board to direct its efforts to studies and surveys of mineral resources and mineral development, and also to studies and surveys leading to the construction of power projects.

The Board's only official source of revenue is such moneys as are appropriated by the State Legislature from the general funds of the State. During the first few years of its existence no moneys were appropriated for the use of the Board by the State Legislature.

In 1938 the Board constructed an earth-filled dam at the town of Fairplay to take care of tailings from the mills and placer mines of the Alma-Fairplay District. Agreements were entered into with the water users below the dam and the miners of the area. To finance the dam construction bonds were issued by the Board and the mine operators were assessed on a basis of tons milled and gravel washed. The project was highly satisfactory to all parties concerned and the Board paid all bonds in full, with interest.

In 1941 the State Legislature granted the Board $5,000.00, which was used to make a survey of the mining claims of the State. Claim owners were contacted to obtain all possible information in an effort to discover why many mining claims were not working, and to determine the principal minerals in each claim. The report was compiled and typed, but there were insufficient funds for printing.

The Board also received from the Nicholson Estate a legacy which enabled it to cooperate with the Federal Government in conducting a geophysical survey to determine the proper location and course of a deep drainage tunnel in the Leadville area.

The State Legislature in 1945 was more generous with the Board and granted funds with which the Board has been able to compile information used in the construction of a huge topographical map, showing in detail the topography of the State of Colorado and its mineralized areas. It also provides a way for the average person to find the exact location of the mineral resources of the State and a key to the map indicates the exact production and gives other statistical data relating to the map.

In addition to the above it was decided to employ a competent geologist to conduct a survey of the mineral resources and some of the mineral developments in the State. The Board employed Dr. John W Vanderwilt for this purpose, and the results of his work are contained in this bulletin.

It is the sincere hope of the Board that this bulletin will be of real assistance to those who seek information regarding the mineral resources of the State of Colorado.

COLORADO STATE MINERAL RESOURCES BOARD

Walter E. Scott, Jr., *Chairman*

PART 1. METALS, NONMETALS, AND FUELS

By John W Vanderwilt

PREFACE

This summary report of the mineral resources of Colorado has been prepared primarily as a ready aid to those who will continue development of these resources, and with this aim all data herein were selected for their relative importance and utility.

Personal opinions regarding many mineral deposits and areas have been omitted; for, although past mineral production may be a reliable guide to the relative importance of some areas, small production from an area may contribute evidence so important as to justify further exploration and development. However, extended discussions of some production records that are small in dollar value might be interpreted as being promotional. Here, also, as in other mining states, too little consideration may have been given to nonmetallic mineral deposits.

Statements regarding the mineral resources of any region are commonly exaggerated, some asserting that the surface has hardly been "scratched" and others alleging that the mineral resources are largely depleted. The optimist may not know that relatively old prospect shafts and tunnels are common in all mining regions—even in remote and seemingly unpromising areas—and the pessimist may not have considered the record of the mineral discovery and production during the last twenty years.

Colorado has large reserves of many nonmetals and offers excellent opportunities to develop new deposits of metals. The extension of ore in depth in the San Juan region in the last few years has changed a former pessimistic outlook to one of optimism. Continued improvements in metallurgy and extensions in electric power. distribution are likely to occur, that will favor further development of mineral deposits. However, merely saying that mineral resources are available or can be developed is not sufficient. It is essential that work is expended to find, develop, and produce mineral products; only if this is done can mineral resources become ore reserves.

Part 1 of this report is largely selections from published reports, supplemented by unpublished data.

Part 2 summarizes published and unpublished geologic studies made by geologists in the United States Geological Survey during the past twenty years in cooperation with the Colorado Geological Survey Board and the Colorado Metal Mining Fund. Most of the summaries were prepared by the geologists who made the original investigations.

Part 3 is a summary of investigations of strategic mineral resources made by the U. S. Bureau of Mines during the war.

ACKNOWLEDGMENTS

This report was prepared with the assistance of associates, friends, and members of the United States Geological Survey, the United States Bureau of Mines, the Board of Directors of the State Metal Mining Fund, and the State Bureau of Mines, who because of their large number can herewith be thanked only collectively for their generous cooperation. J. Douglas Brawner, Jr., assisted in compiling the data on coal, oil, gas and other nonmetallic minerals and materials.

The map, Metallic Mineral Deposits of Colorado, plate 4 (in pocket), was prepared and published by the United States Geological Survey, 1946.

Part 2 was prepared under the supervision of W. S. Burbank, United States Geological Survey, who has contributed many excellent published data on the geology and mineral resources of the State.

Part 3 was written by W. M. Traver, Jr., of the United States Bureau of Mines.

TOPOGRAPHY

A knowledge of the geography and physiography of the mountains, valleys, and plains is helpful in understanding the problems of access, transportation, and weather in an area or mining district.

Colorado is well known for its high mountains that dominate the western half of the State, and for the Great Plains extending eastward into Nebraska, Kansas, and Texas. Near the New Mexico boundary, lava flows resting on soft sedimentary formations form broad tablelands and a distinct rugged topography.

The northern part of the Great Plains in Colorado is drained by the South Platte River and the southern part by the Arkansas River. Near the eastern border of the State the elevation above sea level is 3,400 to 4,000 feet, and this increases to about 5,300 to 6,000 feet in the foothills west of Boulder, Denver, and Canyon City. Palmer Lake, on the foothills divide between the South Platte River and the Arkansas River, is 7,225 feet above sea level.

The heads of four important drainage basins are in the mountains of Colorado. The South Platte River, the Arkansas River, and the Rio Grande drain into the Gulf of Mexico, and the Colorado River flows into the Gulf of California. Tributaries of the South Platte and the Arkansas begin a hundred miles west of the eastern foothills of the Front Range, and the Rio Grande heads in the northeast slopes of the San Juan Mountains in the southwestern part of the State.

The Continental Divide, separating the east and west drainage, follows a winding course from north to southwest in part along and across the north- and northwest-trending mountain ranges. Many of the mountain peaks over 14,000 feet in altitude are either east or west of the Continental Divide, and relatively few are on it. The topographic forms express the major structural arches and troughs, but deep canyons, glacial erosion, and in places extensive lava flows, tend to obscure even strong mountain structures.

The general term Rocky Mountains includes several high mountain ranges with cores of crystalline rocks and intermountain areas usually of sedimentary rocks commonly called parks or valleys. The first mountain group visible from the Great Plains and bordering them is the Front Range extending north into Wyoming and south to the Arkansas River. Farther south the Wet (Greenhorn) Mountains and the Sangre de Cristo Range bound the Great Plains on the west. The Front Range is 30 to 40 miles wide and includes numerous high precipitous peaks, broad glaciated valleys, and narrow canyons. The Wet Mountains are only 10 to 12 miles wide and the Sangre de Cristo Range is still narrower, although the peaks are high in the latter and there are only a few passes suitable for a highway or railroad.

West of the Front Range is a parallel series of intermountain areas commonly called parks. These areas are generally underlain by sedimentary formations that extend well up on the flanks of the bordering mountains, where the beds end in folded or faulted zones. North Park is bounded on the east and west by high mountains, and extends from the Wyoming boundary southerly to Middle Park, which, in turn, extends along the valley of the Blue River to Dillon and Breckenridge. Only 10 to 15 miles south of Breckenridge is the head of South Park, which, with Wet Mountain Valley, extends to Walsenburg, where it joins the plain. Flanking these intermountain areas on the west are four high, rugged, though narrow (5 to 10 miles), mountain ranges named from north to south: Park Range, Gore Range, Mosquito Range, and Sangre de Cristo Range. The Park Range continues north into Wyoming and the Sangre de Cristo south into New Mexico.

The Sawatch Range is a broad elongate domal uplift separated to the east from the Mosquito Range by the Arkansas Valley. The axis of the Sawatch Range trends northwest and thus diverges from the more northerly-trending Park-Sangre de Cristo Ranges. In line with the Sawatch Range to the northwest and in sequence are the White River Plateau, Danforth Hills, Yampa Plateau, and the east end of the Uinta Mountains of Utah. The more open area around Craig is a southeast extension of the Green River Basin that centers in Wyoming.

Southwest of the Sawatch Range-Uinta Mountains belt, a broad parallel intermountain zone includes from northwest to southeast the Roan Plateau, Battlement Mesa, Grand Mesa, West Elk Mountain, Cochetopa Hills, and the San Luis Valley. Paralleling these on the southwest are the Uncompahgre Plateau, a structural arch, and the San Juan Mountains composed of extensive volcanic flows of Tertiary age.

Large areas of the mountain ranges are well over 10,000 feet above sea level and 54 peaks are in excess of 14,000 feet. The intermountain areas also are relatively high, as is shown in the following list of towns at approximately the lowest parts of more prominent areas.

		Elevation
North Park	Walden	8,340 ft.
South Park	Hartsel	8,860 ft.
	Fairplay	9,964 ft.
Wet Mountain Valley	Westcliffe	7,860 ft.
Arkansas Valley	Buena Vista	7,800 ft.
	Leadville	10,182 ft.
San Luis Valley	Alamosa	7,531 ft.
	Monte Vista	7,663 ft.

Other elevations are shown in the table of climatological data in table 1, page 5.

The differences in altitude bring out the rugged topography that bears directly on access and transportation problems. The difficulties to be expected often are more closely related to differences in altitude than to distance in miles.

Altitude also is stressed because it is an excellent guide for estimating the climate and weather to be expected in the mining areas, most of which are in mountainous areas lacking weather stations.

CLIMATE

Climate in Colorado is as diverse as the topography. The extreme contrast is brought out by the fact that the difference (35° F.) in mean temperature between Lamar (altitude 3,615 ft.) and the summit of Pikes Peak (altitude 14,109 ft.) is as great as it is between Florida and Iceland. Lamar is only about 140 miles southeast of Pikes Peak, and the contrast in climate is due largely to the difference in altitude.

Table 1 shows the extremes in temperature and precipitation for a number of towns listed according to altitude in the principal drainage basins selected as representative for the State. The data are from the United States Weather Bureau report. The record for 1944 is used because the deviations from the normal are not large, and the annual precipitation was close to a 57-year average.

It will be noted that the lowest winter temperatures are not always at the highest altitudes, but that the highest summer temperatures do occur at the lower altitudes. As would be expected, the snowfall is greater at higher altitudes than at lower altitudes. The monthly and annual mean temperatures (table 2) show a more consistent relation to altitude in each drainage basin, and table 3 shows the relation of monthly mean temperatures to altitude, irrespective of location in the State.

Weather in general is influenced also by air currents dependent on near-by mountain peaks, ridges, mountain passes, and valleys, but the overall effect probably does not equal the effect of altitude. Personal observations indicate that on the average the winters at

Table 1. Highest and lowest temperatures, precipitation, and sky in Colorado in 1944

Station	County	Temperature, degrees Fahrenheit: Elevation, feet	Length of record, yrs.	Annual mean	Highest	Date	Lowest	Date	Precipitation, in inches: Length of record, yrs.	Total for the year	Greatest monthly	Month	Least monthly	Month	Total snowfall	Sky: Number of rainy days	Number of clear days	Number of partly cloudy days	Number of cloudy days	Prevailing direction of the wind
Arkansas Drainage Basin																				
Holly	Prowers	3,385	43	53.4	100	Sept. 23	—5	Jan. 8	50	22.95	5.79	May	T.	Aug.	22.0	53	223	87	56	se.
Lamar	Prowers	3,615	54	52.7	104	Aug. 3	—10	Jan. 8	56	21.94	7.38	May	0.16	Sept.	38.3	77	96	224	46	s.
Kit Carson	Cheyenne	4,284	11	49.3	101	June 21†	—10	Jan. 8	14	18.57	3.68	Apr.†	0.31	Feb.	28.8	58	151	129	86	s.
Pueblo, 3 mi. sw.	Pueblo	4,808	69	51.1	100	July 30†	—6	Jan. 8	76	11.26	2.91	July	0.03	Dec.	32.0	67	145	112	109	nw.
Canon City	Fremont	5,343	55	54.5	97	July 31	7	Feb. 11	57	10.44	8.51	Apr.	T.	Nov.	36.4	64	187	129	50	sw.
Colorado Springs	El Paso	6,098	66	48.2	92	June 20†	—1	Jan. 8†	66	15.30	3.73	July†	0.12	Sept.	26.0	83	113	177	76	se.
Walsenburg	Huerfano	6,200	9	51.9	98	Aug. 1	0	June 8†	10	13.61	4.09	Apr.	0	Sept.	76.7	41	222	71	73	w.
Trinidad	Las Animas	6,300	43	50.4	95	July 30†	—8	Jan. 8	49	18.56	3.18	Apr.	0.07	Feb.	69.7	83	232	75	59	sw.
Westcliffe	Custer	7,860	41	41.4	89	Aug. 14†	—22	Jan. 8	15	14.81	4.30	do	0.12	Sept.	93.6	58	120	94	152	sw.
Cripple Creek	Teller	9,508	8	38.8	79	July 16†	—8	Mar. 28	24	12.82	3.75	July	0.11	Dec.	69.1	93	160	167	39	sw.
Leadville	Lake	10,182	47	36.0	80	Aug. 1†	—12	Mar. 28	49	12.42	2.24	Apr.	0.11	June	105.1	124	89	169	108	nw.
Climax[1]	Lake	11,465	--	28.4	70	Aug. 8	—19	Mar. --	--	----	---	----	---	----	----	---	---	---	---	----
Colorado Drainage Basin																				
Grand Junction	Mesa	4,668	54	52.2	98	Aug. 14	0	Jan. 9	55	7.18	1.67	Apr.	T.	Sept.	15.1	79	158	114	94	se.
Rifle	Garfield	5,240	31	47.3	96	Aug. 8	—19	Jan. 8	30	9.42	2.03	Nov.	0.07	Sept.	34.4	62	163*	78*	94*	w.
Glenwood Springs	Garfield	5,823	43	48.5	98	Aug. 17	—8	Jan. 8	45	16.66	3.01	Apr.	0.07	do	59.7	93	218	90	58	----
Montrose	Montrose	5,830	51	49.5	97	Aug. 23	—3	Jan. 8†	57	10.44	2.80	do	0.05	Sept.	33.6	72	276	47	43	----
Eagle	Eagle	6,598	2	41.2	92	Aug. 5	—21	Jan. 8	2	8.42	1.15	Apr.	0	Sept.	43.6	65	171	104	91	sw.
Durango	La Plata	6,552	51	44.4	90	Aug. 7†	—9	Dec. 31	53	16.84	2.63	Apr.	0.36	June	93.0	103	146	117	103	s.
Steamboat Springs	Routt	6,770	4	39.4	88	June 28	—29	Jan. 8	42	21.75	5.01	May	0.17	Aug.	142.2	117	153	128	85	nw.
Gunnison	Gunnison	7,683	51	37.7	86	Aug. 8†	—28	Jan. 8	53	7.44	1.35	Apr.	0.16	Sept.	86.2	78	171	103	92	w.
Green Mountain Dam	Summit	7,760	6	39.5	88	Aug. 11†	—24	Jan. 14	6	11.95	2.75	Apr.	0.22	do	75.6	65	139	156	71	nw.
Aspen	Pitkin	7,913	17	39.8	89	Sept. 6	—16	Dec. 27	19	14.27	3.28	Mar.	0.15	May	135.7	83	216	82	68	w.
Telluride	San Miguel	8,756	36	40.0	82	June 16†	—15	Jan. 5	36	26.28	6.11	Apr.	0.89	May	173.6	108	158	130	78	w.
Dillon, 1¼ mi. ne.	Summit	8,900	38	34.5	87	June 21	25	Jan. 15†	38	13.68	3.61	do	T.	Sept.	134.0	70	89	196	81	n.
Crested Butte	Gunnison	8,950	33	34.7	80	Aug. 5	—24	Jan. 8	35	24.29	4.41	Mar.	0.70	Sept.	186.9	95	228	47	91	----
Taylor Park	Gunnison	9,206	5	33.3	78	June 21†	—38	Jan. 9	5	15.56	2.71	Mar.	0.20	Sept.	127.3	78	151	135	80	sw.
Silverton, 1½ mi. ne.	San Juan	9,401	38	34.4	78	June 25†	—18	Feb. 11	39	22.20	4.00	Apr.	0.71	May	197.1	130	117	119	130	sw.
Wolf Creek Pass	Mineral	10,425	7	38.1	84	Aug. 2	—15	Jan. 5	7	54.34	8.85	Mar.	1.23	Sept.	506.0	132	96	194	76	----
Platte Drainage Basin																				
Julesburg	Sedgwick	3,469	32	50.1	101	Aug. 3†	—6	Feb. 11	41	17.90	4.64	July	0.21	Oct.	59.5	65	33	251	82	nw.
Fort Morgan, 1 mi. n.	Morgan	4,321	48	47.8	99	Aug. 8	—14	Jan. 8	54	11.30	2.32	Apr.	0.01	Aug.	49.9	63	218	105	43	----
Greeley	Weld	4,648	52	47.4	102	do	—14	do	57	13.19	4.32	do	0.13	Feb.	52.7	61	206	110	50	n.
Fort Collins	Larimer	5,004	66	46.9	95	Aug. 7†	—13	Jan. 8	65	13.53	4.10	Apr.	0.09	Aug.	60.9	77	104	177	85	n.
Denver Airport, 5½ mi. ene.	Denver	5,299	11	49.7	97	Aug. 7	0	Jan. 8†	11	15.54	3.92	Apr.	T.	do	86.2	78	115	148	103	s.
Boulder	Boulder	5,404	49	49.0	95	Aug. 3†	1	Mar. 28	51	18.65	6.81	Apr.	T.	Sept.	103.3	84	136	118	112	w.
Idaho Springs	Clear Creek	7,540	46	42.7	90	Aug. 7	—10	Mar. 28	55	16.53	5.79	do	T.	do	121.0	88	90	186	90	w.
Estes Park, 1 mi. n.	Larimer	7,750	29	42.0	90	Aug. 13	—14	Mar. 28	36	15.30	4.90	Apr.	0.15	do	90.0	47	154	180	32	----
Walden	Jackson	8,340	15	37.3	84	Aug. 8	—20	Jan. 8	15	7.65	1.50	May	0.08	Jan.	41.7	71	117	159	90	sw.
Rio Grande Drainage Basin																				
Alamosa	Alamosa	7,531	14	40.0	89	Aug. 15	—36	Jan. 8	14	5.84	1.91	July	0.03	June	20.9	47	259	63	44	sw.
Jaroso	Costilla	7,579	5	42.0	90	Aug. 14	—28	Jan. 13	5	9.24	1.95	Apr.	0.02	Sept.	46.5	59	189	125	52	sw.
Wagon Whl. Gap, 3½ nw.	Mineral	8,500	20	33.1	81	July 31†	—30	Jan. 8	20	11.90	2.43	Dec.	0.25	Mar.	104.3	72	---	---	---	w.
Cumbres	Conejos	10,015	5	34.3	75	do	—15	Dec. 31	38	46.27	8.20	Dec.	0.66	Sept.	462.0	123	164	87	115	sw.
Summitville	Rio Grande	11,330	2	30.3	71	Aug. 13	—12	Jan. 5	2	43.23	6.16	July	1.29	Mar.	562.4	143	204	73	89	----
State means and extremes			--	44.9	106	Aug. 3	—38	Jan. 9	--	16.57	8.85	Feb. †	0.00	Mar.	84.6	71	176	117	73	w.

Means, etc., for the State are computed from the records of all stations reporting. T. indicates precipitation less than 0.01 inch.
†Also on subsequent dates. *Record incomplete. [1]Data by the Climax Molybdenum Co., Climax, Colo.

Table 2. Monthly and annual mean temperature for 1944, with departures from the normal, listed according to altitude (see table 1) in each principal drainage basin in Colorado

Station	January T	January D	February T	February D	March T	March D	April T	April D	May T	May D	June T	June D	July T	July D	August T	August D	September T	September D	October T	October D	November T	November D	December T	December D	Annual T	Annual D
Arkansas Drainage Basin																										
Holly	31.8	+1.2	36.4	+1.8	40.0	—3.0	46.6	—6.4	63.7	+1.3	72.2	—0.3	74.8	—3.1	75.0	—1.5	67.6	—0.9	56.5	+0.5	43.0	+1.1	33.8	+2.4	53.4	—0.6
Lamar	29.4	—1.4	35.2	+0.1	38.5	—5.1	46.4	—7.2	62.6	—0.7	72.6	—0.9	75.8	—2.9	76.1	—1.1	67.2	—1.7	55.4	—0.3	41.8	—0.1	31.3	—0.1	52.7	—1.8
Kit Carson	27.4	----	30.4	----	34.2	----	42.2	----	58.0	----	67.8	----	72.6	----	73.3	----	64.2	----	53.2	----	39.8	----	28.8	----	49.3	----
Pueblo, 3 mi. sw.	30.2	+1.5	34.1	+2.0	38.2	—2.6	44.0	—5.4	59.8	+0.9	69.2	+0.6	73.4	—0.8	73.4	+0.7	65.0	+0.4	54.3	+3.1	39.8	+1.5	31.9	+1.8	51.1	+0.3
Canon City	38.2	+2.5	38.5	+1.8	41.2	—1.8	46.4	—4.9	62.2	+2.5	69.2	—0.1	74.2	0	75.3	+2.5	66.2	+1.1	57.6	+3.5	45.2	+1.2	40.0	+2.9	54.5	—2.0
Colorado Springs	30.8	+2.4	32.6	+2.5	35.4	—2.0	41.2	—4.3	55.7	+1.6	63.8	+0.1	67.9	—0.5	68.0	+1.0	60.0	+0.1	52.2	+2.9	38.8	+0.3	31.4	+0.5	48.2	+0.4
Walsenburg	34.1	----	36.2	----	39.4	----	43.8	----	59.0	----	67.2	----	72.5	----	73.0	+1.3	64.6	----	54.8	----	42.9	—0.5	35.2	+0.6	51.9	----
Trinidad	31.6	—2.0	36.4	+0.2	38.6	—3.1	43.6	—5.8	56.6	—1.5	66.4	—0.8	70.0	—1.7	70.8	+0.6	63.4	—0.3	53.4	+0.2	41.4	—0.6	32.6	—1.3	50.4	—1.3
Westcliffe	18.2	—5.8	24.4	—1.8	28.3	—5.1	35.8	—5.4	50.0	+0.3	59.4	+0.7	61.8	—1.4	62.8	+0.9	55.6	+0.6	45.6	+1.2	32.8	—0.3	22.6	—2.2	41.4	—1.5
Cripple Creek	23.8	----	22.8	----	25.1	----	31.0	----	44.4	----	52.4	----	57.2	----	58.6	----	52.0	----	43.8	----	30.0	----	24.4	----	38.8	----
Leadville	18.8	+1.2	19.5	—0.1	19.7	—4.3	28.7	—3.6	41.0	+0.1	51.2	+0.9	56.1	+0.1	57.0	+2.6	51.2	+3.2	41.8	+3.9	27.0	—0.3	20.4	—0.4	36.0	+0.3
Climax[1]	13.4	----	13.2	----	15.5	----	17.7	----	34.3	----	44.4	----	48.1	----	48.0	----	41.9	----	32.4	----	18.9	----	12.8	----	28.4	----
Colorado Drainage Basin																										
Grand Junction	25.8	+1.8	35.0	+1.9	40.2	—3.4	48.0	—4.4	62.3	+1.2	69.4	—0.2	77.5	—0.2	76.0	+0.5	60.3	+2.7	58.6	+5.8	41.5	+2.2	32.2	+4.7	52.2	+0.9
Rifle	19.4	—2.7	31.4	+1.8	37.1	—1.5	44.2	—4.3	56.6	—0.1	61.9	—3.3	68.2	—3.5	67.6	—1.6	61.2	+0.7	53.2	+4.7	39.2	+2.4	28.0	+1.8	47.3	—0.5
Glenwood Springs	22.5	—1.0	32.8	+4.1	37.2	—0.5	45.8	—0.9	56.5	+1.8	63.0	+0.4	70.8	+2.1	70.4	+3.1	64.2	+4.6	54.5	+5.6	37.8	+1.8	27.0	+1.0	48.5	+1.8
Montrose	24.7	+0.4	33.0	+1.7	36.6	—3.0	44.3	—3.9	57.4	+0.6	65.0	—1.1	72.4	+0.8	71.2	+2.0	65.6	+4.1	54.2	+4.5	39.0	+2.2	30.4	+3.8	49.5	+1.0
Eagle	16.8	----	27.1	----	31.5	----	39.2	----	49.3	----	56.1	----	62.8	----	62.2	----	53.0	----	46.0	----	32.2	----	18.6	----	41.2	----
Durango	23.0	—1.6	28.6	—1.2	33.2	—4.1	40.2	—4.9	51.4	—1.1	56.8	—4.1	64.8	—2.2	64.6	—1.1	57.7	—0.8	50.4	+2.5	34.7	—2.0	27.8	+0.6	44.4	—1.7
Steamboat Springs	14.4	+0.4	21.8	+3.8	28.2	+1.8	37.8	—0.9	49.0	+0.7	54.1	—1.4	60.0	—1.4	59.2	—0.2	53.2	+0.7	45.6	+3.7	31.6	+2.9	18.2	+1.6	39.4	+1.0
Gunnison	11.9	+4.2	16.0	+2.4	25.4	—0.5	36.7	—2.9	46.8	—1.1	54.0	—1.9	59.7	—1.8	59.3	—0.5	52.4	0	43.6	+2.2	28.6	+0.8	17.6	+4.7	37.7	+0.5
Green Mountain Dam	13.5	----	21.9	----	27.3	----	35.4	----	47.4	----	55.1	+0.4	60.2	—0.9	61.0	+1.7	54.3	+2.0	44.9	+3.3	31.6	+2.7	21.2	+1.4	39.5	----
Aspen	17.6	—1.3	22.0	—0.4	25.8	—3.5	34.5	—5.6	46.2	—1.9	54.8	—1.2	61.4	—0.6	61.0	+0.3	56.2	+2.4	45.2	+1.8	31.6	+1.2	20.7	—2.5	39.8	—0.1
Telluride	26.0	+5.2	26.2	+2.5	26.4	—1.6	36.2	—0.7	45.6	+0.6	52.6	—0.8	57.6	—0.9	58.6	+2.0	52.6	+1.6	44.7	+3.3	30.5	+0.1	23.6	+1.6	40.0	+1.1
Dillon, 1¼ mi. s.	14.8	+1.7	16.6	+0.8	22.7	+1.6	29.5	—2.4	41.2	—0.6	50.0	+0.8	53.9	—1.1	54.6	+1.0	47.2	+0.3	40.0	+3.7	25.4	+1.3	17.5	+2.5	34.5	+0.8
Crested Butte	14.5	+1.6	16.0	—0.2	20.7	—2.0	29.6	—3.2	42.4	—0.9	50.0	—1.8	55.0	—1.7	54.9	—0.4	49.4	+1.8	41.3	+4.2	25.8	+0.8	17.0	+2.0	34.7	
Taylor Park	15.6	----	13.3	----	16.8	----	26.4	----	40.6	----	50.6	----	56.2	----	54.4	----	48.4	----	40.3	----	24.3	----	13.2	----	33.3	----
Silverton, 1½ mi. ne.	17.2	+0.8	17.4	—1.8	20.4	—4.4	28.4	—4.4	40.9	—0.2	48.6	—0.9	53.0	—2.2	54.8	+1.5	48.8	+1.8	40.8	+2.9	25.0	—1.6	17.9	—0.2	34.4	—0.7
Wolf Creek Pass	23.2	----	22.6	----	23.8	----	31.2	----	43.2	----	50.4	----	57.2	----	58.4	----	52.1	----	43.3	----	27.8	----	24.4	----	38.1	----
Platte Drainage Basin																										
Julesburg	30.0	+4.4	29.8	+1.3	34.5	—2.6	44.8	—3.6	62.2	+4.2	68.2	—0.1	73.2	—1.8	74.2	+1.6	63.4	+0.3	53.4	+3.0	39.8	+2.9	28.0	+0.3	50.1	+0.8
Fort Morgan, 1 mi. n.	24.6	+1.5	28.4	+0.2	32.0	—4.5	44.0	—3.3	59.2	+2.7	66.4	—0.2	72.0	—1.1	72.8	+1.8	61.7	+0.1	52.8	+3.4	37.6	+1.6	22.2	—3.4	47.8	—0.1
Greeley	24.8	+0.1	29.2	+0.8	31.0	—6.2	42.2	—5.2	58.4	+1.5	66.6	—0.1	71.8	—0.4	72.8	+2.3	61.2	—0.1	50.5	+1.1	36.4	+0.1	24.5	—1.3	47.4	—0.6
Fort Collins	26.4	+0.3	30.0	+2.0	32.6	—3.7	41.7	—4.1	56.0	+1.4	63.3	—0.6	69.0	—0.2	70.0	+2.1	59.4	0	50.5	+2.3	37.4	+1.3	26.6	—1.3	46.9	0
Denver Airport, 5½ mi. ene.	30.7	+3.4	32.4	+1.6	33.4	—4.7	42.3	—3.5	58.0	+2.8	67.0	+1.7	71.5	+0.3	72.8	+3.1	63.0	+1.4	54.3	+4.8	40.7	+2.9	30.7	+0.8	49.7	+1.2
Boulder	31.8	—0.5	31.8	—1.6	33.2	—6.4	42.1	—6.3	56.7	+0.2	64.1	—1.9	68.9	—2.7	70.6	+0.1	61.6	—1.2	53.4	+1.3	41.7	+0.1	32.5	—1.0	49.0	—1.7
Idaho Springs	26.8	+0.1	26.0	—2.1	30.4	—2.6	36.2	—4.1	48.6	+0.4	57.3	—0.5	61.8	—0.7	62.0	+2.4	55.6	+0.7	46.4	+2.0	33.8	—0.9	26.0	—2.2	42.7	—0.6
Estes Park, 4 mi. w.	26.4	+1.2	25.6	—2.1	28.0	—3.3	36.5	—2.6	49.6	+2.5	56.0	+0.2	61.2	—0.6	61.6	+1.8	52.7	—0.1	46.1	+2.3	34.4	+0.8	25.8	—2.6	42.0	—0.2
Walden	15.9	—0.4	20.8	+2.0	24.4	—0.9	34.0	—2.8	46.3	+0.1	53.0	—1.4	58.2	—1.6	57.6	—0.6	50.0	—1.9	42.1	+2.0	28.8	+0.2	16.6	—1.8	37.3	—0.6
Rio Grande Drainage Basin																										
Alamosa	6.9	—9.5	16.8	—6.3	28.0	—5.9	43.0	+0.4	48.6	—2.1	58.8	+0.1	63.2	—0.3	62.9	+0.3	55.2	—0.2	45.8	+1.5	30.6	—0.2	19.6	—0.2	40.0	—1.9
aroso	11.8	----	21.0	----	31.6	----	39.4	----	50.4	----	59.0	----	64.9	----	74.6	----	57.8	----	48.3	----	32.8	----	23.0	----	42.0	----
Wagon Wheel Gap	7.3	—4.5	11.0	—4.7	18.4	—7.6	29.2	—6.8	43.3	+0.5	49.9	—0.8	56.4	+0.2	55.4	—0.3	49.0	+0.1	40.9	+1.7	23.3	—3.3	13.4	+0.8	33.1	—2.1
Cumbres	18.3	----	18.2	----	18.7	----	27.0	----	38.6	----	49.0	----	53.6	----	54.2	----	49.0	----	40.0	----	25.0	----	19.5	----	42.3	----
Summitville	15.4	----	15.2	----	16.7	----	23.6	----	34.4	----	43.4	----	49.4	----	50.2	----	43.7	----	34.4	----	20.6	----	16.8	----	30.3	----
Means	23.1	—0.8	27.0	—0.2	31.3	—3.2	39.6	—4.2	53.3	+0.9	60.8	—0.9	66.5	—0.7	66.7	+1.0	58.9	+0.8	49.6	+2.7	35.5	+0.1	26.1	+0.3	44.9	—3.5

The normal may be found by adding the departure when minus (—) or subtracting when plus (+). T indicates Temperature, D indicates Departure.

[1]Data by the Climax Molybdenum Co., Climax, Colo.

Gittings, E. B., U. S. Weather Bureau climatological data (1944), Colorado section, Vol. 49, No. 13, pp. 98-99, 102-103, 1945.

Table 3. Monthly mean temperatures (F.) in 1944 for towns in Colorado listed according to altitude.

	Altitude (feet)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Grand Junction	4,668	26	35	40	48	62	69	78	76	60	59	42	32
Pueblo	4,808	30	34	38	44	60	69	73	73	65	54	40	32
Ft. Collins	5,004	26	30	31	42	56	63	69	70	59	50	37	27
Rifle	5,204	19	31	37	44	56	62	68	68	62	53	39	28
Denver Airport	5,299	31	32	33	42	58	67	72	72	63	54	41	31
Canon City	5,343	38	39	41	46	62	69	74	75	66	57	45	40
Glenwood Springs	5,823	23	33	37	46	57	63	71	70	64	54	38	27
Colorado Springs	6,098	31	33	35	41	56	64	68	68	60	52	39	31
Walsenburg	6,200	34	36	39	44	59	67	73	73	65	55	43	35
Trinidad	6,300	32	36	39	44	56	66	70	71	63	53	41	33
Durango	6,552	23	29	33	40	51	57	65	65	58	50	35	27
Steamboat Springs	6,770	14	22	28	38	49	54	60	59	53	46	32	18
Idaho Springs	7,540	27	26	30	36	49	57	62	62	56	46	34	26
Estes Park	7,750	26	26	28	37	50	56	61	62	53	46	34	26
Green Mountain dam	7,760	14	22	27	35	47	55	60	61	54	45	32	21
Westcliffe	7,860	18	24	28	36	50	59	62	63	56	46	33	23
Aspen	7,913	18	22	26	36	46	55	61	61	56	45	32	21
Walden	8,340	16	21	24	34	46	53	58	58	50	42	29	26
Telluride	8,756	26	26	26	36	46	52	58	59	53	45	31	24
Taylor Park	8,950	16	13	17	26	41	51	56	54	48	40	24	13
Cumbres	10,015	18	18	19	27	39	49	54	54	49	40	25	20
Leadville	10,182	19	20	20	29	41	51	56	57	51	42	27	20
Wolf Creek Pass	10,425	23	23	24	31	48	50	57	58	52	43	28	24
Summitville	11,330	15	15	17	24	34	43	49	50	44	34	21	17
Climax	11,465	13	13	16	18	34	44	48	48	42	32	19	13

about the same latitude are prolonged from 1 to 2 weeks both in the fall and spring for each 1,000 feet rise in elevation. Winter is an indefinite term, but the meaning intended here is the period of consistent freezing and snowfall that affects mining costs. The fall and early winter in mountainous areas are characterized by more trouble from freezing than from snow, and from midwinter to spring snow is the major problem. The severity of the winters arises from their long duration with lower mean temperatures (see table 3) and more snow at high altitudes as compared with lower levels.

The timber-covered slopes do not extend above altitudes of 11,600 to 11,700 feet (timberline) in most of the Colorado mountains. Above timberline there is considerable permanent frost, and the grass-covered slopes are excellent for grazing. Tunnels, even on south-facing slopes at altitudes of 12,000 feet and higher, become blocked by permanent ice unless precautions are taken to keep them well drained.

The general altitude is indicated for each mining district, and with the climatological data given it will be possible to estimate the general character of the climate to be expected in a given area.

GENERAL GEOLOGY OF COLORADO

PRINCIPAL ROCK FORMATIONS

The distribution of the principal rock formations in Colorado is shown in plate 1. (See pl. 2 also.)

The oldest rocks (pre-Cambrian) are shown also in plates 5, 6, and 7. (See pages 230 and 270.) These rocks consist chiefly of quartz-biotite schist and gneiss, probably of sedimentary origin.

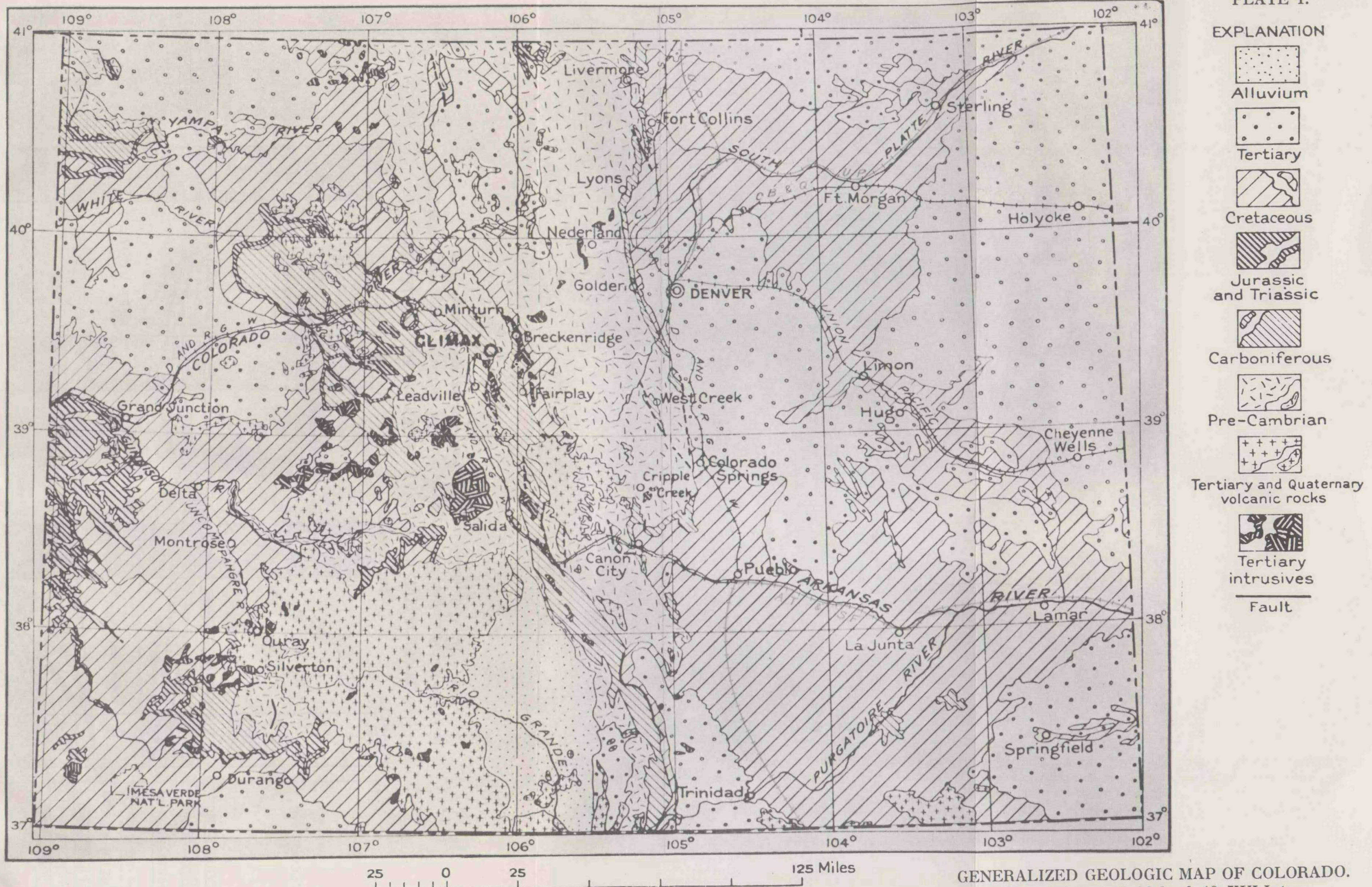
Locally present are extensive masses of greenstone and lenticular bodies of hornblende schist and gneiss; the latter, it is believed, represent metamorphosed andesitic lavas and dioritic sills.

Intruded into the schist and gneiss are several kinds of pre-Cambrian granite, some of which are gneissic but most of which are not. The largest granite masses commonly are a coarse-grained pink rock, locally intruded by medium-grained, light-colored granite in the form of stocks or small batholiths. Pegmatite and aplite are found in the granite and the intruded rock, frequently concentrated relatively near the contact.

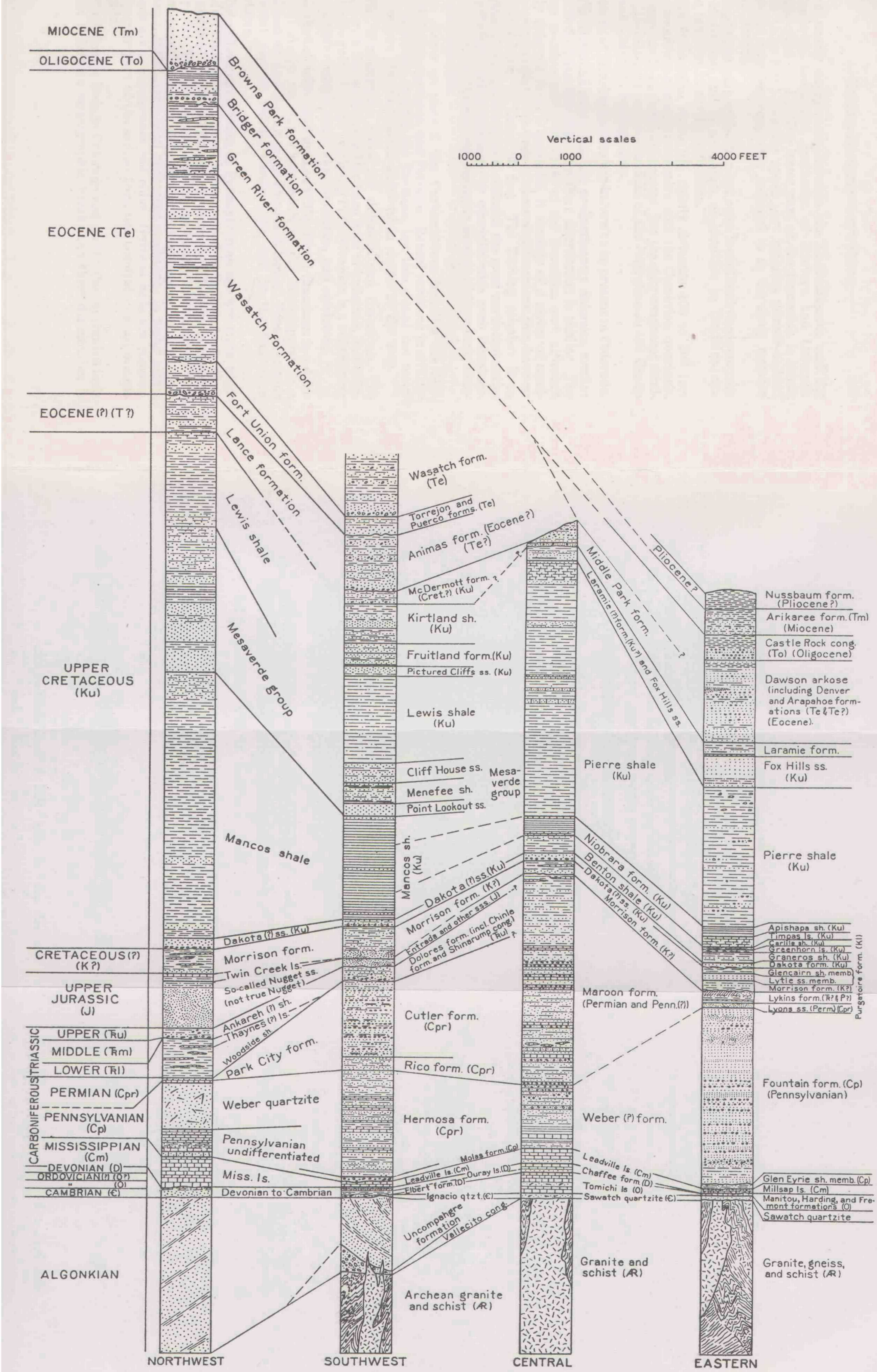
A series of pre-Cambrian slate, quartzite, and conglomerate younger than the schist series and possibly younger also than the granite occurs in the southwestern part of the State. Unmetamorphosed sandstone and quartzite beds in the northwestern part of the State are believed to be late pre-Cambrian or, in part, early Cambrian in age.

The Cambrian rocks (see pl. 2) are predominantly an easily-recognized fine-grained gray quartzitic sandstone 100 to 250 feet thick with quartz pebbles occurring locally at the base. It is

PLATE 1.



GENERALIZED GEOLOGIC MAP OF COLORADO.
(From plate 1, Guidebook 19, XVI International Geologic Congress 1933)



GENERALIZED COLUMNAR SECTIONS FOR COLORADO

Pleistocene and Recent sedimentary formations and Tertiary volcanic rocks not shown.

(From Guidebook 19, XVI International Geologic Congress 1933) present nearly everywhere between the Carboniferous and the pre-Cambrian south and southwest of Minturn and Colorado Springs. (See pl. 1.) The lower part of the formation is thick-bedded (1 to 2 ft.) and the upper part includes thinner-bedded calcareous members commonly referred to as the shaly member of the Cambrian.

Important gold production has come from Cambrian quartzite beds at Gilman and in a number of localities in the Mosquito Range between Leadville and Alma.

The Ordovician rocks are chiefly dolomite 100 to 300 feet thick, occurring almost coextensive with the Cambrian quartzite. Chert and sandy horizons are present, but the only consistent sandstone (Harding) is near the middle of the formation in the Canon City and Colorado Springs area.

Rocks of Silurian age are not known to be present in Colorado.

The Devonian strata also are predominantly dolomite, similar to the Ordovician dolomite, and their distribution is similar. The Parting member marks the base of the Devonian and, although usually referred to as a quartzite, it consists of a series of sandstones or quartzites with beds of shale and limestone that have an overall thickness of about 50 feet. The Parting member is an important horizon marker as it contains the most persistent series of interbedded shale, sandstone or quartzite with some limestone, in the pre-Pennsylvanian stratigraphic section of limestone, dolomite, and quartzite.

As shown on plate 1, the Carboniferous includes the Mississippian, Pennsylvania, and Permian. Recent revisions in stratigraphy, however, exclude the Permian, but this would not materially change the generalized distribution shown on the map.

The Mississippian rocks are dolomite and limestone. The contact with the underlying Devonian beds is indistinct and difficult to recognize, but the overlying Pennsylvanian is a contrasting series of interbedded shale, thin limestone, and sandstone.

In the Leadville area the Leadville (Blue) limestone is a dolomite. At Aspen the upper two-thirds of the Mississippian is a true limestone and the lower one-third is dolomite. True limestone is present also at Salida, Canon City, and in the San Juan Mountains.

The sedimentary rocks of Pennsylvanian age are more widespread in their occurrence and more varied in their make-up than the combined series of Cambrian through Mississippian rocks. (See pl. 2.) They consist of marine shales and limestones as well as continental deposits composed of arkosic sandstone and conglomerate with interbedded micaceous sandstone; in many places the beds are a conspicuous red color. Gypsum beds are common in the upper part of the section from northcentral to southwestern Colorado.

The Permian beds in Colorado rest on the Pennsylvanian beds without a definite stratigraphic break, and their distribution is similar. They consist chiefly of gray to red thin-bedded grit, micaceous sandstone and shale with extensive conglomerate beds and local limestones. (See pl. 2.)

The Triassic period is not well represented in Colorado and no Triassic beds are identified in the eastern half of the State, except for the Lykins formation on the east flank of the Front Range, which is regarded by some as probably of Triassic age. In western Colorado, Triassic red sandstone and shale with some limestone have a maximum thickness of 1,000 feet. The section thickens to the west in Utah and thins eastward in central Colorado.

The distribution of the Jurassic and Triassic is shown by means of one symbol on plate 1 because the two are somewhat similar. The Jurassic beds thin eastward and extend only as far east as the west side of the Park Range.

The Morrison formation of Upper Jurassic (possibly Lower Cretaceous) age is widely distributed in central Colorado and along the east flank of the Front Range. This formation overlaps older Jurassic beds. In the Elk Mountains an angular unconformity at the base of the Morrison cuts across all the Paleozoic beds. Northeast of Gunnison the Morrison rests on pre-Cambrian rocks. The formation is easily recognized by the variegated green, gray, purple shales in the larger part of the section.

Overlying the Morrison formation is a thick and extensive black shale with a basal sandstone (Dakota). These Upper Cretaceous beds, Mancos and Mesaverde beds in central and western Colorado and Pierre shale in eastern Colorado, at one time covered all of Colorado. The principal stratigraphic variations are shown in plate 2.

The Cretaceous period was followed by an interval of erosion and volcanic activity, the first since pre-Cambrian time. Most of the Eocene sediments contain volcanic material mixed with debris from all the older formations. Near Golden, west of Denver, and elsewhere lavas are present in the Eocene section. Volcanic tuff of Eocene age is common in the San Juan region, in North Park, and in the Denver Basin. The oil shales in western and northwestern Colorado were deposited in Eocene time.

White clays and sandstone of Oligocene age rest on the Upper Cretaceous shales and sandstone in northeastern Colorado; these deposits are covered by Miocene gravel, sand, and clay deposits. Similar Miocene deposits are widespread in northwestern Colorado and west of the Front Range, but the Eocene beds are less extensive.

Clay and sand of Pliocene age are nowhere abundant, although their distribution is believed to be fairly extensive in eastern Colorado. Gravel with volcanic tuff and lavas in the San Luis Valley and parts of the San Juan Mountains may be Pliocene.

The glacial deposits and the related terraces and outwash gravel deposits in the mountain valleys are probably Quaternary in age.

TERTIARY, MIOCENE AND QUATERNARY VOLCANIC ROCKS

Volcanic activity probably began in late Cretaceous and early Eocene in the southwestern part of the State and in the Front Range. The earliest intrusive rocks are intermediate basic porphyries of limited extent. These were followed by extensive dikes and sills of monzonite porphyry and these in turn by dikes, sills, and small stocks of quartz monzonite porphyry. Near Golden in Jefferson County small basalt flows occur in the Denver formation and to the south near Castle Rock in Douglas County rhyolite flows and tuffs are found in the upper part of the Dawson arkose.

In Miocene time volcanic activity occurred in a number of centers in the San Juan Mountains and in isolated centers in the southern and northern parts of the Front Range. Lavas and tuffs were deposited that range in composition from basalt to rhyolite, including phonolite, but andesite predominates. The associated intrusive dikes, sills, and small stocks show the same variations in composition.

Andesite and basalt flows occurred in late Tertiary and Quaternary time in several places in Colorado, but related intrusive rocks are not exposed. The most extensive flows of these periods cap Mesa de Maya east of Trinidad, Grand Mesa east of Grand Junction, the Flat Tops north of Glenwood Springs, an area southeast of Glenwood Springs, and the divide between North Park and Middle Park. No mineralization accompanied this last period of volcanic activity.

STRUCTURE

The major geologic structures are summarized in the chapters that describe petroleum and coal.

In eastern Colorado the Denver Basin, over a mile deep and more than 100 miles across, and other lesser subsurface structures are not very evident on the almost featureless plains that extend northward, eastward, and southward beyond the boundaries of the State. Everywhere the underlying shales and sandstones are nearly horizontal, except at their western margin along the mountain front where the beds lie with eastward dips that vary from low angles to vertical.

Tertiary folding and faulting dominate the structural features in the mountainous western half of the State. The easternmost mountains are the Front Range (with the Wet Mountains to the south) which extends north into Wyoming and south as far as Walsenburg. This mountain chain is bounded on the west by three intermountain valleys and plains known from north to south as North Park, Middle Park, South Park, and Wet Mountain Valley. The second mountain chain is the Park Range which extends to the north into Wyoming and southward is continuous with the Mosquito Range west of South Park. Farther south the Mosquito Range converges with the Sangre de Cristo Range which extends south into New Mexico. The Sangre de Cristo Range, bounded on the west by San Luis Valley, is a high, narrow, arcuate mountain range concave to the west and in line northward with the broad and high Sawatch Mountains. The Sawatch Mountains are a domal uplift that trends northwestward towards the White River Plateau, a broad dome north of Glenwood Springs, which in turn is in line with the Uinta Mountains of northeastern Utah.

The Front Range, Park Range, Mosquito Range, Sawatch Range, and White River Plateau are characterized by faulting and steeply dipping beds along their western margins. Steeply dipping beds occur also along the east side of the Front Range but faulting is less extensive than on the west side. The Williams Range thrust fault on the west side of the Front Range opposite Dillon has a displacement of one to two miles. The Mosquito and Gore faults have displacements along the west side of the Mosquito and Park Ranges, and the Castle Creek fault along the west side of the Sawatch Range opposite Aspen has displacement of several thousand feet. Both thrust and normal faults occur.

The Uncompahgre Plateau southwest of Grand Junction is an elongate domal structure like its topographic form. The structure is paralleled to the southwest by a succession of down-faulted anticlines or grabens of which Paradox Valley is the best known because of the vanadium deposits occurring in the area.

The San Juan Mountains in the southwestern part of the State are an accumulation of volcanic extrusive rocks of Tertiary age that occupies an irregular area. The structure and forms of these mountains are unlike those of the mountain ranges referred to above.

Cutting across the north- and northwest-trending mountain ranges is the mineral belt that extends from Aspen in Pitkin County northeast into Boulder County. This belt is marked by numerous porphyry stocks, dikes, and sills and includes numerous important mining districts, but the structure is not expressed by topographic forms.

Although much erosion has taken place since folding and faulting occurred, the high mountain ranges are the areas of major uplift. The areas between are structural basins and in places also former areas of Cretaceous deposition.

MINERALIZATION

Mineralization followed and is probably genetically related to the two (Eocene and Miocene) cycles of intrusive activity. However, some of the areas of volcanic activity show only weak scattered mineralization, and important mines, as the lead-silver deposits at Aspen, are 15 miles or more from known volcanic centers.

Most of the mineral deposits in the northeast-trending belt that extends from Leadville in Lake County to Boulder County formed after the Eocene period of volcanic activity. Early mineralization also occurred in the San Juan Mountains, but the Miocene deposits are more important. The gold deposition at Cripple Creek also occurred in this latter period.

The variations in mineralization are great, but complex ores predominate. Even in areas noted for gold and silver production, appreciable quantities of copper, lead, and zinc are present locally, although the last three may be without value under present conditions of transportation, mill and smelter facilities, and other more general economic factors. The diversity of metals that can be produced from the various districts in Colorado is brought out by the production figures given for different periods including the recently completed war. Some districts have produced certain metals since an early date, and others show changes related to changing economic conditions. Changes in metal production related to differences in geologic conditions, found as depth of mining increased, have been the least important.

Secondary enrichment, formerly an important consideration, is no longer of great interest because most known deposits have been mined and explored well into the zone of primary ore.

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ELECTRIC POWER

The electric power plants and transmission systems in Colorado are shown on plate 3, which is Chart 1 borrowed from the report prepared by the Power Committee of the Denver Metropolitan Planning Project referred to below. Available electric power is adequate in the larger mining communities, but some districts are outside the reach of existing power lines. In such areas diesel-generator units are practical, and portable units are used extensively for preliminary exploration and development.

The outlook is favorable for improvement in the future, as hydroelectric power in quantity can be developed in connection with irrigation projects. Three major and a number of smaller projects are under consideration in the State. One of the lesser is the Animas-La Plata project in southwestern Colorado for which no approximation is available as to the amount of power development that might be involved. The Collbran project on Plateau Creek east of Grand Junction and near Collbran in Mesa County may furnish about 20 million kilowatt hours yearly according to preliminary estimates.

The three major proposed and prospective multiple-purpose water projects in Colorado, with the estimated potentially available hydroelectric energy, are:

	Average annual energy in million Kwh.	Minimum year energy in million Kwh.
Colorado-Big Thompson	740	530
Blue River-South Platte	1200	800
Gunnison-Arkansas	1400	700
	3500	2130

These projects, quoting from the report of the Power Committee, are described as follows:

1. "Colorado-Big Thompson (Transmountain Diversion) Project. The Colorado-Big Thompson Project, located in north-central Colorado, is so named because it provides for transmountain diversion of surplus water from the headwaters of the Colorado River Basin to the Big Thompson River watershed in the Platte River Basin. Construction of this project was started in 1940, discontinued by order of the War Production Board in the fall of 1942, and resumed in the fall of 1943.

"The project, when completed, is expected to have the following principal features: three reservoirs, two collection canals, one power plant, and one pumping power plant and canal on the western slope of the Rocky Mountains; a thirteen-mile tunnel through the Continental Divide which will make possible transmountain diversion of water to the eastern slope; and three reservoirs, together with inlet and outlet canals, and five power plants on the eastern slope of the Rocky Mountains.

"The recently completed Green Mountain Reservoir on the Blue River (one of the three western slope reservoirs) will provide replacement storage to compensate for any encroachment on the present or future irrigation water requirements of western slope lands that might result from diversion to the eastern slope.

"Although the primary purpose of the Colorado-Big Thompson Project is the average diversion of 310,000 acre-feet of water annually from the west slope to the east slope of the Rocky Mountains to supply supplemental irrigation water for some 615,000 acres of farm land in the South Platte Valley north of Denver, the falling water will make possible the generation of 740 million kilowatt-hours of electric energy annually on an average. The greater portion of this potential energy will be generated at east slope plants, but a substantial amount of power will be generated at Green Mountain on the western slope.

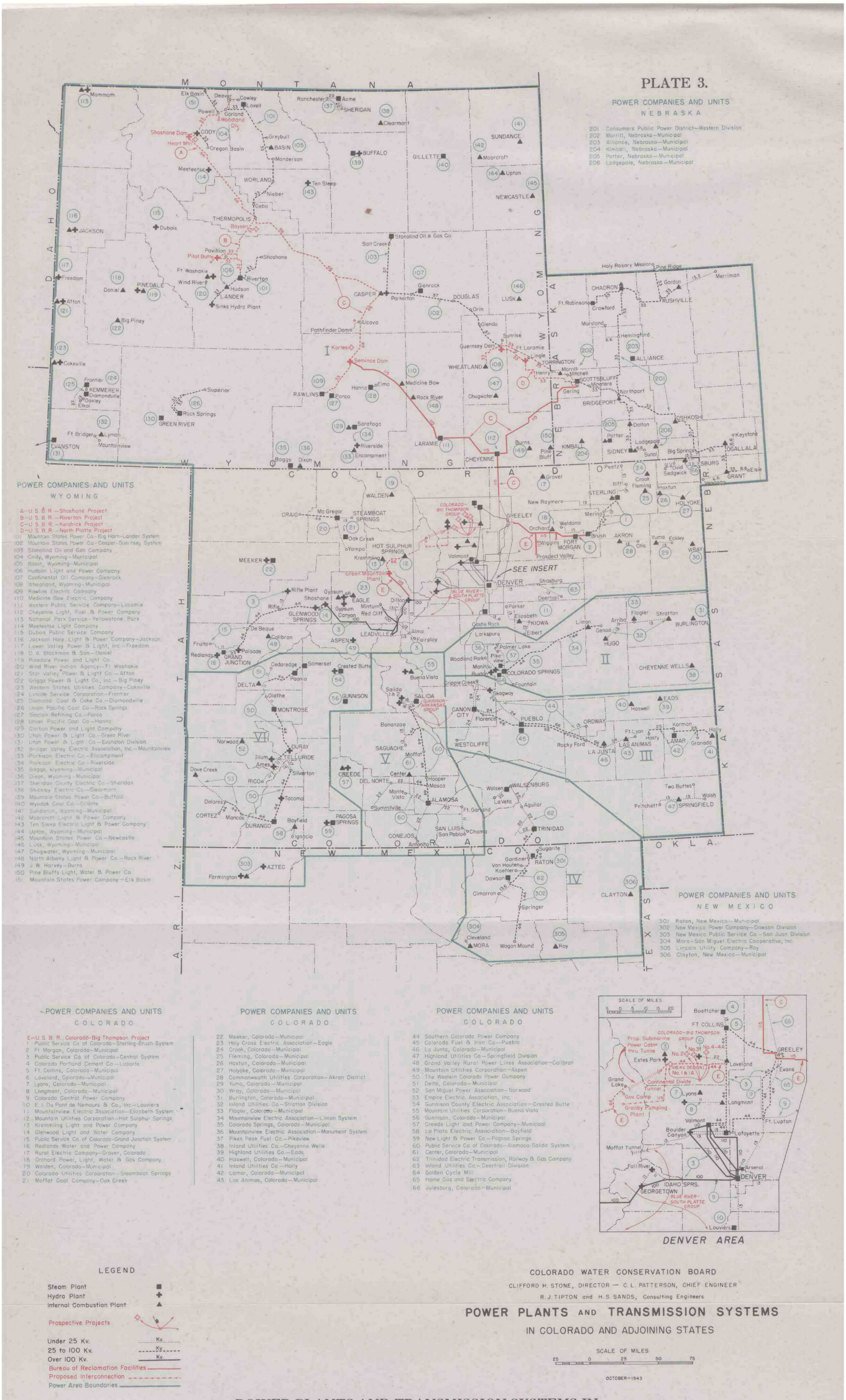
"The five eastern slope power plants are estimated to have an average annual potential energy output of approximately 700 million kilowatt-hours. This energy combined with the net salable energy available from the Green Mountain plant provides a total of approximately 740 million kilowatt-hours from the entire project. The amount of energy that could be generated in a minimum year is estimated to be 530 million kilowatt-hours.

"The extent to which the project's potential energy output could be utilized to provide dependable capacity for local or regional loads has not yet been determined. Preliminary studies by the United States Bureau of Reclamation have indicated that the total installed generating capacity should be about 150,000 kilowatts.

2. "Blue River-South Platte (Transmountain Diversion) Project. The City and County of Denver has for several years been studying the possibility for additional diversions of water from the Colorado River Basin to the eastern slope of the Rockies to augment its municipal water supply, much of which is already obtained by transmountain diversion. One of the projects under study involves diversion of Colorado River water from a tributary, the Blue River, to the South Platte Basin.

"In order that the greatest benefits for the entire upper South Platte Valley (of which Denver is the center) may be derived from the diversion of west slope water for domestic purposes, this diversion project is being considered for much larger development than that contemplated for the Denver metropolitan water supply alone. With this purpose in mind, the United States Bureau of Reclamation, the Colorado Water Conservation Board, the Denver Board of Water Commissioners, and the South Platte Water Users Association are working cooperatively toward the plan of development for the Blue River-South Platte Project which would bring about the most beneficial and efficient use of this water resource in the interest, not only of the Denver Metropolitan Area, but of the South Platte Valley and the entire state of Colorado.

"Final plans for this project have not been formulated or agreed upon by all interests concerned; but, for the purpose of this report, it is considered appropriate to indicate its potential



POWER PLANTS AND TRANSMISSION SYSTEMS IN COLORADO AND ADJOINING STATES.

Bureau of Reclamation facilities are shown in red; those of all other utility systems, in black. The voltage of the transmission facilities is indicated for systems of the Bureau of Reclamation as well as for other systems (see legend), by the kind of line shown.

power characteristics on the basis of very preliminary studies made by the Bureau of Reclamation. The Bureau is giving consideration to a number of alternate plans whereby between 300,000 and 500,000 acre-feet of water annually may be brought to the eastern slope from the drainage areas of the Eagle, Blue, and Williams rivers. Three of the alternate plans may be identified as Montezuma, Empire, and Moffat, according to the route that would be followed by the tunnel through the Continental Divide. Under all plans being considered, regulatory storage would be provided by reservoirs located both in the Colorado River watershed and the South Platte watershed.

"The average annual power production would be practically the same for the Montezuma as for the Empire route; it would amount to approximately 1,200 million kilowatt-hours, about 800 million of which could be assured under minimum water conditions. Comparable figures for the Moffat tunnel route are 1,700 million kilowatt-hours average annual output, and 1,000 million in a year of minimum water supply. The greater power output with the Moffat route is due to the greater head below the tunnel on the eastern slope and the diversion and incidental use for power production of about 100,000 acre-feet of water annually from the Fraser River, in addition to the water from the Eagle, Williams, and Blue rivers.

3. "Gunnison-Arkansas (Transmountain Diversion) Project. The Gunnison-Arkansas Project would involve diversion of water from the Gunnison River (a tributary of the Colorado River in southwestern Colorado) to the upper Arkansas Basin.

"Studies of the power phases of this project are in a very preliminary stage and only rough estimates have been made. In general, the plan of development contemplates the construction of a tunnel under the Continental Divide, which would terminate west of Salida, Colorado. As in the case of the other diversion projects described above, reservoirs and power plants would probably be located on both the east and west slopes of the Rocky Mountains. It is estimated that the available power head would approximate 3,500 feet and that it would be possible to generate, on an average, approximately 1,400 million kilowatt-hours annually. The annual output in a year of minimum water supply should total about 700 million kilowatt-hours."

It may be desirable to develop locally additional power with fuel electric plants to supplement new hydroelectric capacity.

The schedule of completion for the above projects is uncertain, but the outlook is favorable for a continued aggressive program by the U. S. Bureau of Reclamation to develop the water resources of the western States. It is, therefore, virtually certain that the future supply of power and the power cost will continue to improve in areas not adequately supplied at the present time.

The question of power rates is too uncertain to attempt any analysis. Much depends on the actual plant capacities finally decided on. For some time the trend of power cost has been downward; in view of the proposed development, still lower rates would seem to be in prospect, particularly in less favored areas. In addition it is also a reasonable expectation that there will be a more abundant supply of power, which is another important factor for general industrial development.

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PAST PRODUCTION AS A BASIS FOR ESTIMATING THE FUTURE

The total production from 1859 through 1944 of the more important minerals and metals in Colorado, calculated at average yearly prices is as follows:

1.	Gold (38,814,345 ounces)	$852,380,789
2.	Silver (725,959,747 ounces)	564,176,596
3.	Copper (494,944,420 pounds)	65,316,123
4.	Lead (4,855,604,583 pounds)	232,266,447
5.	Zinc (2,534,555,985 pounds)	186,212,730
6.	Coal (445,819,368 short tons)	967,259,615
7.	Tungsten (18,351 short tons, 60% concentrates)	21,646,305
8.	Radium (through 1930)	18,000,000
9.	Petroleum (50,026,930 barrels)	51,539,430
10.	Molybdenum (291,560,315 pounds) (value estimated)	218,670,236
11.	Vanadium (Pounds produced prior to 1939 not available; 14,440,693 pounds V_2O_5, 1939 to 1944, with an estimated value of $7,220,000)	14,126,000
12.	Fluorspar (value for 1938 not included) (391,581 short tons)	6,239,621
13.	Iron (2,000,000 short tons; ore tonnage through 1930, iron content unknown)	3,916,000
14.	Manganese (34,010 short tons) (Latest production 1939 through 1943 is 1,661 short tons with 35 per cent or better manganese; value estimated $60,000.00)	4,267,000

Colorado leads all other states in the total production of silver, is second in gold, third in lead, fourth in zinc, and fifth in copper. In addition, Colorado exceeds all other states in the production of molybdenum and vanadium. Inasmuch as uranium accompanies much of the vanadium, the State in all probability leads in the production of this metal, although production figures are not available. Colorado also was a pioneer and leader in the production of radium prior to the discovery and development of radium ores in the Belgian Congo about 1920. Tungsten production has been important at times, and iron, manganese, and bismuth alsó have been produced.

It is interesting that as a result of a higher price, the ounces of gold produced from 1935 to 1940 exceeded all but the previous peak years from 1895 to 1915. The production of silver does not show a similar response to a greater percentage increase in price. The production of copper from 1935 to 1940 exceeded all previous years by 200 to 300 percent, but lead and zinc did not fare as well as the other metals. However, lead and zinc production increased during the war years when the production of copper and silver decreased. The decrease during the war years in the total value of the five metals was caused by the closing of the gold mines through governmental order.

Many of the deposits yield complex ores that contain gold, silver, copper, lead, and zinc in different proportions. These ores require corresponding milling practices that are more costly than milling of simple ores. Thus the price of each metal affects each of the others, which makes analyses of the influence of price a difficult undertaking.

The diversity in metal content of gold, silver, copper, lead, and zinc, plus the occurrence of other metals such as molybdenum and vanadium, has had the advantage in bringing about a somewhat steady yearly production in terms of overall total dollar values throughout most of the period of active mining in Colorado. Improvements in metallurgy also has played an important part in maintaining production. The variety of the metals, the large ore reserves in some of the major mining districts, the probability of development of new reserves as occurred recently in the San Juan area, and further possible improvements in metallurgy are favorable for the extension of the past record of production into the future.

It is not difficult to present a summary of past production, but interpretations as to the future lead to differences of opinion. For several years and especially since 1942, the beginning of the war, economists and statisticians have had much to say on the country's vanishing ore reserves. Interpretations have been presented that the United States is now or is soon to become a "have-not" nation. With the use of production curves and figures, certain individuals have presented arguments in favor of importing cheap metals. These conclusions may well constitute an example of interpretations that represent a particular interest. Fortunately many well-qualified mining men do not agree with the "have-not" philosophy.

The past 20 years have seen the development of the world's largest molybdenum mine in Colorado and of a potash industry in New Mexico. Before the war a drainage tunnel over 30,000 feet long was completed by a mining company in the Cripple Creek district, but war regulations closed gold mines and thus delayed the benefits this tunnel is certain to bring. Within the last 3 to 5 years the Rangely field, a major oil pool in northwestern Colorado, has been under deep-sand development, and more recently a large deposit of lead, zinc, and copper ore with gold, at a depth 1,000 feet below older workings, has been brought into production in

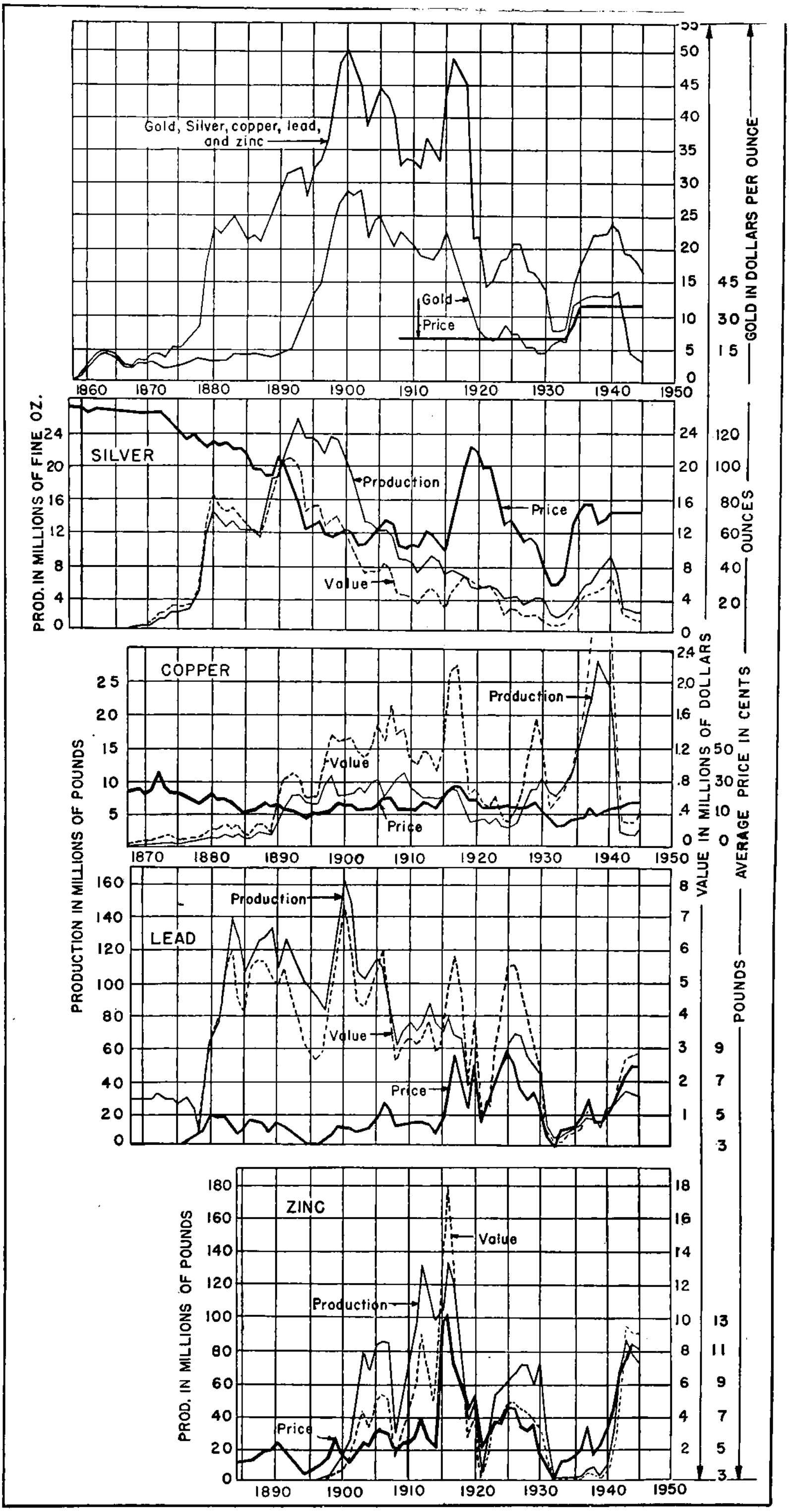

FIGURE 1.—Production, price, and value of gold, silver, copper, lead and zinc in Colorado.

the San Juan region. A similar history of development has taken place in other states and these are not evidence of an exhaustion of mineral resources.

The uncompleted deep-level drainage tunnel in the Leadville district deserves mention for two reasons. First, the tunnel represents the only major failure in the development of a mining district in recent years in Colorado, which in itself does not speak well for the only strictly government-managed mining undertaking of its kind in the State. Second, a lower drainage tunnel would be desirable, but the completion of the present tunnel would assist materially in the further development of parts of the Leadville district.

Another development that is of interest is with respect to gold placers. A large dredge was put into operation near Fairplay in South Park in June 1941 and subsequently closed by government order L 208 in October 1942; the dredge resumed operation in 1945. The use of draglines with floating and dry-land dredges have operated successfully in places where other methods of gold recovery did not pay. In recent years near Denver, gold has been recovered as a byproduct from washing sand and gravel used in construction. Placer gold is found in as many counties in Colorado as are lode deposits, but they are not as well represented in published reports. The outlook seems promising for a sustained development and production of placer gold in the future.

Visible ore reserves seldom prove to be an accurate measure of the life of an individual mine, and even less so for the country as a whole. The inaccuracies of past predictions as to the limitations of mineral reserves are proof that measured ore alone should not be used for predicting future production.

The production of metallic and nonmetallic minerals is dependent on the same economic factors that influence industry. It is therefore logical that the past history of production over a long period is the safest guide for the future.

Two accompanying charts (figs. 1 and 2) show the production from the earliest date through 1945 of gold, silver, copper, lead, zinc, coal, and petroleum in Colorado. It will be noted that the production of coal has varied, in spite of the existence of large reserves, nearly as much as the metals, for which reserves are seldom large. The material increase, which is likely to continue, in the production of oil in recent years is an expression of development of the Rangely field as well as other fields in the northwestern part of the State. These production curves do not suggest the pending exhaustion of mineral resources in Colorado.

The record of new mineral resources developed during the past 20 years and general production over a much longer period justifies the belief that substantial reserves of undiscovered and undeveloped minerals are present in Colorado and elsewhere in the United States. No one with experience in developing mineral deposits will deny that these concealed deposits are hard to find, nor will they admit that they cannot be found. New technique

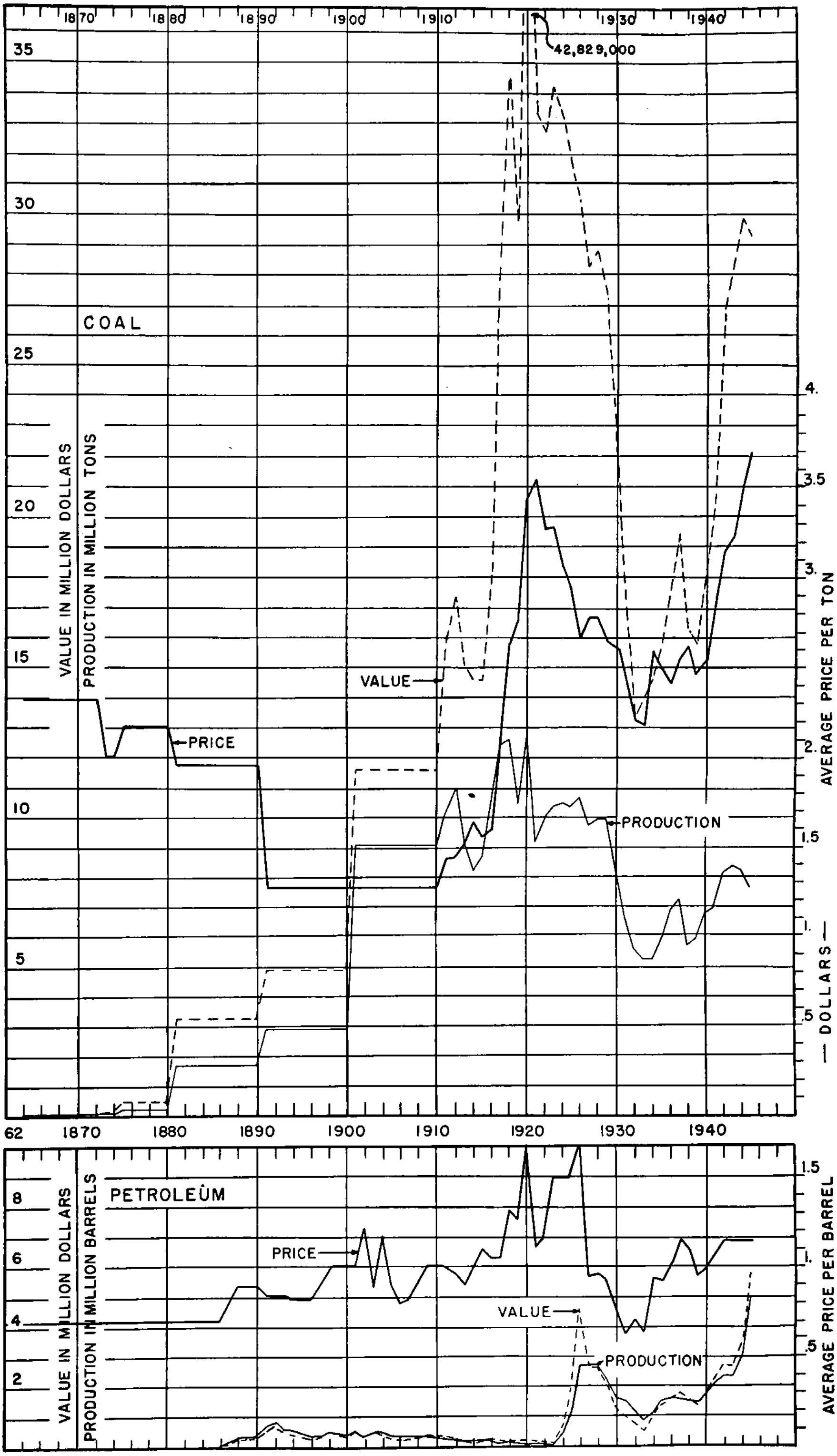

FIGURE 2.—Production, price, and value of coal and petroleum in Colorado.

coupled with the old, consistently and intelligently applied to developing mineral deposits, can supply metals for the future as has been done in the past.

Colorado is fortunate in the diversification of its mineral resources. The production of gold has been important. Lead and silver ores have been favored by relatively conveniently located smelters in the State, and with reasonable prices new ores will be developed. More zinc could be produced at better prices, but zinc is known as the "poison metal" and to be avoided, as ore is penalized because of it. An unknown, but undoubtedly large, quantity of zinc has been lost because metallurgy has not been able to save the metal as a byproduct at existing market prices, and zinc production in Colorado is handicapped further by the location of zinc smelters, the nearest being at Amarillo, Texas.

Artificial regulations and restrictions should be eliminated, which discourage the prospector, mining companies, and the mining industry in general in their search for and development of mineral deposits. If discriminations against prospecting and mining are removed, Colorado can continue to carry its proportionate share with other mining States to produce metals for the future.

METALS

GOLD, SILVER, COPPER, LEAD, AND ZINC DISTRICTS BY COUNTIES

Introductory Statements

Mineral districts originally were officially designated areas related to mineral monuments established for locating mineral claims. This was in the period before land surveys. After land surveys were completed, most of the old mineral districts lost their official status, but the names were continued chiefly for convenience in cataloguing mines and production.

In the literature common use is made of the terms district, area, and even region referring to a town, a mountain or other geographic feature without much regard to former officially designated districts. In this way confusion has arisen as regards general references to locations of some mines and mineral deposits. The U. S. Bureau of Mines has been more consistent than most others in using district names, but here, too, new names have been added and old ones dropped or changed. In the following list the mining districts are those used in recent years by the U. S. Bureau of Mines. Where more than one name has been used in the literature the extra name or names are included in parentheses. With the use of all the names given and the location by township and range, the possibility of mistaken identities can be kept at a minimum.

The list is relatively complete; that is, every locality on which a record could be found of creditable mention in the literature has been included. Any omissions that may have been made were unintentional, and it is hoped that they are few. Undoubtedly a number of localities occur with veins that have never been described, and, naturally, most of these are not included. One can only assume that the more interesting of the mineral occurrences have been reported in the literature and therefore these latter omissions are probably not serious.

In listing the metallic mineral and mining districts of Colorado, the object was to assemble factual data that can be used by a reader to form his own opinion in the light of the particular interest that may be involved. An attempt was made to avoid an expression of evaluation based on personal opinion of any locality, because an analysis of available data to determine the possible merit of a deposit was considered beyond the scope of this presentation. Finally, numerous occurrences have been included about which very little information is available.

Location and access

The township and range of each district can be used to identify the corresponding area on plate 4 that shows the metalliferous deposits. Inasmuch as this map shows railroads, shipping points are not mentioned. The U. S. and State highways nearest to or leading to each district is described, but unfortunately it was not possible to show roads on the map. However, any standard highway map of Colorado can be used for determining the general access to the districts.

Water and timber

The problems pertaining to water and available timber could not be considered satisfactorily with respect to each district, because available data are insufficient.

In the larger streams and tributaries an adequate supply of water is available for current mining operations, but sufficient water for power development is an exceptional occurrence. As a rule the water supply is greater on the western slope and in the San Juan Mountain area than east of the Continental Divide. Nearly everywhere an ample supply of water is present during spring and early summer months while the winter accumulation of snow melts. In late summer and early fall small streams with limited drainage areas usually dry up. At altitudes of 10,000 feet or higher, tributary streams begin to freeze in October. On the whole, however, the supply of water is adequate in the various mining areas in Colorado.

Timber for mining in Colorado is obtained from local sawmills and from the usual sources of lumber outside the State. Small operators often supply their own needs from nearby forests. However, conditions vary greatly, and in appraising the merits of a prospect or mine the available supplies of mine timber as well as lumber for buildings must be considered separately for each area.

Production Figures

Statistical data as to production come from the regular publications, Mineral Resources (1880-1930) and Minerals Yearbook (1931-1945), of the U. S. Bureau of Mines, although the figures used for years prior to 1924 were taken from the compilation of C. W. Henderson in "Mining in Colorado," (U. S. Geological Survey Professional Paper 138).

The past activity of an area is brought out by means of two sets of data: one is a listing of page references in Mineral Resources and Minerals Yearbook that refer to districts arranged by counties, and the second set of data is actual production figures.

Frequently the activity of individual mines, including production figures, is given. Thus the page references to Mineral Resources and Minerals Yearbook are useful in showing the years or periods a district or area was active, and how brief, intermittent, or continuous such activity may have been.

The data are not specific for inactive areas and rather detailed for districts where appreciable production occurred. A summary of these data would constitute a partial and useful history of each district, but such a summary was not considered practical because the data are insufficient and the report would be too lengthy.

Production by districts since 1932 is on a yearly basis, but these figures are not available for prior years. County production is divided into five periods, and the first two periods selected are from the tables compiled by Henderson in Professional Paper 138 referred to above.

Relatively complete records begin with the second period (1909 to 1923), which was selected partly for the reason that it includes a major world war. The third period (1924 to 1931) includes a postwar period of prosperity and the beginning of a depression, while the fourth period (1932 to 1941) includes a depression and world forces that led to the second major war. The fifth and last period (1942-1945) includes the war years during which exceptional efforts were made to increase production at minimum prices and in the face of rising costs and labor shortages. It is believed that in a given county a study of changes in the relative importance of crude ore shipped to smelters, ore treated in gold and silver mills, and ore treated in concentrating mills will be useful in estimating the kind of ore that can be expected in the future, if reasonably normal conditions prevail. The production records of districts will show the kind of metals produced as well as the changes that have occurred during the 13 years following 1932.

Maps

Plate 4, Metallic Mineral Deposits of Colorado, was prepared by the U. S. Geological Survey and shows mining districts with those mines that have produced ore worth a minimum of $1,000. In a few places, unproductive deposits that are known to be large and of potential value are shown; and, where mine symbols are not closely spaced, prospects having produced less than $1,000 are shown to bring out the presence of mineralization and the possibility of deposits of value.

Numerous placer areas in the state, many of which yielded only minor quantities of gold, have been worked intermittently by an individual or a small group of persons. The placer areas known to have yielded significant production are shown on the map, and placers are shown only in counties with a reported total placer production of more than $10,000.

Under the above limitations a number of minor mining districts as well as placer localities are not represented on the map. Nevertheless, enough prospects are shown in outlying areas to bring out the indefinite boundaries of many districts and the merging of neighboring districts. In some areas the distribution of prospects is confined to less than a township and in others it extends outside the township listed. The township given in the text was based on three sources: 1—description used by Henderson in U. S. Geological Survey Professional Paper 138; 2—the references listed under each district; and 3—plate 4, Metallic Mineral Deposits of Colorado.

The topographic quadrangle (quad.) maps and national forest maps that cover each district are listed. Topographic maps can be obtained from the U. S. Geological Survey, Washington 25, D. C. Many of these maps are old and even obsolete in terms of modern mapping technique that utilizes aerial photography, but in the absence of other maps they are useful. The Forest Service maps do not show topography, but they are excellent for geography, such as trials and other cultural features, including land survey lines.

Most Forest Service maps are prepared for use in administering the National Forests, and consequently the supply does not permit of their general distribution. However, the maps are available for study at the U. S. National Forest regional office in Denver, Colorado, and for special needs it may be possible to obtain copies or have photostat copies made of a particuluar area. The maps usually are available for study at the forest supervisors' offices listed below:

Offices of Supervisors of U. S. National Forests

1. Arapahoe National Forest, Idaho Springs.
2. Grand Mesa National Forest, Grand Junction.
3. Gunnison National Forest, Gunnison.
4. Montezuma National Forest, Cortez.
5. Pike National Forest, Colorado Springs.
6. Rio Grande National Forest, Monte Vista.
7. Roosevelt National Forest, Fort Collins.
8. Routt National Forest, Steamboat Springs.
9. San Isabel National Forest, Pueblo.
10. San Juan National Forest, Durango.
11. Uncompahgre National Forest, Delta.
12. White River National Forest, Glenwood Springs.

During the past fifteen years most of the Forest Service maps have been revised through the use of aerial photography, and consequently these newer editions are accurate. Forest boundaries have been changed, which must be taken into account if older editions of maps are to be used. The former Holy Cross National Forest has been incorporated with the White River National Forest, and Cochetopa has been divided among the Rio Grande, San Isabel, and Gunnison National Forests.

The boundaries of the map of each national forest extend well beyond the limits of the forest itself, and consequently the maps overlap generously so that the maps of 2 or even 3 forests may cover a given area.

In addition to the maps listed, aerial photographs made by the U. S. Forest Service of the national forests are available. Individual photographs cover a few square miles and copies can be obtained at a nominal cost from the Forest Service, New Custom Building, Denver 2, Colorado. It is of course necessary to know the section, township, and range of an area in question in order to obtain the proper photograph.

Geology and Bibliography

Geologic descriptions were obtained from publications of the U. S. Geological Survey, Colorado Geological Survey, Colorado Scientific Society and miscellaneous societies, as well as from periodicals, unpublished reports, personal communications, and personal knowledge.

The most important reference for a number of areas is a geologic summary in Part 2 of this report as indicated by the page numbers given. The geologic summary was prepared for this bulletin by the geologists who made detailed studies of, or were otherwise personally acquainted with the respective areas described.

The references that are given were selected for utility. If only one reference was found, it is given regardless of the worth of the data contained. However, for districts favored with several published descriptions, the best one or two were selected with the intent that these will in turn refer a reader to additional references if detail should be desired. The geologic summaries referred to above also include selected bibliographies which are not repeated for respective districts.

Following the list of mining districts by counties is a tabulation also arranged by counties of page references to Mineral Resources and Minerals Yearbook. These references are to exploration, mine development, and operation that has been recorded by the U. S. Bureau of Mines.

Gold Placer Deposits

The recovery of gold from placer deposits in Colorado has continued since 1858 and seems destined to continue for some time in the future. In spite of the long history of production, only general information is available concerning many of the known placer areas. (See districts listed according to counties.) Reports on the various gold districts may or may not have a brief account of the placer deposits in the area, and they usually cover only placers that were being operated at the time of the report. Private companies have done considerable sampling, but the results are seldom made known and many of the private records have probably been lost. No studies have been made of the placer possibilities of the State as a whole. The description of the placer deposits in northwestern Park County (see pages 346-349) is almost unique, and reports of other areas would be desirable because the placer deposits are an important source of gold production in Colorado.

The bulk of the yearly production is obtained from a relatively few operations, leaving a small yield from a large number of small operators including numerous individuals who work at their placers only a few weeks or months out of the year. Thus, excepting the larger placer operations, the records of production are of little value except for indicating the general distribution of placer deposits.

In recent years two developments have occurred that bear on gold placering. The first development is the new price, $35.00 per ounce of gold, as compared with $20.76 prior to 1933. The second important development is the use of equipment designed for moving gravel, sand, and dirt in placer operations. Dry land and floating dredges in combination with draglines and power shovels with a capacity of 1,000 to 4,000 cubic yards per day can operate in places too small for bucket dredges. The costs vary from about 10 to 24 cents per cubic yard which is considerably higher than for large bucket dredges but this is partly offset by the lower initial cost of the smaller units. As a result, gold is being recovered at a profit from placer deposits that were not considered workable prior to 1933. This justifies the recommendation that anyone interested in developing placer deposits should restudy the general situation as regards gold placers in Colorado.

In a statistical analysis, Prommel gives total placer gold production by counties from 1858 to 1944 inclusive, and divides the placer industry into five periods of productivity as follows:

Counties	Placer Gold Value in Dollars	Counties	Placer Gold Value in Dollars
Summit	$15,627,868	Denver	8,449
Lake	7,308,290	Eagle	7,847
Gilpin	6,479,550	Rio Grande	7,213
Park	6,423,464	Mesa	5,066
Clear Creek	2,914,408	Miscellaneous	5,000
Chaffee	1,651,373	Fremont	4,501
Routt and Moffatt	456,017	Ouray	4,299
Jefferson	348,544	Elbert	3,983
San Miguel	206,143	Grand	2,497
Adams	87,239	La Plata and Montezuma	1,582
Montrose	76,392	Delta	1,384
Boulder	71,963	Dolores	663
Costilla	32,264	Pitkin	220
Gunnison	24,877	Huerfano	132
Douglas	20,200	Rio Blanco	56
Larimer and Jackson	17,794	Garfield	40
Arapahoe	16,729		
San Juan	13,161		
Teller	12,142		$36,841,350

		Number of Years	Value
Flush production period	1858-1867	9	$14,923,918
Hydraulicking and ground sluicing	1868-1907	40	7,201,638
Large bucket dredges	1908-1931	24	8,526,023
Dry land, dragline and bucket dredges	1932-1942	11	6,159,531
Hand sluicing	1943-1944	2	30,240
Total			$36,841,350

After the period of flush production when the relatively small but rich placers were exhausted, placer operation became more dependent on mechanization and careful engineering. Highly mechanized dredges produced more gold in 24 years than had been recovered by hydraulicking and ground sluicing in the preceding 40 years.

It is interesting to note that the dry land, dragline, and bucket dredges since 1932, with the advantage of the higher price for gold, have maintained about the same average yearly rate of production in ounces made by the bucket dredges of the preceding period. At first and including 1941, production by dry land and floating dragline dredges predominated, but in 1942 bucket dredges near Fairplay, Park County, were operating and the gold produced by them exceeded that of the other methods. In 1943 and 1944 War Order L 208 stopped all dredges; however, the larger dredges have resumed operation and the pre-war rate of production can be expected soon, and in addition new activities are indicated which may lead to increased placer production.

Unfortunately, the available data are inadequate for appraising the relative merits of the various areas from which placer gold is being obtained. However, the record of placer development since 1933, although interrupted for 2 years by the war, justifies the view that the gold placer deposits rank among the important mineral resources of Colorado.

Gardner, E. D., and Guiteras, J. R., Placer operations of Humphry's Gold Corporation, Clear Creek, Colorado: U. S. Bureau Mines Inf. Circ. 6961, 16 pp., October 1937.

Gardner, E. D., and Allsman, P. T., Power-shovel and dragline placer mining: U. S. Bureau Mines Inf. Circ. 7013, 68 pp., May 1938.

Prommel, H. W. C., Colorado placer mining: Mining Congress Jour., vol. 31, no. 12, pp. 24-31, December 1945.

Adams County

Production of Placer Gold and Silver in Terms of Recovered Metals

Year	Placer Mines Producing Yearly	Gold (fine ounces)	Silver (fine ounces)	Total Value
1922-1923	2	41	7	$ 845
1924	1	35	6	732
1925	1	89	13	1,845
1926	2	212	35	4,405
1927	2	162	23	3,353
1928	3	201	29	4,163
1929	2	197	28	4,088
1930	2	103	13	2,130
1931	3	66	7	1,367
Total 1924-1931	1–3	1,064	154	22,083
1932	4	12	4	247
1933	2	5	....	97
1934	16	20	2	684
1935	19	45	7	1,592
1936	13	85	13	2,992
1937	11	185	23	6,486
1938	11	92	14	3,222
1939	12	317	53	11,131
1940	7	259	41	9,094
1941	3	282	45	9,902
Total 1932-1941	3–19	1,302	202	45,447
1942	1	274	45	9,622
1943	2	145	20	5,089
1944	1	126	45	4,442
1945	3	319	52	11,202
Total 1942-1945	1–3	864	162	30,355

Clear Creek placers

The particular localities that have produced placer gold are not recorded, but they are included in T. 3 S., R. 68 W. (see pl. 4) and the adjoining township to the west in Jefferson County. The altitude is 5,000 to 5,500 feet.

The discovery of placer gold on Clear Creek was soon after 1860, but the record of production begins with 1922, after which a small yearly production was maintained. From 1924 to 1931 a production of 35 to 212 fine ounces yearly was reported from only 1 to 3 placer mines, while from 1935 to 1939 the production was 45 to 317 fine ounces yearly from 11 to 19 producers.

Most of the production has come from Clear Creek, although some gold has come from the South Platte River, of which Clear Creek is a tributary. In recent years some gold came as a byproduct from sand and gravel plants north of Denver.

Denver Quad., 1:125,000, contours 50 & 100 ft., ed. 1901, reprint 1919.

Derby, Arvada, and Golden Quads., 7½-minute series, 1:31,680, contours 10 ft., ed 1944.

Henderson, C. W., Mining in Colorado; a history of discovery, development, and production: U. S. Geol. Survey Prof. Paper 138, pp. 17, 18, 104, 1926.

Alamosa County

Blanca or West Blanca

T. 28 S., R. 73 W., (SE corner). (See pl. 4.)

Altitude 10,000 to 14,000 feet.

Granite and metamorphic rocks of pre-Cambrian age. Small veins are reported.

Production has been limited to trial shipments of a few tons of gold ore in 1928 and in 1934.

San Isabel National Forest Map.

Rio Grande National Forest Map.

Arapahoe County

Production of Placer Gold and Silver in Terms of Recovered Metals in Arapahoe County

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1885-1904		392	101	$8,165
1925	1	2		46
1930	1	5		104
1931	1	11		232
Total 1924-1931	1	18		382
1932	1	2		32
1933	1	2		38
1934	42	60	2	2,083
1935	33	60		2,109
1936	6	38		1,330
1937	6	16		546
1938	8	20	1	701
1939	8	13		455
1940	5	5		175
1941	1	22	4	773
Total 1932-1941	1–42	238	7	8,242

Arapahoe County

1. Cherry Creek and Dry (Cottonwood) Creek, T. 5 S., Rs. 66 and 67 W, (see pl. 4).
2. South Platte River, T. 5 S., R. 68 W., (not shown on pl. 4).
3. Little Dry Creek, T. 5 S., R. 68 W., (not shown on pl. 4).
4. A number of placers, the localities of which have not been reported.

Altitude 5,200 to 5,700 feet.

Placer gold was discovered in 1858 south of Denver in bars along the South Platte River, Cherry Creek, and some of the tributaries. The fine gold has been reconcentrated from the Dawson arkose and Castle Rock conglomerate of Tertiary age. See also Douglas and Elbert Counties.

Denver Quad., 1:125,000, contours 50 & 100 ft., ed. 1901, reprint 1919.

Englewood, Fitzsimons, Ft. Logan, Highland Ranch, Littleton, and Parker Quads., 7½-minute series, 1:31,680, contours 10 ft., ed. 1942-1944.

Henderson, C. W., Mining in Colorado; a history of discovery, development, and production: U. S. Geol. Survey Prof. Paper 138, pp. 27, 104, 1926.

Archuleta County

Occasional small lots of ore are reported from Archuleta County but the source is not known. The only metal production since 1904 is:

1937—5 tons 43 ounces silver
800 pounds lead
2,000 pounds zinc
1938—7 tons, 38 ounces gold
4 ounces silver

San Juan National Forest Map.
Rio Grande National Forest Map.

Baca County

Carizzo Creek (Estelene)

T. 34 S., R. 50 W. (See pl. 4).

Altitude 4,600 to 5,000 feet.

The district is 45 miles southwest of Springfield, Colorado, and the canyon roads are fair to poor.

Chalcocite is partly altered to malachite and azurite in white sandstone. The gold reported in ore of this type is somewhat unusual. Recorded production is:

	Ore (tons)	Gold (ounces)	Silver (ounces)	Copper (pounds)	Total Value
1900, 1901, 1902		14	241	11,419	$2,242
1915, 1916, 1917	14		115	10,092	2,717

Mt. Carizzo Sheet, 1:125,000, contours 25, 50, and 100 ft., ed. 1892.

Henderson, C. W., Mining in Colorado; a history of discovery, development, and production: U. S. Geol. Survey Prof. Paper 138, p. 105, 1926.

LIST OF MINING DISTRICTS WITH PAGE REFERENCES TO MINERAL RESOURCES AND MINERALS YEARBOOK

Districts not listed have not been referred to except for occasional mention under county.
Mining districts are not described for the years 1889 through 1903 except for three instances where references for 1900 are listed under 1888.
Page references to Mineral Resources 1907 to 1931 are in Part I.
Page references to Minerals Yearbook 1932-33 are in the Statistical Appendix.
Minerals Yearbook 1932-33 to 1940 cover the production years 1932 to 1939, respectively, as shown in parentheses.
Mineral Resources 1882 to 1923 was published by the U. S. Geological Survey; Minerals Resources 1924 to 1932 and Minerals Yearbook 1932-33 through 1944 were published by the U. S. Bureau of Mines.
†Mill operation only.

District	1882	1883-84	1885	1886	1887	1888	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	Appendix (1932) 1932-33	(1933) 1934	(1934) 1935	(1935) 1936	(1936) 1937	(1937) 1938	(1938) 1939	(1939) 1940	1940	1941	1942	1943	1944
Adams County (Clear Creek placers)																									531	624	558	712	747	541	831	932	1057	520	152	172	211	249	317	261	287	263	293	299	329	326	313
Alamosa County (Blanca or West Blanca)																															832	933	1057				211										
Arapahoe County (Cherry Creek, Dry Creek, South Platte River, Little Dry Creek, and other placers)																																	1057	520	152	172	211	249	317	261	287	263	293	299			
Archuleta County																																933		520										299			
Baca County (Carrizo Creek (Estelene))																		436	345	810												933		520													
Boulder County																																				172											
Central (Jamestown)								194	208	245	371	303	400	532	667	244	272	437	346	810	834	763	575	490	531	624	558	712	747	541	832	933	1057	521	152		211	250	317	261	287	263	293	299	329	326	313
Gold Hill (Salina, Rowena, Sunshine)								194	208	245	371	303	400	532	668	245	272	437	346	810	834	763	575	490	531	624	558	712	747	541	832	933	1057	521	152		212	250	317	261	287	263	293	299	329	326	313
Grand Island (Cardinal, Caribou, Eldora, Nederland)								195	208	245	371	304	401	532	668	245	273	437	346	810	834	763	575	490	531	624	558	712	747	542	833	933	1058	521	152		212	251	318	262	288	264	293	299	329	326	
Magnolia									208	245, 712	371, 722	304	401	532	668		273	438	347	811		763	576	490	531	625	558	712	748	542	833	933	1058	521	152		213	251	318	262	288	264	293	229	329		
Nederland							330	411		712	722	578																																			
Sugarloaf							330	195, 411	208	245, 712	372	304, 579	401	533	668	245	273	438	347	811	834	763	576	490	531	625	558	712	748	542	834	933	1058	521	153		213	251	318	262	288	264	293	299	329	326	313
Ward													401	533	668	245	274	438	347	811	835	764	576	491	532	625	558	712	748		834	934	1058	521	153		213	252	319	262	288	264	293	300	330	326	313
Chaffee County																																															
Arkansas River placers (Buena Vista, Nathrop, Salida)																				811					532			713								173	213	252									
Brown Creek placers (Brown Canyon)																																		521	153							264					
Chalk Creek (Alpine, Romley, St. Elmo)									209	247	373	305	402	534	669	246	274	439	348	811	835	764	576	491	532	625	558				834	934	1058		153	172	214	252	319	262	288	264	294	300	330		313
Cleora									209		373	305	402						349																												
Cottonwood								195											349	814		764	576	491		625																					
Four Mile														534	669	246	275	440													834						214	252	319	262				300			
Free Gold																246					835			491										522	153	173											
Garfield-Monarch			256		105	87		195	210	247	373	305	402	534	669	247	275	440	349	814	835	764	576	491	532	625	559	713	748	543	834	934	1059				214	252		263	289	265		300	330	326	313
Granite (and Lost Canyon)											373	305	402	534		246	275		349	814	835					625		712	748	542	834	934	1058	522	153	173	214	252	319	262	288	264	294	300	330	326	313
La Plata (Winfield)								195	209	247	373	305	402						349		835			491	532		558	713		543					153							265		300			
Riverside (Mount Harvard)									210	247	373	305	403	535	670	247	275	440		814	836			492												173	214	253	319	263	289	265					
Sedalia		341								247	373																																				
Trout Creek																																			153	173	214		319	263	289	265					
Turret Creek								196	210	247, 602	373	305	403	535	670	247	275	441	349	814	836	765	576	492											153		214	253	319			265		300			
Twin Lakes (Red Mountain)																															835			529										300			
Clear Creek County																																															
Alice (Lincoln, Yankee)								197			377	307	405	536	671	248	276	441	350	815	836	765	576	492	532	626	559	713	748	543	835	934	1059	522	153	173	214	253	320	263	289	265	294	300	330		
Argentine, West Argentine			256					197	212	249	375	307	405	536	671	248	276	441	350	815	836	765	577	492	533	626	559	713	748	543	835	934			154	173	214	253	320	263	289	265	294	300	330	327	314
Dailey (Atlantic)																	276																										294				
Empire (Upper Union)									212	251	377	307	405	536	671	248	276	442	351	815	836	765	577	492	533	626		713	749	543	835	934	1059	522	154	173	215	253	320	263	289	265	294	301	330	327	
Geneva Creek (Collier Mountain)																					837	765								543						173			320			266	295				
Griffith (Georgetown, Silver Plume, Queens)	310		256					197	211	249	375	307	406	536	671	248	277	442	351	816	837	766	577	492	533	626	559	713	749	543	836	935	1059	522	154	174	215		320	264	290	266	295	301	330	327	314
Idaho Springs (Cascade, Coral, Jackson Bar, Payne's Bar, Spanish Bar, Virginia Canyon)		341	256					196	211	250	376	309	407	537	672	249	277	443	351	816	837	766	577	492	533	626	559	713	749	544	836	935	1059	522	154	175	215	254	320	264	290	266	295	301	331	327	314
Montana (Lawson, Dumont, Downieville)			256					197	213	250	377	309	408	538	673	250	278	444	353	817	838	767	578	493	534	626	559	714	750	544	837	937	1060	523	154	174	216	254	321	264	290	266	296	302	337	327	314
Trail (Freeland, Lamartine)		341	256					196	212	251	377	309	408	538	673	250	278	444	353	817	838	767	578	493	534	627	559	714	750	544	837	937	1060	523	154	174	216	255	321	264	291	266	296	302	331	327	314
Conejos County																				818																											
Platoro (Ute)								198	213	251					675	250	279	445																									296	302			
Stunner																																									291						
Costilla County																								493																							
Plomo (Rito Seco)																																											296				
Russell (Grayback)									213	251			409	539	676	250	279															937		523	154	174	216	255	321	265	291	267	296	302			
Custer County													409	539	676	250	279	445	353	818	839		578	493	534	627																					
Fairview																																											296			328	
Oak Creek (Ilse, Spaulding)								198	213	251	378																559		750	545	837																
Rosita Hills (Rosita Querida)																											559				838	937				174	216	255	322	265							
Hardscrabble (Silver Cliff, Westcliffe)		549	256					198	213	251	378	309															559	714	750	545	837	937		523	154		216	255	321	265	291	267	296	302	331	328	314
Delta County													410																							174	217	255		265							
Denver County (Cherry Creek and Platte River placers)																						768	578	493	535							937		523	154	175	217	255		265	291	267		302			

LIST OF MINING DISTRICTS WITH PAGE REFERENCES TO MINERAL RESOURCES AND MINERALS YEARBOOK—(Continued)

	1882	1883-84	1885	1886	1887	1888	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Dolores County																				
Lone Cone (Dunton)								199					410	539	677	251	280	446	354	
Pioneer (Rico)				145				199	214, 476	252	378	310	410	539	677	251	280	446	354	
Douglas County															677	252		446		
Newlin Gulch placers													410				281			
Eagle County																				
Brush Creek																253	282	447	356	820
Burns & McCoy													411		678				356	
Fulford								199	215	253	379								356	
Gypsum																				
Holy Cross (Eagle River)									215	253	379	311				253	282	447		
Mount Egley															678	253	282		356	
Red Cliff (Battle Mountain, Gilman, Belden)	310	422	255	144				199	215	253	378	311	411	540	678	252	282	447	355	820
Elbert County (Gold Creek or Ronk Creek placers)																				
El Paso County																				
Blair Athol																253	282	447		
Fremont County																253	283	447	356	821
Arkansas River placers																				
Canon City																				
Cotopaxi													411	540	678					
Currant Creek (Parkdale, Micanite)									215											
Grape Creek (Greenhorn)	404	281			53				216											
Hillside																				
Red Gulch										253	380									
Garfield County (Rifle Creek and Elk Creek)													411			253	283	447		821
Gilpin County																				
Northern districts (Perigo, Independence, Pine-Kingston-Apex)		341						200	217	255	383, 389	314	414	543	680	255	284	449	358	822
Southern districts (Central, Nevada, Gregory, Russell, Quartz Mountain)	227	341	256				344	200	216	255	380, 747	312	413	541	679	254	284	448	357	821
Grand County													415				285	449	358	
Blue Ridge																				
Grand Lake (Wolverine)								201												
La Plata (Williams Fork)									218											
Monarch (Harmon)								201	218											
Placers																				
Gunnison County																				
Box Canyon										257	384	315				256				823
Cebolla (Vulcan, Domingo, Powderhorn, White Earth)	144	283								105, 257	111							450	359	823
Cochetopa (Green Mountain, Gold Basin)									218	257	384		415	544	681					
Elk Mountain									218	257	385	315		544			285	450	359	823
Gold Brick													416	544	681	256	285	450	359	823
Goose Creek (Madera)																				
Quartz Creek								202	219	257	385	315	416	544		256	285	450	359	824
Rock Creek (Marble)								201	218	257	385		416	544	681	256	286		359	824
Ruby								201			385									
Spring Creek (Spring Gulch)																				
Taylor Park																				
Tincup								201	219	257	385	315	416	544	681	256	286	450	359	824
Tomichi (Whitepine)			256		28			202	219	258	385	315	416	544	681	256	286	451	360	824
Hinsdale County																				
Galena (Henson Creek)								202	220	258	386	316	417	544	682	257	286	451	360	825
Lake Fork (Lake San Cristobal)								202	220	259	386	316	417	544	682	257	286	451	360	825

	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	Appendix (1932) 1932-33	(1933) 1934	(1934) 1935	(1935) 1936	(1936) 1937	(1937) 1938	(1938) 1939	(1939) 1940	1940	1941	1942	1943	1944
Dolores County								714	750	545																	
Lone Cone (Dunton)		769	578	494	535	627	560			546	838	938	1061						322	265	291		296	302			
Pioneer (Rico)	819	769	578	494	535	627					838	938	1061	524		175	217	256	322	265	291	267	296	302	331	328	315
Douglas County				494	535			715	751					524	155	175	217	256	322	265	292	268	297	303			
Newlin Gulch placers										546	839																
Eagle County																											
Brush Creek	841	769	579	494	536	628	560	715																			
Burns & McCoy	841	769		495							839	938		524		175	218	256	322		292	268	297				
Fulford					536								1061														
Gypsum				495	536											175											
Holy Cross (Eagle River)		769							751	547	839		1061							265	292	268	297				
Mount Egley				495											155							268		303			
Red Cliff (Battle Mountain, Gilman, Belden)	841		579	494	536	628	560	715	751	547	839	938	1061	524	155	175	218	256	322	265	292	268	297	303	332	328	315
Elbert County (Gold Creek or Ronk Creek placers)									751					524	155	175	218	256			292	268	297				
El Paso County	†841	†769	†579	†495	†536	†628	†560	†715	†751	†548	†839	†939	†1061	†524	†155	†176	†218	†256	†322	†266	†292	†268	†297	†303	†332	†328	†315
Blair Athol																											
Fremont County	842	†770	†579	†495	†537	†628	†560	†715	†752			†939		†524			219	257	323	266	293	269	298	303			
Arkansas River placers															156	176											
Canon City										†548	†840																
Cotopaxi										548	840														333	329	316
Currant Creek (Parkdale, Micanite)																											
Grape Creek (Greenhorn)																									333	329	316
Hillside																								303			
Red Gulch																											
Garfield County (Rifle Creek and Elk Creek)		842							752	548	840	939	1062	525		176					293	269	298	304			
																							298	304			
Gilpin County									752	549	841	940	1062	525													
Northern districts (Perigo, Independence, Pine-Kingston-Apex)	843	771	580	496	538	629	561	715	753	549	841	940	1063	526	157	177	220	259	324	267	294	270	299	304	333		
Southern districts (Central, Nevada, Gregory, Russell, Quartz Mountain)	843	770	579	495	537	628	560	715	752	549	841	940	1062	525	156	176	219	258	323	267	293	269	298	304	333	329	316
Grand County	844	771	580	496	538				753						157				325		295	270	299	305	333	330	
Blue Ridge								716																			
Grand Lake (Wolverine)																											
La Plata (Williams Fork)						629						940					220										
Monarch (Harmon)																											
Placers										550		940					220	259		268							
Gunnison County																											
Box Canyon															157						295	270					
Cebolla (Vulcan, Domingo, Powderhorn, White Earth)	844	771		496		629		716				941	1063	526	157	177	220							305			
Cochetopa (Green Mountain, Gold Basin)														526	157	177	220					271	299	301			
Elk Mountain	844	771	580	496	538		561		753	550	842	941			157	177	220	259	325	268	295	270	299			330	
Gold Brick	844	771	580	496	538	629	561	716	753	550	843	941	1063	527	157	178	220	259	325	268	295	271	299	305	334		
Goose Creek (Madera)					538	629																271	299				
Quartz Creek	845	771		497	538	629			753	550	843	941	1063	527			221	260		268	295			305		331	
Rock Creek (Marble)												941	1063	527		178	221	260		268			299	305			316
Ruby																											
Spring Creek (Spring Gulch)																				268	295						
Taylor Park										550	843	941		527	157	178	221	260	325	268	295	271	299	305	334	330	317
Tincup	845	771			538						843	941			157	178											
Tomichi (Whitepine)	845	772	580	497	539	630	561	716	754	550	843	942	1063	527		179	221	260		268		271	299	305	334	331	317
Hinsdale County			581	497	539				754	551									325	268							
Galena (Henson Creek)	845	772				630	561	716			843	942	1063		157		221	260			295	271	300	334	334	330	317
Lake Fork (Lake San Cristobal)	845	772				630	561	716						527	157			260			295	271	300	306			

LIST OF MINING DISTRICTS WITH PAGE REFERENCES TO MINERAL RESOURCES AND MINERALS YEARBOOK—(Continued)

	1882	1883-84	1885	1886	1887	1888	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	Appendix (1932) 1932-33	(1933) 1934	(1934) 1935	(1935) 1936	(1936) 1937	(1937) 1938	(1938) 1939	(1939) 1940	1940	1941	1942	1943	1944
Hinsdale County (Continued), Park (Sherman)								202																																							
Huerfano County													417																						158		221										
Malachite (Huerfano)												316																																			
Jackson County																															844	942			158	178	221	260		269	296	271	300				
Independence Mountain																									539																						
Pearl									224				417						360	825	846																										
Jefferson County																						772												527	158		222	260	325	269	296	271	300	306	334	330	
Evergreen								202	220	259		316																																			
Golden placers								203																																							
Lake County																														551																	
Alicante (Birdseye)																				832	853						563	718	757				1066					261		270		272					
Box Creek																					853	777	585	500		623, 633	563	719	757														330	307	336		
Colorado Creek (Gulch)																											563	718																			
Granite																				832		777					564							528	158	179	223	262	326	270	296	272	301				
Leadville (California, Evans, Iowa, Empire)	310	419	250, 348	144	105	53, 87	276	203	221, 475,517	105 259,601	152, 386	317	422, 417	549, 545	682	258	287	452	361	826	847	773	581	497	539	630	561	717	754	551	844	943	1064	528	158	179	222	261	325	269	296	272	300	306	334	330	317
St. Kevin, Sugar Loaf													422	549	686	261	291	457	365	831	852	777	585	500	541	633	563	718								179	223	262	326	270	297	272	301	307	336		
Tennessee Pass (Harrington, East Tennessee)																							585																327		297	273	301	307			
Twin Lakes (Lackawanna Gulch)													422	550	686	261	291	457	365	831	852	777												529	158	179	223	262	327	270	297	273	301	306	336		
Weston Pass																		458																													
La Plata County													423										585	500	541	634	564	719	757	554	849	946	1066	529													
Animas River																																									297						
California (La Plata, Oro Fino, May Day)								205	224	262	389		423	550	687	262	291	458	366	832	853	778								555	849	946	1066	530	159	179	223	262	327	270	297	273	301	307	336	332	318
Cave Basin (or Mount Runlett)																262	292	459	366	833	853										849																
Needle Mountains (Tacoma, Florida River, Vallecito)								205	224		389									833	853											947					224	263	327								
Larimer County													424	551	687					833									758			947					224	263	327	271	297						
Manhattan																																			159								302	307			
Las Animas County																																					224	263									
Mesa County													424	551	687	262	292		367																159		224	263	328	271							
Sinbad																		459												555	850	947	1067	530									302				
Unaweep																		459																													
Mineral County																								500	541	634	564	719	758	556																	
Creede (King Solomon, Sunnyside)								205	224	262	390	320	425	551	687	263	293	459	367	833	854	778	585								850	947	1067				224	263	328	271	298	273	302	307	336	332	318
Moffat County																									542				758																		
Douglas Mountain															688				367	834	854											948	1067	530		180		263		271	298						
Fourmile Creek (and Timberlake Creek)													430	552	688	264	293	460	368	834	854		585				564			556	850		1067	530	159	180	225	263	328	271	298	273	302				
Lay									230	269	395	324	430					460			854															180	225	263	328								
Round Bottom																																				180	225										
Skull Creek (and Blue Mountain)											741, 748																																				
Montezuma County													425		688				368	834												948			159	180	225	264	328	271	274		302	307	336		
Bear Creek																																															
East Mancos River										263																																					
Montrose County													424	551	687	262	292	460	368	834	855	778	585		542	634	564		758	556	850		1067	530	159												
La Sal Creek						1900-261				264	741, 748																564										225	264	329	272	298	274	302	308	336	332	318
Naturita																																				180	225	264	329	272	298	274	303	308			
Ouray County																																															
Red Mountain								206	227	265	391	322	427	553	689	265	294	461	368	834	855	779	585	500	542	634	564	719	758	556	850	948	1068	530	159			264	329	272	299	274	302	308	337	332	318
Ridgway																																		530	159		225	264			299	274					
Sneffels (Imogene Basin)								206	226	264	391	322	427	553	689	265	294	461	369	835	855	779	586	500	542	634	564	719	759	557	851	949	1068	531	159	180	225	264	329	272	299	274	303	308	337	332	319
Uncompahgre (Upper Uncompahgre, Ouray)								206	227	265	392	322	428	554	690	265	295	465	370	836	855	779	586	501	542	634	564	719	759	557	851	949	1068	531	159	181	226	264	329	272	299	275	303	307	337	333	319
Park County																																															
Alma placers																																			160	181	226	265	330	273	299	275	302	307	337	333	
Beaver Creek														555																		950	1068		160	181	226	330	330	273	299	275	302	307	337		

LIST OF MINING DISTRICTS WITH PAGE REFERENCES TO MINERAL RESOURCES AND MINERALS YEARBOOK—(Continued)

	1882	1883-84	1885	1886	1887	1888	1904	1905	1906	1907	1908	1909	1910	1911
Park County (Continued), Buckskin								207	228	266	392	323	428	555
Consolidated Montgomery									228	266	393		428	555
Fairplay														
Guffey														555
Hall's Gulch						1900-228				267	393			555
Horseshoe									228	267	393		429	555
Mosquito								207	228	267	393	323	429	555
Sacramento												323		
Pulver														
Tarryall Creek									228	267	393	323	429	555
Pitkin County														
Ashcroft					28	33			230	269	394	324	430	556
Avalanche														
Independence														
Lincoln Gulch								208	230	268	294	324		556
Roaring Fork (Aspen, Lenado, Richmond Hill)		422	256	145	105	87		208	229	268	294	324	429	556
Snowmass														
Rio Grande County														
Embargo											395			
Jasper (Decatur)														
Summitville								198	213				430	
Routt County														
Hahns Peak (Columbine)								208	230	269	395	324	430	556
Slater (or Three Forks)													430	
Slavonia									230					
Yarmony													430	
Saguache County														
Blake (Mirage, Cotton Creek)								209	231	270		324		
Cochetopa Creek														
Crestone (Baca Grant)								209	231	270	394	324		557
Crystal Hill										270				
Embargo Creek													431	557
Kerber Creek (Bonanza)								209	231	270		324	431	557
Music (Liberty)														
San Juan County														
Animas								209					432	558
Eureka (Cement Creek, Mineral Creek, Animas Forks)								209	232	272	297	326	433	558
Ice Lake Basin														
San Miguel County														
Klondyke														
Lower San Miguel (Placerville, Sawpit, Newmire)							1900-262	211	234	274	399	328	437	561
Mount Wilson								211	234	274	399	328		
Ophir (Iron Springs, Ames)				145		1900-262		210	234	273	399	328	436	560
Upper San Miguel (Telluride)								210	233	273	398	327	435	560
Summit County														
Breckenridge (Bevan, Union, Minnesota, Blue River, Swan River, Illinois Gulch, French Gulch, etc.)								211	235, 475	274	400	329	437	562
Frisco (see Consolidated Tenmile)														
Green Mountain (Wilkinson)														
Montezuma (Snake River, Peru)								211	236, 475	275	401	329	438	562
Consolidated Tenmile (Robinson, Kokomo, Frisco)								211	236	275	401	329	438	562
Teller County														
Cripple Creek								212	236	275	401	330	439	563

	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928
Park County (Continued), Buckskin	691	266	296	465	371	836	858	780	586	501	543	635	564	720	759	557	852
Consolidated Montgomery	691	266	296	466	371	836	858	780	586	501	543	635			759	557	852
Fairplay							858	780			543	635	565	720	759		
Guffey				466		837	858	780									
Hall's Gulch						837	858	780	586	501	543	635	565	720	759	558	852
Horseshoe	691	267	296	466	371	837	858	780	586	501	543						
Mosquito	691		296	466	372	837	858	780	587	502	543	635	565	720	759	558	852
Sacramento																	
Pulver		267	296		371	837	858	780									
Tarryall Creek	691	267	297	466	372	837		781	587	502	543	635			760		852
Pitkin County													565				
Ashcroft		268		467													
Avalanche															760		853
Independence																	
Lincoln Gulch																	853
Roaring Fork (Aspen, Lenado, Richmond Hill)	692	268	297	466	372	837	859	781	587	502	544	636		720	760	558	853
Snowmass							859										
Rio Grande County			297											721			
Embargo																	
Jasper (Decatur)																	
Summitville	692	268		467		838					544	636	565		760	558	854
Routt County								781		502	545						
Hahns Peak (Columbine)	692	268	297	467	373	838	860		587			636					854
Slater (or Three Forks)																	
Slavonia																	
Yarmony				467	373												
Saguache County													565				
Blake (Mirage, Cotton Creek)						839		782	587					721	761		854
Cochetopa Creek	693	269	298			839											
Crestone (Baca Grant)	693	269	298	467	373	839					545						854
Crystal Hill					373	839	860		587								
Embargo Creek	693					839											
Kerber Creek (Bonanza)	693	269	298	467	373	839	860	782	588	503	545		636	721	761	559	854
Music (Liberty)					373	839											
San Juan County																	
Animas	694	269	299	468	374	840	861	782	588	503	545	637	565	721	761	559	855
Eureka (Cement Creek, Mineral Creek, Animas Forks)	694	270	299	469	374	840	862	783	588	503	546	637	566	721	761	559	856
Ice Lake Basin					375				588								
San Miguel County																	
Klondyke											546						
Lower San Miguel (Placerville, Sawpit, Newmire)	697	272	302				866					638				561	
Mount Wilson		272	302				866				546						
Ophir (Iron Springs, Ames)		272	302	471	378	843		785	589	504	546	638	566	722	762	560	857
Upper San Miguel (Telluride)	695	271	300	470	375	841	862	783	589	504	546	638	566	722	762	561	858
Summit County																	
Breckenridge (Bevan, Union, Minnesota, Blue River, Swan River, Illinois Gulch, French Gulch, etc.)	697	273	303	472	379	844	867	786	591	506	549	641	569	724	768	562	859
Frisco (see Consolidated Tenmile)																	
Green Mountain (Wilkinson)																	
Montezuma (Snake River, Peru)	698	274	304		380		869	788	592	507	551	642	570	725	769	563	860
Consolidated Tenmile (Robinson, Kokomo, Frisco)	698	273	304	474	380	846	869	788	592	507	550	642		725	768	563	860
Teller County									593	507	551	643	570	725	769	563	861
Cripple Creek	699	274	305	475	381	847	870	789									

	1929	1930	1931	Appendix (1932) 1932-33	(1933) 1934	(1934) 1935	(1935) 1936	(1936) 1937	(1937) 1938	(1938) 1939	(1939) 1940	1940	1941	1942	1943	1944
Park County (Continued), Buckskin	950	1068	531	160	181	226	265	330	273	300	275	304	307	337	333	319
Consolidated Montgomery	950	1068	531	160	181	227	265	330	273	300	275	304	307	338	333	319
Fairplay		1069		160	181	227	265	330	273	300	275	304	307	338	333	
Guffey	950	1069														
Hall's Gulch	950	1069	532		181	227			273		276	304	309			
Horseshoe			532	160	181			330	273	300		304				
Mosquito	950	1069	532	160	181	227	265	330	273	300	276	304	309	338	333	319
Sacramento																
Pulver															333	319
Tarryall Creek				160	182	227	266	331	274	301	276	305	309	338		
Pitkin County																
Ashcroft																
Avalanche	951	1070	532					331								
Independence			532	160			228					305				
Lincoln Gulch	951	1070					266			301	276					
Roaring Fork (Aspen, Lenado, Richmond Hill)	951	1070	532	160	182	228	266	331	274	301	276	305	310	339	333	320
Snowmass																
Rio Grande County					182	228	267	331	275	301	277	305	310	339	334	
Embargo																
Jasper (Decatur)	952	1071	533													
Summitville	952	1071	533	160												320
Routt County				160												
Hahns Peak (Columbine)	952	1071	533		182	228	267	332	275	302	277		310	339	334	320
Slater (or Three Forks)																
Slavonia			533													
Yarmony																
Saguache County																
Blake (Mirage, Cotton Creek)						229	267			302	277					
Cochetopa Creek																
Crestone (Baca Grant)	953	1071	533	161		229	267	332	275	302	277					
Crystal Hill																
Embargo Creek																
Kerber Creek (Bonanza)	953	1072	533	161	182	229	267	332	275	302	277	306	311	339	334	320
Music (Liberty)						229		332								
													311			
San Juan County																
Animas	953	1072	534	161	183	229	268	332	276	302	277	306	311	340	334	320
Eureka (Cement Creek, Mineral Creek, Animas Forks)	955	1073	535	161	183	229	268	333	276	303	278	306	311	341	335	321
Ice Lake Basin								333		303	278	307	312	341	335	321
San Miguel County																
Klondyke									277		278					
Lower San Miguel (Placerville, Sawpit, Newmire)		1075	535	161	183	230	268	333	277	304	278	307	312			
Mount Wilson				161	183	230	268	333	277	304	279	307	312			
Ophir (Iron Springs, Ames)	956	1074	535		183	230	268	333	276	303	278	307	312	341		
Upper San Miguel (Telluride)		1075	535	162	183	230	268	333	277	304	279	307	312	341	335	321
Summit County																
Breckenridge (Bevan, Union, Minnesota, Blue River, Swan River, Illinois Gulch, French Gulch, etc.)	957	1075	535	162	183	230	269	334	277	304	279	307	312	341	336	322
Frisco (see Consolidated Tenmile)																
Green Mountain (Wilkinson)								335	278	305	280	308	313	342	336	322, 323
Montezuma (Snake River, Peru)	958	1076	536		184	231	269	334	278	305	280	308	313	342	336	322
Consolidated Tenmile (Robinson, Kokomo, Frisco)	958	1076	536	162	184	231	270	334	278	305	280	308	313	342	337	322
Teller County	958	1077	536													
Cripple Creek				162	184	231	270	335	278	305	280	309	313	342	337	323

Boulder County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (Short Tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08..						716,687			5,636,257	617,774	1,354,713		$20,514,606
1909-23..	217,416			65,205		65,205	2,358,515		2,358,515	349,853	5,159,448		3,510,836
1924-31..	97,234	32–71		22,026		22,026	235,781		235,781	11,028	705,397		650,897
1932-41..	688,101	99–218	4–20	209,729	2,137	211,866	395,249	177	395,426	638,400	1,048,000	11,000	7,688,597
1942-45..	94,035	11–43		19,682		19,682	50,217		50,217	79,300	531,000	77,700	784,223
CRUDE ORE SHIPPED TO SMELTERS													
1909-23..	61,742					41,877			1,990,118	326,196	3,989,873		
1924-31..	793					910			53,647	4,139	121,647		
1932-41..	5,234					7,272			70,720	109,936	97,073		
1942-45..	1,774					2,434			4,287	39,262	38,258		
ORE TO GOLD AND SILVER MILLS													
		Bullion Gold	Bullion Silver		Concentrates Tons	Concentrates Gold			Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc	
1909-23..	63,441	16,066	38,863										
1924-31..	16,875	8,356	9,763		282	765			8,605		21,623		
1932-41..	477,449	140,181	81,067		14,243	23,576			110,555	434,174	624,396		
1942-45..	36,231	11,773	2,971		1,886	3,590			10,798	13,981	165,377	72,000	
ORE TO CONCENTRATING MILLS													
1909-23..	92,233				5,600	7,262			329,534	23,657	1,169,575		
1924-31..	79,566				2,780	11,995			163,766	6,889	562,127		
1932-41..	205,418				14,526	38,700			132,907	94,290	326,531	11,000	
1942-45..	56,030				907	1,885			32,161	26,057	327,365	5,700	

Boulder County

Central (Jamestown) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode				
1932	20	3	846	474	4	478	954				$ 10,157
1934	27	4	5,832	3,000	6	3,006	28,221				123,296
1935	30		4,086	2,273		2,273	3,108	4,700	16,500		82,825
1936	19		10,654	2,825		2,825	2,106	150			100,506
1937	14		9,160	3,057		3,057	3,722	5,100	46,000		113,198
1938	16		7,468	4,021		4,021	475				141,028
1939	18		7,724	3,376		3,376	1,015	500			118,901
1940	20		19,553	7,169		7,169	1,097		2,100		251,800
1941	13		13,498	7,753		7,753	2,936	300	14,600	7,000	274,835
1942	6		2,918	1,606		1,606	360	400	4,100		56,789
1943	4		16,229	61		61	3,489	5,400	94,200		12,383
1944	1		12,146	8		8	3,091	3,800	86,400		9,903
1945	3		21,170	18		18	4,884	8,400	147,000		17,879

Boulder County

Boulder County, like Clear Creek and Gilpin Counties, annually lists a large number of active mines, the majority of which produce small lots of ore. Gold placers have been worked intermittently even in recent years, but lode production predominates.

The ore is in veins in granite and schist of pre-Cambrian age. Tertiary dikes and stocks, and in places premineral fault zones, are structurally important.

Central (Jamestown)

T. 2 N., Rs. 71 and 72, W. (See pl. 4).

Altitude 6,500 to 8,500 feet.

Jamestown is 12 miles northwest of Boulder. Good local roads make the area easily accessible.

The ore is in veins and brecciated areas in granite and schist cut by dikes.

The country rock is pre-Cambrian granite and schist cut by dikes and a quartz monzonite of Tertiary age. Veins and brecciated zones intersect all rocks. The predominating values are gold (some as a telluride) and silver, but considerable lead, some copper, and a little zinc have been produced. Local fluorite deposits carry small quantities of the sulfides.

For a summary of the general geology and ore deposits (including fluorspar) of this district, with selected bibliography, refer to pages 323-27.

Boulder Quad., 1:62,500, contours 100 ft., ed. 1904.

Jamestown and Vicinity, 1:24,000, contours 50 ft., surveyed 1931.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Gold Hill (Rowena, Salina, Sunshine)

T. 1 N., Rs. 71 and 72 W. (See pl. 4.)

Altitude 6,200 to 9,000 feet.

The mountain roads are good, and the distance to Boulder is 12 miles.

The pre-Cambrian granite in the area is cut by dikes of Tertiary age. The veins trend northeast and the ore is commonly found at or near the intersection of the veins and northwest—trending siliceous zones locally called "dikes." These dikes are ancient fault lines.

Although the predominating metal is gold, considerable silver, lead, and copper have been produced. Some zinc is present in places.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 315.

Boulder County

Gold Hill (Rowena, Salina, Sunshine) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	45	2	1,267	682	16	698	1,195	4	1,199				$ 14,752
1934	78	4	24,657	6,371	5	6,376	17,458		17,458	17,200	60,100		237,739
1935	68	4	34,005	6,680	20	6,700	12,224	3	12,227	11,300	8,900		244,581
1936	64	1	47,075	10,738	4	10,742	35,508		35,508	30,130	78,600		409,838
1937	43	2	25,750	8,411	5	8,416	21,810		21,810	41,300	68,800		320,486
1938	65	3	55,926	11,783	4	11,787	31,779		31,779	78,800	153,500		447,872
1939	63	2	72,494	17,781	2	17,783	29,663		29,663	154,200	72,000		661,961
1940	42		53,880	15,346		15,346	28,748		28,748	106,000	154,400		577,251
1941	32	3	45,470	12,601	7	12,608	24,701		24,701	50,000	130,700		472,195
1942	15		24,020	8,156		8,156	9,461		9,461	10,600	118,300	5,700	301,927
1943	5		1,334	457		457	433		433		13,600	19,600	19,440
1944	5		1,311	340		340	1,305		1,305	600	20,900	33,000	18,343
1945	6		1,469	338		338	997		997	1,000	11,100	14,000	15,239

Boulder Quad., 1:62,500, contours 100 ft., ed. 1904.
Arapahoe National Forest Map.
Roosevelt National Forest Map.
Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Worcester, P. G., Geology of the Ward Region, Boulder County, Colo.: Colorado Geol. Surv. Bull. 21, map, 1920.

Grand Island (Cardinal, Caribou, Eldora, Nederland)

T. 1 S., R. 73 W. (See pl. 4.)

Altitude 8,200 to 10,500 feet.

Nederland in the central part of the area is 14 miles on State 119 west of Boulder. Local roads are fair to good, and access to mines and prospects is fair considering the high relief and rugged character of the general area.

The country rock is pre-Cambrian granite and schist intruded by dikes and stocks, predominantly quartz monzonite, of Tertiary age. The tungsten veins (see pp. 328-36) are usually independent of the sulfide veins. The chief values are gold and silver with some lead and copper. Zinc production is subordinate.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 315.

Central City Quad., 1:62,500, contours 100 ft., ed. 1912.
Nederland Quad., 7½-minute series, 1:31,680, contours 50 ft., ed. 1944.
Arapahoe National Forest Map.
Roosevelt National Forest Map.
Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Magnolia

T. 1 S., R. 71 W. (See pl. 4.)

Altitude 6,750 to 8,000 feet.

The road to Magnolia joins State 119 in Boulder Canyon, a few miles west of Boulder. The distance from Boulder is about 7 miles, but the last 4 miles is a winding road with steep grades.

The country rock is granite and schist intruded by dikes of porphyry. The veins in the district are relatively small, and production has been on a modest scale. However, the veins are numerous and the grade of ore often is high. The chief values are gold and silver. Small tungsten veins are present in the area.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 316.

Blackhawk Quad., 1:125,000, contours 100 ft., ed. 1906.
Eldorado Springs Quad., 1:31,680, contours 50 ft., ed. 1944.
Arapahoe National Forest Map.
Roosevelt National Forest Map.
Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Boulder County

Grand Island (Cardinal, Caribou, Eldora, Nederland) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932......	8	1	58	302	4	306	4,057		4,057		7,000		$ 7,680
1934......	17	11	862	921	81	1,002	6,056	7	6,063		8,000		39,225
1935......	16	4	1,127	643	209	852	10,869	11	10,880		10,900		38,063
1936......	9	2	8,497	846	94	940	11,286	5	11,291	350	47,765		43,858
1937......	6	2	970	348	23	371	8,039	1	8,040		5,000		19,478
1938......	8	4	2,350	402	9	411	2,421		2,421		8,500		16,355
1939......	7	2	1,297	315	18	333	1,868	3	1,871	100	4,100		13,128
1940......	8		839	272		272	744		744		1,800		10,139
1941......	9	1	16,953	2,898	3	2,901	25,851		25,851	2,900	73,600	4,000	124,755
1942......	4		4,474	1,227		1,227	13,836		13,836	2,100	19,700		54,358
1943......	1		150	2		2	6,328		6,328	800	2,400		4,854
1945......	1		10				471		471		200		352

Magnolia District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Lead (pounds)	Total Value
1932	18	421	257	53		$ 5,332
1934	18	828	354	31		12,399
1935	21	5,052	1,599	50		56,015
1936	22	4,262	1,213	124		42,544
1937	14	2,321	827	185		29,074
1938	15	1,821	824	14		28,849
1939	14	2,664	841	56		29,473
1940	15	2,801	1,423	1,042	1,100	50,601
1941	8	1,664	960	388		33,876
1942	4	444	612	3		21,422

Sugarloaf

T. 1 N., R. 72 W. (Shown but not named on pl. 4.)

Sugarloaf is 7 miles on State 119 west of Boulder. The roads in the area are fair to good.

The predominating feature in this area is a large stock of quartz monzonite that centers in Sugarloaf Peak. The veins are generally small but numerous and commonly rich in concentrations of gold and silver. Lead and copper are subordinate to gold, and zinc has not been important. Small tungsten veins are present.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 319.

Boulder Quad., 1:62,500, contours 100 ft., ed. 1904.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Ward

T. 1 N., Rs. 72 and 73 W. (See pl. 4.)

Altitude 8,500 to 9,500 feet.

Ward is on State 160 about 20 miles northwest of Boulder and 9 miles north of Nederland. State 160 is a good road and some of the branch roads are fair, but the area is rugged and local areas are difficult to reach.

The country rock is granite and schist cut by numerous dikes of Tertiary age. Gold and silver are the predominating metals

Boulder County

Sugarloaf District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	31	4	2,863	1,682	122	1,804	3,057	10	3,067				$ 38,166
1934	46	1	19,247	6,025	19	6,044	4,429	2	4,431				214,103
1935	49	9	37,555	10,058	549	10,607	6,421	50	6,471		10,100		376,293
1936	36	8	34,660	9,114	276	9,390	9,264	26	9,290	1,090	6,680		336,259
1937	31	4	22,208	7,048	102	7,150	6,450	9	6,459	1,600	200		255,445
1938	29	4	9,066	3,861	418	4,279	2,221	34	2,255	3,000	1,000		151,584
1939	37	8	5,975	4,310	57	4,367	5,685	6	5,691	900	5,000		157,037
1940	22		12,259	6,076		6,076	3,476		3,476		400		215,152
1941	26		7,114	3,662		3,662	5,493		5,493	600	4,700		132,415
1942	11		3,280	2,644		2,644	1,253		1,253		1,000		93,498
1943	5		814	732		732	730		730		2,000	2,400	26,548
1944	3		246	220		220	52		52				7,737
1945	5		414	202		202	83		83		4,300	3,000	7,844

with lead and copper. Local occurrences of large low-grade pyrite deposits are reported.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 318.

Boulder Quad., 1:62,500, contours 100 ft., ed. 1904.

Rocky Mountain National Park, 1:125,000, contours 100 ft., ed. 1919.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Worcester, P. G., Geology of the Ward Region, Boulder County, Colo.: Colorado Geol. Survey Bull. 21, 74 pp., map, 1920.

Ward District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1932	26	268	322	365		2,000	$ 6,825
1934	31	4,289	755	967	4,200	900	27,362
1935	34	3,693	601	1,312	2,000	2,600	22,241
1936	23	1,085	855	763	280	1,955	30,620
1937	12	1,410	1,315	1,603	3,000	1,000	47,687
1938	21	2,280	1,727	1,819	3,200	1,000	61,974
1939	27	7,586	2,234	1,749	6,300	1,900	80,121
1940	17	5,168	3,335	4,995	56,000	7,200	126,965
1941	11	5,259	2,845	3,406	49,200	1,400	107,883
1942	3	2,071	1,675	1,987	26,800	4,600	63,589
1943	4	1,222	979	1,125	13,800	800	36,919
1944	2	285	360	277	5,000		13,472
1945	2	28	45	52	600	400	1,727

Chaffee County

Arkansas River placers (Salida, Nathrop, Buena Vista)

Placer gold is reported in places along the Arkansas River from Buena Vista southeast 25 miles to the Fremont County line (not shown on pl. 4) and near Granite (see pl. 4) near the county line about 15 miles northwest of Salida.

Altitude 7,400 to 7,600 feet.

An excellent highway, U. S. 24, follows the valley of the Arkansas River.

Chaffee County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Placer	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08...				197,550	72,393	269,943			3,657,028	5,363,026	106,655,759	6,143,294	$14,434,958
1909-23...	415,111			85,622	2,507	88,129	1,564,865	444	1,565,309	4,268,369	23,856,759	22,438,211	7,166,474
1924-31...	3,286	1–5	1–18	679	189	868	22,869	27	22,896	35,567	554,246	284,200	98,823
1932-41...	10,366	9–19	6–45	6,604	2,555	9,159	60,569	398	60,967	83,800	1,267,000	241,000	442,406
1942-45...	5,737	2–5	1–4	294	332	626	16,072	45	16,117	18,200	561,000	711,200	159,990
CRUDE ORE SHIPPED TO SMELTERS													
1909-23...	141,878					48,674			1,276,335	3,424,060	12,746,039	9,577,545	
1924-31...	2,853					583			21,944	33,217	533,546	215,900	
1932-41...	4,598					3,194			41,955	49,683	956,773		
1942-45...	2,143					118			8,867	4,120	487,422	93,921	
ORE TO GOLD AND SILVER MILLS													
		Bullion: Gold	Bullion: Silver		Concentrates: Tons	Concentrates: Gold			Concentrates: Silver	Concentrates: Copper	Concentrates: Lead	Concentrates: Zinc	
1909-23...	141,698	840	457										
[1]1924-31...	87	79	57										
1932-41...	2,454	1,435	7,016		130	1,373			5,068	12,500	121,000		
1942-45...	3,518	45	329		796	102			6,211	13,293	62,869	600,579	
ORE TO CONCENTRATING MILLS													
1909-23...	131,535				34,942	36,108			288,073	844,309	11,110,720	12,860,666	
[2]1924-31...	346				107	17			868	2,350	20,700	68,300	
[3]1932-41...	3,314				791	602			6,530	21,617	189,227	241,000	
[4]1942-45...	76				32	29			665	787	10,709	16,700	

[1]Production in 1930 and 1931 only.
[2]Production in 1926 only.
[3]No production in 1932, 1933, 1935, 1936, and 1940.
[4]No production in 1943.

Placer operations have been small and intermittent. In 1934 operations were reported by 11 individuals yielding 11 fine ounces of gold. The gold in sand bars at the surface is believed to be derived in part from former milling operations at Leadville. The Granite district placers are listed separately.

Gunnison National Forest Map.

Pike National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Browns Creek placer (Browns Canyon)

T. 15 S., R. 78 W. (Not shown on pl. 4.)

Altitude 7,600 feet.

The placers are near U. S. 285 and 2 to 3 miles south of Nathrop.

Production is 2 ounces of gold in 1932 and also in 1939.

Gunnison National Forest Map.

Pike National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Calumet (Whitehorn in Fremont County)

T. 51 N., R. 9 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,500 to 10,000 feet.

Calumet is 16 miles north-northeast of Salida on fair to poor mountain roads.

Small veins with gold, silver, and copper ore have been reported in a porphyry stock of early Tertiary age. No production is recorded.

Gunnison National Forest Map.

Pike National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Chalk Creek (Alpine, Romley, St. Elmo)

T. 15 S., Rs. 80 and 81 E.; T. 51 N., R. 6 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,000 to 10,500 feet.

The district is on State 162 on Chalk Creek 16 miles west of Nathrop on U. S. 285.

Veins are in granite of the Mount Princeton batholith of Tertiary age. The Mary Murphy mine was the chief producer in the district.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Chalk Creek (Alpine, Romley, St. Elmo) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Yr.	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	2	83	50	642		4,000		$ 1,335
1933	4	254	188	1,860	300	16,000		5,142
1934	2	1,113	1,275	7,512	100	59,300		51,610
1935	2	978	1,109	6,361	13,500	85,400		47,911
1936	4	1,213	1,324	11,654	15,935	205,700		66,306
1937	3	1,449	844	11,360	19,300	198,450	145,000	61,789
1938	1	248	137	1,778	4,400	57,700	48,000	11,340
1939	4	163	142	1,918	1,000	27,600		7,673
1940	2	118	74	817	600	21,000		4,289
1941	2	98	130	641	1,600	20,800	18,000	7,731
1942	1	50	39	415	600	7,400	8,200	2,992
1944	1	36	11	322	400	5,600	8,500	2,085

Clear Creek placers

T. 12 S., R. 80 W. (See pl. 4.)

Altitude 9,000 to 9,500 feet.

Clear Creek joins the Arkansas River about 3 miles south of Granite. A fairly good local road follows Clear Creek, and the placers are four to ten miles southwest of Granite (U. S. 24).

The downstream part of the placer area is on:

Leadville Quad., 1:125,000, contours 25, 50, and 100 ft., ed. 1891, and Mt. Elbert Quad., 1:62,500, contours 50 ft., ed. 1939.

Gunnison National Forest Map.

Pike National Forest Map.

San Isabel National Forest Map.

Cleora

T. 49 N., R. 9 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 7,000 to 7,500 feet.

Cleora is four miles south of Salida near U. S. 50.

Chalcopyrite is found in schist of pre-Cambrian age. No production has been reported.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Lindgren, Waldemar, Notes on the copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, p. 166, 1908.

Cottonwood

T. 14 S., R. 81 W. (See pl. 4.)

Altitude 10,250 to 10,750 feet.

This area is on State 306 near the head of Cottonwood Creek 14 miles west of Buena Vista. 10 miles of the road west of Buena Vista are fair, and the last 4 miles are poor.

Small veins with lead, silver, and gold are found in pre-Cambrian granite and schist.

No production is recorded.

Gunnison National Forest Map.

San Isabel National Forest Map.

Four Mile

T. 13 S., R. 78 W. (Not shown on pl. 4.)

Altitude 8,500 to 10,500 feet.

This district is a few miles northwest of Buena Vista, but its exact location is not known.

The only information available on the district is the production record:

1935, 1936, and 1937—78 tons that yielded 53.5 ounces gold.

1940—67 tons that yielded 39 ounces gold, 336 ounces silver, 1,000 pounds copper, 1,200 pounds lead, and 30,000 pounds zinc.

Pike National Forest Map.

San Isabel National Forest Map.

Free Gold

T. 14 S., R. 78 W. (Shown but not named on pl. 4.)

Altitude 7,600 feet.

This district is on Trout Creek about 5 miles southeast of Buena Vista and about 1 mile east of the Arkansas River.

Access is by U. S. 285, which is nearby.

Silver occurs in small veins in pre-Cambrian granite.

The production on record is a few ounces of placer gold in 1932 and a few tons of low-grade gold ore in 1933.

Gunnison National Forest Map.

San Isabel National Forest Map.

Garfield-Monarch

Tps. 49 and 50 N., R. 6 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,000 to 10,500 feet.

U. S. 50 and a broad gauge spur of the D. & R. G. W. Railroad are at Monarch.

The country rock is pre-Cambrian granite, Cambrian to Leadville limestone, quartz monzonite and quartz monzonite porphyry of Tertiary age. The sedimentary beds are highly folded and faulted.

Garfield-Monarch District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	1		1					$ 16
1934	1	28		288	900	18,000		931
1935	1	10		72	800	4,300		297
1937	3	319	39	2,481	5,000	133,650		11,774
1938	5	517	43	2,931		151,300		10,374
1939	5	165	6	1,472	3,000	56,400		4,172
1940	4	426	10	2,125		139,000		8,811
1941	2	28	13	682	400	5,700		1,312
1942	1	82	13	824	200	4,600		1,373
1943	3	1,404	28	4,455	1,400	331,000	44,000	33,907
1944	3	2,695	143	7,020	9,600	188,400	324,500	63,358
1945	1	1,454	36	3,028	6,000	24,000	326,000	43,777

Replacement deposits in limestone, fault-fissure veins, contact deposits in sedimentary deposits, and small veins in quartz monzonite are present. The ores carry lead-silver, zinc, and a little gold and copper. (See Jewell Tunnel, page 491.)

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Crawford, R. D., Geology of the Monarch Mining District: Colorado Geol. Surv. Bull. 9, 78 pp. (with topographic and geologic map), 1910.

Granite (and Lost Canyon)

Tps. 11 and 12 S., R. 79 W. (a part of the district is in Lake County). (See pl. 4.)

Altitude 9,000 to 9,500 feet.

U. S. 24 and the D. & R. G. W. Railroad pass through Granite. The veins carrying gold, silver, and lead are in pre-Cambrian granite cut by Tertiary dikes. Placer gold is found on the Arkansas River.

The Lost Canyon district, now included in the Granite district, was well-known at one time for its placer operations on Cache Creek, a few miles southwest of Granite. Extensive deposits were worked by hydraulic mining in the early days. In recent years land dredges have been in operation.

Leadville Quad., 1:125,000, contours 25, 50, & 100 ft., ed. 1891.

Mt. Elbert Quad., 1:62,500, contours 50 ft., ed. 1939 (covers only part of district).

Pike National Forest Map.

San Isabel National Forest Map.

Chaffee County

Granite (and Lost Canyon) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total			
1932	3	14	27	9	67	76	14	14	28		600	$ 1,599
1933	1	10	51	94	68	162		12	12			3,334
1934	6	34	68	126	138	264	31	23	54		2,500	9,349
1935	6	20	78	121	223	344	46	49	95		800	12,142
1936	7	20	81	119	108	227	213	13	226	65	4,200	8,305
1937	4	6	53	25	143	168	53	20	73		950	5,999
1938	3	16	22	19	253	272	31	37	68		1,000	9,610
1939	5	25	547	189	350	539	237	53	290	500	1,000	19,161
1940	4	17	26	54	867	921	170	128	298	300		32,481
1941	3	15	10	8	291	299	10	45	55			10,504
1942	1	4	11	21	195	216	7	28	35			7,585
1943		1			128	128		17	17			4,492
1944	1	1	*	1	9	10						350
1945	1		5	2		2	1		1			71

*Less than ½ ton.

La Plata (Winfield)

T. 12 S., R. 81 W. (See pl. 4.)

Altitude 9,750 to 12,000 feet.

Winfield is on Clear Creek and 15 miles west from Granite. 13 miles of the road is fair to poor. The mineralized area is 1 to 3 miles west and southwest of Winfield.

Small veins with silver, gold, copper, and lead occur in the Twin Lakes porphyry of Tertiary age. Also present are small quartz veins with molybdenite.

Production is recorded only in 1932, 1939, and 1941 when a few tons were shipped that yielded a little gold, silver, and lead.

Gunnison National Forest Map.

San Isabel National Forest Map.

Riverside (Mt. Harvard)

T. 13 S., R. 80 W. (Shown as Mt. Harvard on pl. 4.)

Altitude 12,000 to 13,000 feet.

This district is 6 miles from State 24 but the last 2 miles are very difficult.

Veins with gold, silver, lead, and some copper occur in granite (pre-Cambrian) cut by dikes of Tertiary age.

Gunnison National Forest Map.

San Isabel National Forest Map.

Riverside (Mt. Harvard) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1933	1	16	7				$ 152
1934	4	44	9	23	1,700	200	483
1935	3	101	47	775	2,000	9,500	2,754
1936	3	190	95	1,756	1,820	24,100	5,954
1937	2	1,431	71	1,585	3,700	12,950	4,930
1938	1	12	18	57		2,000	752
1939	1	16	3				105

Sedalia

T. 51 N., R. 8 E. New Mexico Principal Meridian.

Altitude 7,500 feet.

The Sedalia mine is 8 miles northwest of Salida and on the east side of the Arkansas River valley.

Mineralization consists of chalcopyrite disseminated through schist of pre-Cambrian age. Some of the ore averaged 5 percent copper and the stopes varied in width up to 50 feet. Locally sphalerite is plentiful with some galena and a little silver. Gold is not important. The ore minerals are intimately intergrown with the minerals of the schist. Below a pegmatite dike that crosses the ore, only low-grade ore is reported, but the manner in which the ore dies out laterally or with depth is not described. Lindgren concludes that the ore is pre-Cambrian in age.

Production is reported at 60,000 to 75,000 tons of 5 percent copper and $1.00 to $2.50 in gold and silver per ton. Development extended from the surface down through an oxidized zone about 200 feet thick and into the sulfide ores for a depth of 100 to 150 feet.

No production has occurred in recent years.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Lindgren, W., Notes on the copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Surv. Bull. 340, pp. 161-166, 1908.

Trout Creek

T. 13 S., R. 77 W. (Not shown on pl. 4.)

Altitude 9,500 to 10,000 feet.

This area is just south of Trout Creek Pass on U. S. 24 and 13 miles northeast from Buena Vista.

The country rock is "Weber" shale of Carboniferous age. The character of the mineralization is not known.

Pike National Forest Map.

San Isabel National Forest Map.

Trout Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1932	3	11	9	71		1,400	$246
1933	2	39	5				95
1934	1	5	10				343
1936	2	10	1	142	180		169
1937	3	6	6				203
1938	1	11	2				70
1939	1	5	2				70

Turret Creek

Tps. 50 and 51 N., R. 9 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,000 to 8,500 feet.

Turret is 11 miles north of Salida on a fair to poor mountain road.

Copper (chalcopyrite) with a little gold and silver occurs in pre-Cambrian schist. Reported production since 1931 is as follows:

Year	Lode Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Total Value
1932	2	11	7			$143
1935	1	67	9	86	5,700	834
1936	2	12	10			345
1939	1	10	4			140
1941	2	14	12	14		430

Gunnison National Forest Map.

Pike National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Lindgren, W., Notes on the copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, p. 166, 1908.

Twin Lakes (Red Mountain)

Tps. 11 and 12 S., Rs. 81 and 82 W. (See pl. 4.)

Altitude 11,000 to 12,000 feet.

This district includes a number of prospects on either side of Twin Lakes Creek from the Continental Divide east to Twin Lakes Post Office. The road, State 82, along the valley is excellent, but most of the prospects are high above the valley and difficult to reach.

Red Mountain is at the head of Peek-a-boo Creek, a tributary of the South Fork of Lake Creek, 18 miles from Granite. From Red Mountain it is 2 miles by trail, 3 miles by poor road, 10 miles by State 82, and 3 miles by U. S. 24 to Granite and the D. & R. G. W. Railroad.

Small gold veins are present in altered rhyolite and diorite, and small veins with a little native gold occur in pre-Cambrian schist.

The recorded production since 1931 is a few tons of ore in 1941 that yielded 1 ounce of gold and 1½ ounces of silver per ton.

Mt. Jackson Quad., 1:125,000, contours 100 ft. ed. 1911.

Gunnison National Forest Map.

San Isabel National Forest Map.

Howell, J. V., Twin Lakes district of Colo.: Colorado Geol. Survey Bull. 17, pp. 99-102, map, 1919.

Clear Creek County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08..				726,517	137,471	863,988			52,478,012	6,766,253	136,319,982	11,649,559	$73,741,017
1909-23..	1,293,608			226,222	540	226,762	5,331,477	101	5,331,578	5,131,826	41,737,066	19,327,262	13,450,203
1924-31..	262,751	31–59	1–41	26,588	58	26,646	935,723	13	935,736	167,841	3,126,171	533,400	1,397,917
1932-41..	1,336,446	52–153	8–84	234,387	1,763	236,150	1,057,190	247	1,057,437	1,807,900	6,663,300	160,000	9,356,698
1942-45..	184,727	22–45	1–2	23,953	6	23,959	608,127		608,127	169,300	4,569,100	3,631,000	2,051,585
CRUDE ORE SHIPPED TO SMELTERS													
1909-23..	160,395					111,826			2,582,399	3,186,429	16,497,075	1,025,597	
1924-31..	4,769					4,006			200,328	77,669	996,372		
1932-41..	8,188					6,218			152,360	90,234	748,730	13,000	
1942-45..	462					176			15,943	8,084	92,713	33,967	
ORE TO GOLD AND SILVER MILLS													
		Bullion			Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23..	339,557	23,193	23,430										
1924-31..	70,540	14,960	33,154		1,136	3,160			24,921	16,143	188,153	37,000	
1932-41..	1,045,199	128,217	78,672		41,392	60,148			414,097	1,242,182	3,258,957		
1942-45..	97,612	13,274	3,531		4,258	5,052			66,971	44,308	826,047	534,017	
ORE TO CONCENTRATING MILLS													
1909-23..	793,656				130,796	91,203			2,725,648	1,945,397	25,239,991	18,301,665	
1924-31..	187,442				8,460	4,462			677,320	74,029	1,941,646	496,400	
1932-41..	283,059				28,766	39,804			412,061	475,484	2,655,613	147,000	
1942-45..	86,653				10,128	5,451			521,682	116,908	3,650,340	3,063,016	

Clear Creek County

Clear Creek County, like Boulder and Gilpin Counties, annually lists a large number of active mines, most of which produce small tonnages of ore.

Gold placers have operated intermittently.

The ore is in veins in pre-Cambrian granite and schist. Tertiary dikes and stocks are important structurally in places. The ores have a greater average lead and zinc content than those in adjoining counties.

Alice (Lincoln, Yankee Hill)

T. 2 S., R. 74 W. (See pl. 4.)

Altitude 10,000 to 11,000 feet.

The mineralized area is 10 miles northwest of Idaho Springs, 2 miles on U. S. 40 and 8 miles on State 285, a fair to good mountain road.

Veins with lead, zinc, gold, and silver are found in pre-Cambrian granite and schist intruded by Tertiary quartz monzonite porphyry.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 313-14.

Central City Quad., 1:125,000, contours 100 ft., revised 1910.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey Prof. Paper 94, pp. 106, 319-330, pls. I and II, 1917.

Argentine (West Argentine)

Tps. 4 and 5 S., Rs. 74 and 75 W. (See pl. 4.)

Altitude 9,250 to 12,000 feet.

The Argentine district includes mines along Leavenworth Creek on the southeast side of Leavenworth Mountain 2 miles south of Silver Plume and Georgetown, and mines on the southeast slope of McClellan Mountain at the head of Leavenworth Creek 6 miles farther southwest. The mineralized area on McClellan Mountain is continuous to the southwest with the adjoining Montezuma district in Summit County. Georgetown is on U. S. 6. The road along Leavenworth Creek is fair to poor.

The Stevens mine and the Josephine mine at the head of Stevens Gulch on the northwest side of McClellan Mountain are 7 miles southwest of Silver Plume, the last 3 miles of this distance being on a poor road with steep grades.

The Colorado Central, Kirtley and Argentine vein systems on Leavenworth Mountain are famous for silver-lead ores. The Waldorf, Paymaster, and Santiago mines, at the head of Leaven-

Clear Creek County

Alice (Lincoln, Yankee Hill) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode			
1932	1		4	2		2				$ 37
1933	4		134	54		54	13			1,111
1934	5		374	128		128	79			4,518
1935	9		13,642	1,443		1,443	4,359	24,650	10,700	56,119
1936	6		26,980	2,830		2,830	12,878	119,000	200	119,986
1937	3	1	86,278	7,573	1	7,574	26,556	267,600	800	318,037
[1]1938	16	2	151,128	23,401	5	23,406	32,005	306,800	3,900	870,159
1939	4		709	527		527	109			18,519
1940	7		1,267	560		560	97	400	400	19,734
1941	6		1,178	473		473	772	1,000	14,000	18,020
1942	2		1,129	400		400	699	800	16,000	15,666
1945	1		1	5		5	17		200	204

[1]Includes Empire district, Clear Creek County.

Clear Creek County

Argentine (West Argentine) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode		Lode	Lode	Total				
1932	1	18	7	145	145	600	1,200		$ 268
1933	1	31	29	284	284	1,000	2,700		858
1934	3	1,137	125	2,331	2,331	3,400	24,700		7,062
1935	5	406	19	8,498	8,498		14,700		7,354
1936	2	3,566	405	6,581	6,581	18,000	26,500		22,151
1937	2	1,704	178	2,936	2,936	7,400	9,360		9,948
1938	2	3,043	314	11,863	11,863	12,200	36,000		21,504
1939	2	771	162	3,191	3,191	7,500	31,000		10,101
1940	6	7,358	155	13,171	13,171	4,200	57,000		18,116
1941	3	3,770	53	21,614	21,614	2,100	43,000		19,924
1942	1	506		14,732	14,732		12.700		11,327
1943	5	754	53	1,838	1,838	1,500	88,600	38,000	14,106
1944	1	998	66	803	803	600	78.900	14,000	10,870
1945	1	2,495	153	2,084		2,400	224,500	59,400	33,299

worth Creek, and the Stevens and Josephine mines at the head of Stevens Gulch have produced ores characterized by lead, silver, and gold with some zinc and copper.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 300-02.

Leavenworth Mtn: Georgetown Quad., 1:62,500, contours 100 ft., ed. 1905.

Head of Leavenworth Creek: Montezuma Quad., 1:62,500, contours 100 ft., ed. 1926.

Pike National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Lovering, T. S., Geology and ore deposits of the Montezuma quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 178, pp. 69, 85-86, 104-105, 109-112, 1935.

Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 104, 136, 245-271, 1908.

Dailey (Atlantic)

T. 3 S., R. 75 W. (See pl. 4.)

Altitude 10,750 to 12,000 feet.

Dailey is near head of West Fork of Clear Creek and Butler Gulch, 2 miles east and southeast of Jones Pass. The district is 2 miles with no road and 2 miles of fairly good road from U. S. 40, and is 55 miles from Denver.

Small veins with lead, zinc, and some silver occur in pre-Cambrian granite.

One ton of lead-silver ore was shipped in 1940.

Fraser Quad., 1:62,500, contours 100 ft., ed. 1926.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Empire (Upper Union)

T. 3 S., R. 74 W. (See pl. 4.)

Altitude 8,500 to 10,500 feet.

Empire is on U. S. 40 and 41 miles from Denver.

The principal veins are 1½ miles north of Empire on good to fair roads.

The veins are in pre-Cambrian granite.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 306-07.

Central City Quad., 1:125,000, contours 100 ft., revised 1910.

See reference to Prof. Paper 63 given below.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 383-410, map, 1908.

Clear Creek County

Empire (Upper Union) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Total				
1932	10		526	273		273	319	319		300		$ 5,731
1933	8		797	346		346	118	118				7,187
1934	18	3	9,913	1,660	1	1,661	507	507	700	1,600		58,501
1935	21		19,075	4,574		4,574	1,006	1,006	700	12,800		161,376
1936	10		34,750	11,571		11,571	1,601	1,601	800	300		406,317
1937	8		56,020	13,787		13,787	2,618	2,618	8,530	4,400		485,869
[1]1938												
1939	11	2	75,124	16,386	1	16,387	2,870	2,870	700	700		575,599
1940	8		79,109	16,693		16,693	2,714	2,714	1,400	400		586,363
1941	8		74,173	14,612		14,612	6,445	6,445	68,500	300		524,103
1942	4		29,986	7,893		7,893	724	724	4,700	2,300		277,493
1943	2		10,651	2,500		2,500	758	758		4,200	2,300	88,602
1945	3		42	16		16	367			8,500	4,000	2,012

[1]Included with Alice district, Clear Creek County.

Geneva Creek (Collier Mountain)

T. 5 S., R. 75 W. (Name not shown on pl. 4.)

Altitude 10,250 to 12,000 feet.

The district is at the head of West Geneva Creek, and is continuous with the Montezuma district in Summit County to the northwest. The district is 2 miles southeast from Montezuma, but the trail is poor and over a 13,000-foot pass. The more direct access is over the 10 to 12 miles of poor road along Geneva Creek from Grant (Olava) (U. S. 285). Grant is 59 miles from Denver.

Montezuma Quad., 1:62,500, contours 50 ft., ed. 1926.

Arapahoe National Forest Map.

Pike National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Lovering, T. S., Geology and ore deposits of the Montezuma quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 178, pp. 69-70, 106, maps, 1935.

Geneva Creek (Collier Mountain) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1933	1	6	1	185	400	317	$ 130
1935	1	14	28	1,198	1,300		1,949
1936	1	347	164	2,909			8,007
1939	1	2	1	9		100	46
1940	2	1,803	50	772	300	500	2,358

Griffith (Georgetown, Silver Plume, Queens)

T. 4 S., R. 74 W. (See pl. 4.)

Altitude 8,500 to 11,000 feet.

Georgetown and Silver Plume are on U. S. 6, and 40 and 42 miles, respectively, from Denver. The roads to surrounding mines are fair to poor with local steep grades.

The veins in this district are complex sulfides that vary from gold-silver-lead ores to lead-silver-zinc ores with gold subordinate. Copper is usually present in small quantities.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 302-06.

Georgetown Quad., 1:62,500, contours 100 ft., ed. 1905.

Silver Plume Special Map, 1:12,000, contours 50 ft., ed. 1906.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 278-301, 1908.

Clear Creek County

Griffith (Georgetown, Silver Plume, Queens) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Total				
1932	3		769	65		65	4,213	4,213		4,600		$ 2,663
1933	8		1,231	493		493	3,035	3,035		21,767		12,049
1934	13		2,863	578		578	10,901	10,901	2,600	61,400		29,721
1935	17		1,132	109		109	10,343	10,343	800	15,500		11,933
1936	10		1,284	201		201	7,157	7,157	1,400	27,000		13,931
1937	9		7,222	110		110	37,404	37,404	8,600	249,120	18,000	49,691
1938	9	1	6,961	319	1	320	18,369	18,369	3,500	46,300		25,534
1939	10		3,065	355		355	7,033	7,033	8,000	49,800		20,372
1940	8		4,781	29		29	16,816	16,816	400	56,400		15,838
1941	6		739	42		42	10,908	10,908	500	67,000	112,000	21,505
1942	4		9,700	51		51	133,314	133,314	5,100	417,000	462,000	168,108
1943	7		9,018	63		63	145,243	145,243	6,200	335,400	448,000	179,884
1944	4		10,119	61		61	83,676	83,676	9,000	928,500	889,400	238,525
1945	6		6,673	67		67	75,524		10,000	933,000	1,037,000	256,894

Clear Creek County

Idaho Springs (Cascade, Coral, Jackson Bar, Paynes Bar, Spanish Bar, Virginia Canyon) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	29	37	11,479	5,310	57	5,367	22,688	7	22,695	5,400	60,000		$119,478
1933	42	8	12,138	4,432	50	4,482	23,823	6	23,829	9,550	103,632		105,437
1934	89	81	43,162	8,303	182	8,485	55,895	19	55,914	58,300	276,100		347,580
1935	72	81	49,165	8,767	209	8,976	64,402	39	64,441	98,400	442,900		386,381
1936	48	51	55,835	6,527	81	6,608	73,570	9	73,579	45,100	481,800		314,588
1937	38	28	66,168	7,302	74	7,376	77,113	9	77,122	60,800	645,100		363,218
1938	53	44	46,671	5,738	89	5,827	49,486	14	49,500	46,200	520,500	17,000	265,211
1939	62	31	50,371	10,841	37	10,878	68,435	6	68,441	129,700	693,400		473,266
1940	42	12	97,507	15,301	148	15,449	112,306	38	112,344	183,200	933,900		688,001
[1]1941	42	16	67,997	11,959	826	12,785	75,548	100	75,648	106,700	549,000		545,153
[1]1942	24		39,504	6,171		6,171	30,611		30,611	56,100	193,300		257,492
1943	13	1	6,664	857	3	860	22,576		22,576	34,500	231,400	153,000	84,518
1944	11		2,017	226		226	10,658		10,658	10,800	113,600	139,600	41,949
[2]1945	9		3,990	352	3	355	11,264		11,264	11,600	155,000	202,200	58,584

[1]Includes Cascade and Ute Creek districts, Clear Creek County.
[2]Includes Cascade district.

Idaho Springs (Cascade, Coral, Jackson Bar, Paynes Bar, Spanish Bar, Virginia Canyon)

T. 3 S., R. 73 W. (See pl. 4.)

Idaho Springs, on U. S. 40 and U. S. 6, is 33 miles from Denver. Good roads traverse the district, but access to individual mines may be difficult.

The veins show a wide variation in types of ore, but gold-silver-lead-copper ores predominate.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 308-13.

Georgetown Quad., 1:62,500, contours 100 ft., ed. 1905.

Central City Quad., 1:62,500, contours 100 ft., ed. 1912.

Idaho Springs Special Map, 1:12,000, contours 50 ft., ed. 1906.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 & 100 ft., 1939.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin Co. and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey Prof. Paper 94, pp. 281-303, 356-369, maps, 1917.

Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 341-382, maps, 1908.

Montana (Lawson, Dumont, Downieville)

T. 3 S., Rs. 73 and 74 W. (See pl. 4.)

Altitude 8,000 to 9,500 feet.

Lawson and Dumont, on U. S. 6 and U. S. 40, are 37 and 38 miles, respectively, from Denver.

This district is the westward extension of the Idaho Springs district, and mineralization is similar, as is brought out by the production figures, except that the silver and lead content of the ore is greater and the gold content is less.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 307-08.

Central City Quad., 1:62,500, contours 100 ft., ed. 1912.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 and 100 ft., 1939.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin Co. and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey Prof. Paper 94, pp. 334-356, map, 1917.

Clear Creek County

Montana (Lawson, Dumont, Downieville) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	5	118	54	596		5,900		$ 1,470
1933	3	19	4	400		3,584		347
1934	19	2,858	287	24,521	8,000	86,600		29,722
1935	12	1,114	41	6,727	300	17,200		6,992
1936	7	258	13	1,823		6,700		2,157
1937	7	1,123	167	1,594	3,400	9,220		8,033
1938	10	6,677	1,164	12,389	49,300	27,000		54,829
1939	9	9,617	1,279	22,692	77,300	57,200		70,895
1940	8	1,658	113	4,988	1,400	73,800		11,350
1941	2	175	8	6,895	300	77,000		9,607
1942	4	6,161	53	22,164	3,300	247,100		34,571
1943	2	2,875	34	19,613	1,600	71,600	3,000	21,039
1944	3	261	5	775	400	4,500		1,140
1945	1	4,179	26	13,621	1,400	88,300	51,855	24,336

Clear Creek County

Trail (Freeland, Lamartine) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	3	45	46	156		3,000		$ 1,086
1933	3	93	105	342	50	9,000		2,633
1934	6	2,934	638	3,191	4,500	4,600		24,873
1935	8	4,214	1,180	4,363	3,850	44,200		46,538
1936	7	12,555	2,650	5,357	3,100	35,800		98,817
1937	8	22,508	3,181	7,567	11,670	45,000		121,255
1938	7	9,131	2,298	6,008	5,000	51,300	13,000	87,788
1939	11	16,551	5,341	8,829	2,800	77,200		196,847
1940	11	27,675	5,232	11,351	6,700	227,000		203,329
1941	10	31,402	5,225	7,134	1,900	196,700		199,384
1942	6	27,154	3,537	4,895	2,300	135,300		136,619
1943	3	8,917	1,018	7,657	3,200	102,200	21,700	51,500
1944	3	291	69	1,087	1,200	44,500	35,000	10,900
1945	2	642	277	3,427	2,600	132,500	70,600	31,997

Trail (Freeland, Lamartine)

Tps. 3 and 4 S., Rs. 73 and 74 W. (See pl. 4.)

Altitude 8,500 to 9,500 feet.

The Freeland mine is on Trail Creek and the Lamartine is 2 miles to the southwest on the divide between Trail Creek and Ute Creek. The district has a good to fair road, and is 2 to 4 miles from U. S. 40 and U. S. 6 and 2½ miles west of Idaho Springs.

Mineralization is similar to that of the Idaho Springs district.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 308-13.

Georgetown Quad., 1:62,500, contours 100 ft., ed. 1905.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 and 100 ft., 1939.

Spurr, J. E., and Garrey, G. H., Economic geology of the Georgetown quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 63, pp. 314-340, 1908.

Conejos County

The Axell, Gilmore, Lake Fork, Platoro (Ute) and Stunner districts listed on plate 1 of U. S. Geological Survey Professional Paper 138 are in an area that is commonly referred to as the Platoro district. T. 36 N., R. 4 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,500 to 11,000 feet.

The area is about 55 miles by road from Alamosa and 40 miles from U. S. 285 south of Alamosa. The road to Jasper, shown on current highway maps, is fair to good, but in the district the roads are fair to poor, depending on the season.

The veins show a small and spotty distribution of values that locally are high-grade. The country rock is a complex of rhyolite, latite, and monzonite porphyries of the Potosi volcanic series and Hinsdale formation. Outcrops are poor in many places and exploration is difficult.

The production prior to 1909 of gold, silver, copper, and lead has a total value of $72,669. Since 1909 the production has been:

Year	Lode Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Total Value
1938	1	500	13	916	$1,033
1940	1	29	5	83	234
1941	1	45	7	204	390

Summitville Quad., 1:125,000, contours 100 ft., ed. 1915.

Rio Grande National Forest Map.

Patton, Horace B., Geology and ore deposits of the Platoro-Summitville mining district: Colorado Geol. Survey Bull. 13, pp. 1-61, 89-107, maps, 1917.

Costilla County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total				
[1]1885-08				723	174	897			2,603	1,827	50,048		$22,097
[2]1909-23				2	1,204	1,206		112	112				25,004
[3]1924-31	17	1		5		5	11		11				107
[4]1932-41	90	1	1–3	4	108	112		11	11		4,000	8,000	4,423
[5]1942-45			1–2		9	9							315

[1]No production from 1906 to 1910.
[2]No production from 1915 to 1921.
[3]Production in 1929 only. Production since 1929 is from the Russell Grayback district.
[4]Production in 1940 and 1941. Lead and zinc production in 1941 only.
[5]Production in 1942 and 1945.

Costilla County

Plomo (Rito Seco)

T. 32 S., R. 71 W. (See pl. 4.)

Altitude about 8,000 feet.

This deposit is on Rito Seco Creek about 16 miles southeast of Ft. Garland (State 160) and 7 miles northeast from San Luis (State 159), the county seat. The secondary road along Rito Seco is fair to good.

Considerable rock alteration has occurred over an area three-quarters of a mile in diameter. The rock has been classified as granite-gneiss but probably is an altered latite-andesite flow. The ore consists of gold with pyrite in quartz occurring as partial replacements of the rock and filling along numerous fractures. The ore is low-grade and the boundary between rock and ore is gradational.

Production in recent years has been limited to small trial shipments.

San Isabel National Forest Map.

Gunther, C. G., The gold deposits of Plomo, San Luis Park, Colo.: Econ. Geology, vol. 1, pp. 143-154, map, 1905.
Vanderwilt, J. W., Personal files.

Russell (Grayback)

T. 28 S., Rs. 71 and 72 W. (See pl. 4.)

Altitude 8,500 to 10,500 feet.

Grayback Mountain, where mineralization is found, is 5 miles north of Russell (U. S. 160). The roads from Russell into the district are fair to poor.

Narrow veins with low-grade gold mineralization in sandstone and limestone of Carboniferous age are intruded by monzonite and diorite. Copper stain is found along a steeply dipping contact between the sedimentary beds and pre-Cambrian schist. Low-grade gold placer gravels account for the gold produced since 1932.

Russell (Grayback) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Silver (fine ounces) Total	Lead (pounds)	Zinc (pounds)	Total Value
[1]1932		1		8					$ 158
1933		2		17	2	2			341
1934		2		9					304
1935		1		2					70
1936		3		13	1	1			463
1937		2		13	2	2			443
1938		2		14	3	3			485
[1]1939		3		19	1	1			666
1940		1		8	1	1			281
[1]1941	1	1	46	7	1	1	4,000	8,000	1,074
[1]1942		2		7					245
[1]1945		1		2					70

[1]Total production for Costilla County.

Huerfano Park Quad., 1:125,000, contours 25, 50, and 100 ft., ed. 1892.

The topography shown on this sheet differs from the topographic map in the report listed below on the Grayback district.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Patton, H. B., and others, Geology of the Grayback mining district, Costilla Co., Colo.: Colorado Geol. Survey Bull. 2, 111 pp., maps, 1910.

Custer County

Fairview

T. 23 S., R. 70 W. (Not shown on pl. 4.)

Altitude 10,000 to 11,000 feet.

No data as to access, but this general area of the Wet, or Greenhorn, Mountains is very rugged and there are few roads.

No production is recorded.

Canon City Sheet, 1:125,000, contours 25, 50 and 100 ft., ed. 1892.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hardscrabble (Silver Cliff—Westcliffe)

T. 22 S., R. 72 W. (See pl. 4.)

Altitude 8,000 feet.

Silver Cliff and Westcliffe are on State 96, and 33 miles southwest of Florence via State 67 and 96. The roads are fair to good.

North of Silver Cliff, rhyolite and tuff, presumably from the Rosita Hills area, rest on pre-Cambrian granite. Relatively small veins that produced high-grade ore occur in both the granite and volcanic rock, but production has come chiefly from the veins in the rhyolite. The chief values are silver and gold with lead and some copper and zinc.

One mine, the Bull Domingo, is in an agglomerate or breccia pipe in pre-Cambrian rock with the silver, lead, gold, and other minerals deposited between the boulders. Silver chloride, or horn silver, is characteristic of oxidized surface outcrops at Silver Cliff.

Canon City sheet, 1:125,000, contours 25, 50 and 100 ft., ed. 1896.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Cross, C. W., Geology of Silver Cliff and the Rosita Hills, Colo.: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 263-403, maps, 1896.

Emmons, S. F., The mines of Custer County, Colo.: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 405-472, 1896.

Custer County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Gold (fine ounces) Lode	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1872-08........			101,239	101,239	3,993,764	3,993,764	170,552	29,759,200	61,471	$7,457,722
1909-23........	115,727		4,518	4,518	547,813	547,813	394,192	4,805,818	155,756	984,232
1924-31........	150,159	2–8	210	210	37,370	37,370	2,381	5,165,478		438,744
1932-41........	6,502	1–11	583	583	37,272	37,272	13,400	380,100	6,000	68,355
1942-45........	13,933	4–6	345	345	41,670	41,670	5,900	791,000	869,000	204,925
CRUDE ORE SHIPPED TO SMELTERS										
1909-23........	22,760			1,657		517,725	389,800	1,370,620	114,079	
1924-31........	1,169			127		36,851	2,381	242,478		
1932-41........	1,464			39		32,275	13,400	380,100	6,000	
1942-45........	1,116			10		10,470	192	307,411		

ORE TO GOLD AND SILVER MILLS

Year	Ore (short tons)	Bullion Gold	Bullion Silver	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
1909-23........	24,848	2,847	24,121						
[1]1924-31........	1,513	83	519						
1932-41........	5,038	544	4,997						
[2]1942-45........	12,382	88	2,001	1,524	242	27,690	5,586	451,914	817,600
ORE TO CONCENTRATING MILLS									
1909-23........	68,119			2,846	14	5,967	4,392	3,435,198	41,677
[3]1924-31........	147,477			3,985				4,923,000	
1932-41........									
1942-45........	435			97	5	1,509	122	31,675	51,400

[1]Production in 1924 and 1931 only.
[2]No production in 1942.
[3]No production after 1927.

Custer County

Hardscrabble (Silver Cliff-Westcliffe) District
Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	1	1		14				$ 4
1934	5	170	6	4,534	1,300	23,000		4,096
1935	5	230		7,499	4,000	37,100		7,212
1936	6	360	52	2,913	1,870	9,300		4,661
1937	5	692	27	7,116		107,800	6,000	13,197
1938	3	1,549	145	2,772		24,000		7,971
1939	6	1,420	119	2,690	1,800	23,000		7,259
1940	10	1,520	152	3,600	2,000	50,400		10,626
1942	3	18		384		4,000		541
1943	5	4,440	131	11,693	300	161,400	272,000	54,420
1944	5	4,760	99	11,496	1,600	206,000	274,000	59,572
1945	6	4,689	115	18,097	4,000	397,000	323,000	88,721

Oak Creek (Ilse, Spaulding)

T. 21 S., R. 70 W. (See pl. 4.)

Altitude 8,000 feet.

Ilse is on State 143, a fair road, and 16 miles southwest of Florence, the nearest railroad. Ilse was formerly known as Spaulding.

Cerussite (lead carbonate) deposits extend in a narrow belt for several miles along the east side of Oak Creek. Country rocks are granite and granite-gneiss, and the cerussite belt shows crushing, slickensided surfaces, clay gauge, and alteration. Two zones may be present but only one locality, the Terrible mine, has had appreciable production. The ore body in the Terrible mine is roughly elliptical in plan (150x300 ft.). Considerable honeycomb limonite and manganese stain are present. Streaks and veinlets of chert and chalcedony are scattered throughout the mineralized parts of the rock. On the 200-foot level, the lowest level of the mine, the grade of the ore had decreased, but otherwise it remained unchanged. The ore consists of cerussite in lenses, stringers, and small pockets along cracks usually less than one to two inches wide in the country rock. Assays show a small amount of silver, but no zinc, arsenic, antimony, or sulphur. The mine produced around 300,000 tons of 5 per cent to 8 per cent ore prior to 1895. Since that time production has been relatively small.

Production since 1931 consists of 10 tons in 1940 that yielded 7 ounces silver and 1,600 pounds of lead, and a total of 26 tons in 1942 and 1943 that yielded 22,600 pounds of lead.

Canon City Sheet, 1:125,000, contours 25, 50, 100 ft., ed. 1892.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hunter, J. F., Some cerussite deposits in Custer County, Colo.: U. S. Geol. Survey Bull. 580, pp. 25-37, 1914.

Rosita Hills (Rosita, Querida)

T. 22 S., R. 71 W. (See pl. 4.)

Altitude 9,000 feet.

Rosita Hills is on a local road about 2 miles from State 96 and about 14 miles east of Silver Cliff and 25 miles southwest of Canon City. The roads are fair to good. The ores are principally silver with some copper and gold in veins and pipes.

The Rosita Hills are a series of andesite to rhyolite flows and agglomerates from a local volcanic source. The volcanic rock rests on a floor of pre-Cambrian granite and schist. Pipes of agglomerate in the area may be the necks of volcanoes. Veins carrying silver minerals and gold are found chiefly in the volcanic rocks. Galena, pyrite, and barite are present, and in general the mineralization is similar to that found at Silver Cliff several miles to the northwest.

The ore in the Bassick mine is an elliptical (20x100 ft.) vertical pipe in a large mass of agglomerates that may represent the neck of a volcano. The ore in the Bassick mine is similar to that found in the veins, except that there seems to be a higher gold content with some quartz and no barite.

Canon City Sheet, 1:125,000, contours 25, 50, 100 ft., ed. 1892.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Cross, C. W., Geology of the Silver Cliff and Rosita Hills, Colo.: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 263-403, 1896.

Emmons, S. F., The mines of Custer County, Colo.: U. S. Geol. Survey 17th Ann. Rept., pt. 2, pp. 405-472, 1896.

Rosita Hills (Rosita, Querida) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Total Value
1933	1	3	3					$ 54
1934	1	12	13	37	37			483
1935	1	6	1	149	149			129
1936	4	302	40	2,985	2,985	430	34,700	5,363
1937	1	49	25	734	734		3,200	1,613

Delta County

The production recorded for Delta County from 1894 to 1904 and in 1910 is 207 ounces of gold and 306 ounces of silver, but no mining districts are listed and the source of the production is not given.

In 1933 a 1-ton shipment of ore yielded 100 ounces of silver and 400 pounds of lead. From 1933 through 1937, 41 fine ounces of gold and 5 ounces of silver were produced from placers in T. 15 S., R. 97 W., on the Gunnison River 8 miles west of Delta.

Grand Mesa National Forest Map.

Uncompahgre National Forest Map.

Henderson, C. W., Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, p. 114, 1926.

Denver County

Cherry Creek and Platte River placers

T. 4 S., R. 68 W. (Not shown on pl. 4.)

Altitude 5,000 to 5,200 feet.

These placers are the northward continuation of the placers found along the same streams in Arapahoe County to the South. See Arapahoe County placers for general description.

Production of Placer Gold and Silver in Denver County in Terms of Recovered Metals

Year	Placer Mines Producing Yearly	Gold (fine ounces)	Silver (fine ounces)	Total Value
1929......	1	6		$ 115
1931......	39	29		598
Total 1924-1931......	1–39	35		713
1932......	12	31	7	648
1933......	8	20	6	407
1934......	115	124	4	4,347
1935......	59	39		1,377
1937......	7	2		84
1938......	9	7		259
1939......	9	9		315
1941......	3	6		210
Total 1932-1941......	3–115	238	17	7,647

Denver Quad., 1:125,000, contours 50 and 100 ft., ed. 1901.
Englewood Quad., 1:31,680, contours 10 ft., ed. 1944.
Fort Logan Quad., 1:31,680, contours 10 ft., ed. 1937.

Dolores County

Lone Cone (Dunton)

T. 40 N., R. 11 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 10,500 feet.

This area is on West Dolores River, on State 331 and 16 miles northwest of Rico.

Production since 1933 came from one mine and is limited to 3 years as follows:

	Tons Ore	Gold Ounces	Silver Ounces	Lead Pounds	Total Value
1938..........	173	19	285		$ 832
1940..........	4,800	194	9,734		13,712
1941..........	11,201	966	37,762	4,300	60,908

Montezuma National Forest Map.
San Juan National Forest Map.
Dunton Mining area (advance topographic sheet), 1:12,000, contours 25 ft.

Dolores County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1879-08				90,240		90,240	10,560,890		10,560,890	1,314,644	26,660,933	3,215,959	$11,776,030
1909-23	97,746			5,437		5,437	1,113,037		1,113,037	4,929,237	10,361,211	7,570,357	2,951,352
1924-31	199,363	2–13		2,887		2,887	1,024,418		1,024,418	1,822,458	35,351,341	35,173,800	5,512,383
1932-41	133,840	3–8	1–4	3,980	19	3,999	568,995	2	568,997	1,295,000	11,489,500	14,064,000	2,213,140
1942-45	142,582	2–3		544		544	529,996		529,996	623,600	20,229,100	29,786,800	5,284,629
CRUDE ORE SHIPPED TO SMELTERS													
1909-23	81,336					4,290			980,297	4,917,122	7,682,441	5,071,098	
1924-31	12,913					749			198,326	467,743	3,819,884	192,800	
1932-41	3,738					1,487			166,480	79,245	1,045,073	841,000	
1942-45													
ORE TO GOLD AND SILVER MILLS													
		Bullion Gold		Bullion Silver	Concentrates Tons	Concentrates Gold			Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc	
1909-23		1		44									
1924-31													
1932-41[1]				23									
1942-45													
ORE TO CONCENTRATING MILLS													
1909-23	16,409				6,535	1,074			132,696	12,115	2,678,770	2,499,259	
1924-31	186,450				75,844	2,138			826,092	1,354,715	31,531,457	34,981,000	
1932-41[2]	130,102				26,412	2,483			402,492	1,215,755	10,444,427	13,223,000	
1942-45	142,582				48,700	544			529,996	623,600	20,229,100	29,786,800	

[1]Production in 1933 only.
[2]No production from 1932 to 1936.

Dolores County

Pioneer (Rico) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1933	3		41	40		40	4,820		4,820	800	6,000		$ 2,777
1934	7	1	930	341	11	352	49,300	2	49,302	19,800	239,000	214,000	63,788
1935	7		1,082	656		656	71,040		71,040	25,000	280,500	283,000	99,751
1936	3		808	309		309	20,031		20,031	14,000	238,000	279,000	52,501
[1]1937	6		25,907	924		924	63,320		63,320	14,000	256,000	272,000	115,782
1938	3	4	220	34	6	40	4,642		4,642	3,400	57,000	60,000	10,246
1939	8	1	12,317	121	2	123	41,356		41,356	129,000	1,504,000	1,734,000	206,649
1940	3		38,735	275		275	153,990		153,990	965,000	3,855,000	5,214,000	749,406
1941	4		37,626	102		102	112,715		112,715	124,000	5,049,700	6,008,000	836,788
1942	2		35,371	119		119	110,918		110,918	70,100	4,564,100	5,528,800	911,495
1943	2		34,055	127		127	145,021		145,021	144,500	5,132,000	7,304,000	1,300,088
1944	3		36,941	141		141	121,791		121,791	237,000	5,653,000	9,114,000	1,614,773
1945	3		137,996	117		117	49,171		49,171	16,000	1,143,000	31,610,000	3,774,669

[1]Includes Lone Cone district, Dolores County.

Pioneer (Rico)

Tps. 39 and 40 N., Rs. 10 and 11 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 10,500 feet.

Rico is on State 145, a fair to poor road, 36 miles to Dolores to the southwest, and 27 miles to Telluride to the north.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 414-16.

Rico Quad., 1:62,500, contours 100 ft., ed. 1897.

Rico district, 1:23,600, contours 50 ft., ed. 1899.

Montezuma National Forest Map.

San Juan National Forest Map.

Cross, C. W., and Ransome, F. L., Rico, Colo.: U. S. Geol. Survey Geologic Atlas folio 130, 1905.

Cross, C. W., and Spencer, A. C., Geology of the Rico Mountains, Colo.: U. S. Geol. Survey 21st Ann. Rept., pt. 2, pp. 7-165, map, 1900.

Ransome, F. L., The ore deposits of the Rico Mountains, Colo.: U. S. Geol. Survey 22nd Ann. Rept., pt. 2, pp. 229-397, map, 1901.

Douglas County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1885-1908		137	155	$2,968
1910-1923		81	6	1,669
1925	2	5		97
1926	2	3		62
1928	1	15		313
1931	23	39		808
Total 1924-1931	1–23	62		1,280
1932	3	34	7	708
1933	6	24		494
1934	72	104		3,644
1935	27	72		2,513
1936	10	24		854
1937	8	19		651
1938	15	41		1,442
1939	17	80		2,800
1940	14	21		735
1941	6	13		455
Total 1932-1941	3–72	432	7	14,296

Cherry Creek placers

Tps. 6 and 7 S., R. 66 W. (See pl. 4.)

Altitude 5,900 to 6,100 feet.

Placer gold is found locally along Cherry Creek from Franktown on State 83 for several miles to the north. Placer gold is reported also on Lemon Creek, 4 to 5 miles northwest of Franktown, a tributary of Cherry Creek.

Castle Rock Quad. (15-minute series), 1:62,500, contours 20 ft., ed. 1945.

Parker Quad. (7½-minute series), 1:31,680, contours 10 ft., ed. 1942.

Dry Creek placers

T. 6 S., R. 67 W. (See pl. 4.)

Altitude 5,700 to 5,800 feet.

Some maps show this to be Big Dry Creek, a tributary of the Platte River. The placer gold along Dry Creek extends northwest across the county line into Arapahoe County.

State 177 southeast of Denver crosses Dry Creek.

Production from Dry Creek is not reported separately.

Highland Ranch Quad. (7½-minute series), 1:31,680, contours 10 ft., 1942.

Pike National Forest Map.

Newlin Gulch placers

T. 6 S., R. 66 W. (See pl. 4.)

Altitude 5,800 to 5,950 feet.

Newlin Creek joins Cherry Creek from the southwest and about 1½ miles northwest of Parker on State 83.

Happy Canyon, northwest of Newlin Creek, and Lemon Creek, southeast of Newlin Creek, have yielded small quantities of placer gold. All are tributaries of Cherry Creek.

The gold is found in the recent alluvian or wash that partly fills the bottom of the gulches and in some of the Monument Creek beds higher up on the adjoining slope. The particles of gold vary in size from those as large as a pinhead down to the finest grains visible with a lens.

The latest reported production for Douglas County was in 1940 and 1941, all of which came from the Newlin Gulch district.

Parker Quad. (7½-minute series), 1:31,680, contours 10 ft., ed. 1942.

Pike National Forest Map.

Butler, G. M., The gold of Newlin's Gulch, near Denver, Colorado: Min. Sci., vol. 65, pp. 486-487, 1912.

Russellville Gulch placers

T. 8 S., Rs. 65 and 66 W. (Not named on pl. 4.)

Altitude 6,200 to 6,400 feet.

Russellville Gulch is a tributary of Cherry Creek. The placers extend along the gulch for a distance of 3 miles beginning 1 mile south of Franktown on State 83. These placers are continuous with the Cherry Creek placers where the streams join.

Production from this area is not known, as county production is not subdivided.

Castle Rock Quad. (15-minute series) 1:62,500, contours 20 ft., ed. 1945.

Elizabeth Quad. (15-minute series) 1:62,500, contours 20 ft., ed. 1945.

Eagle County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Total	Placer	Total	Lode	Placer	Total				
1880-08....				109,200		109,200			4,003,673	1,053,518	72,755,446	2,480,839	$ 9,093,052
1909-23....	838,376			36,189	12	36,201	3,639,181	11	3,639,192	5,794,920	14,896,034	152,612,290	19,242,175
1924-31....	823,527	1–9	1	16,582	25	16,607	4,783,259	2	4,783,261	17,419,935	28,264,112	18,969,000	13,048,340
1932-41....	2,332,459	5–15	1–8	145,145	210	145,355	37,601,249	32	37,601,281	51,823,700	13,399,200	21,760,000	47,912,474
1942-45....	842,108	1–2		3,026		3,026	754,750		754,750	999,700	12,033,700	176,062,400	20,456,592
CRUDE ORE SHIPPED TO SMELTERS													
1909-23....	248,478					32,963			3,332,796	5,743,263	3,151,376	20,526,803	
[1]1924-31....	213,702					14,210			4,357,129	17,128,235	1,958,634	14,000	
1932-41....	2,204,794					143,471			37,527,078	51,813,346	11,652,438		
1942-45....	23,954					2,151			350,729	932,578	185,982		
ORE TO GOLD AND SILVER MILLS		—Bullion—							Concentrates				
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23....		28	7										
[2]1924-31....	8	10	159			2							
1932-41....	568	1,296	3,958										
[3]1942-45....		11	45										
ORE TO CONCENTRATING MILLS													
1909-23....	589,898				259,213	3,198			306,378	51,657	11,744,658	132,085,487	
[4]1924-31....	770,277				233,166	4,975			635,703	388,090	32,356,357	139,903,400	
[5]1932-41....	127,097				27,654	378			70,213	10,354	1,746,762	21,760,000	
1942-45....	818,154				207,478	864			403,976	67,122	11,847,718	176,062,400	

[1]1926 production includes both Eagle and Summit Counties.
[2]Production in 1930 and 1931 only.
[3]Production in 1942 only.
[4]1924 through 1929 includes both Eagle and Summit Counties.
[5]Production in 1932 and 1941 only.

Eagle County

Brush Creek

T. 5 S., R. 83 W. (See pl. 4.)

Altitude 7,500 feet.

This locality is on Brush Creek, which flows northwesterly and joins the Eagle River about 1 mile west of Eagle (U. S. 24). The mineralized area is 6 to 8 miles up Brush Creek on the road to Fulford several miles farther upstream. The road from U. S. 24 to the area (State 307) affords easy access to the area.

Northwest-trending veins with steep northerly dips occur in sandstone (probably Dakota). The value is silver in the form of chloride (cerargyrite) or horn silver. Locally malachite and azurite stains occur in the sandstone. Analyses of sandstone specimens show about 0.2 to 0.3 of one percent of vanadium and a trace of uranium which are probably not related to the veins. The district was active from about 1912 to 1926 and considerable production is indicated by the presence of stopes of moderate size.

White River National Forest Map.

George, R. D., Geological relations in the Brush Creek region (Colo.): Mining Science, vol. 67, pp. 148-149, map, 1913.

Burns and McCoy

T. 2 S., R. 84 W. (Not shown on pl. 4.)

Altitude 7,000 feet.

These placers are 5 miles, on a fairly good branch road, west of McCoy. McCoy is 17 miles on State 131 southeast of Yampa, and 22 miles on State 131 and 11 north of Wolcott. Wolcott is on U. S. 6. The roads north of Wolcott are very slippery when wet.

The placer gold occurs in bench gravels near the Colorado River.

White River National Forest Map.

Burns and McCoy District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1933	1	13	2	$ 269
1934	8	72	14	2,511
1935	7	59	14	2,077
1936	1	2		56
1938	7	18		637
1939	4	5		175
1940	7	4		140

Fulford

T. 7 S., R. 83 W. (See pl. 4.)

Altitude 10,000 to 11,000 feet.

Fulford is at the head of Brush Creek and on a poor to fair road about 20 miles southeast of Eagle. Eagle is on U. S. 6.

Lead-silver mineralization similar to that found farther down the valley (see Brush Creek district) is said to occur in dolomite beds of Paleozoic age.

White River National Forest Map.

Gypsum

T. 4 S., R. 85 W. (Not shown on pl. 4.)

Altitude 6,500 feet.

Gypsum is on U. S. 6 and 24, 24 miles east of Glenwood Springs.

The occurrence of placer gold is recorded along the Eagle River in the vicinity of Gypsum.

A total of 4 fine ounces of gold and 1 fine ounce of silver was reported in 1933 from 1 placer.

White River National Forest Map.

Holy Cross (Eagle River)

T. 7 S., R. 82 W. (See pl. 4.)

Altitude 10,000 to 11,000 feet.

This district is at the head of Cross Creek and about 10 miles southwest of Minturn. The lower part of Cross Creek has a poor road, and the upper part is little better than a wagon road or trail. Minturn is near U. S. 6 and on U. S. 24.

Small veins contain spotty high-grade gold, silver, and some lead mineralization in pre-Cambrian granite and schist.

White River National Forest Map.

Holy Cross (Eagle River) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1937	2	1	3	1			$ 92
1938	1	63	6				217
1939	1	2	3	99	200	400	212
1940	1	22	21	294	1,600	4,200	1,335

Eagle County

Red Cliff (Battle Mountain, Gilman, Belden) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode				
1932......	6		51,238	2,897		2,897	1,110,819	5,620,000	441,000		$ 740,430
1933......	9	1	91,258	4,308	2	4,310	1,484,140	8,163,000	15,000		1,131,530
1934......	14		135,650	6,896		6,896	1,942,270	9,819,000	104,400		2,286,009
1935......	14		210,587	9,851		9,851	2,792,256	13,183,000	309,000		3,458,261
1936......	15		254,968	11,945		11,945	3,697,632	15,932,700	982,800		4,792,922
1937......	7		257,964	12,562		12,562	4,073,363	18,915,000	1,160,000		5,947,585
1938......	9		327,678	17,421		17,421	5,307,342	24,026,000	1,865,000		6,481,075
1939......	10		340,462	22,918		22,918	6,073,924	23,841,800	2,273,600		7,511,442
1940......	6		333,911	31,148		31,148	6,766,432	21,103,400	2,823,800		8,427,739
1941......	4		328,655	25,162		25,162	4,352,677	11,218,000	3,420,000	21,760,000	7,126,571
1942......	2		243,689	2,040		2,040	395,252	645,700	4,480,700	45,760,400	4,986,522
1943......	1		258,879	421		421	176,116	229,000	3,522,000	57,709,000	6,666,465
1944......	2		201,544	448		448	134,211	109,000	2,888,000	40,983,000	5,028,936
1945......	1		137,996	117		117	49,171	16,000	1,143,000	31,610,000	3,774,669

Homestake

T. 7 S., Rs. 80 and 81 W. (Not shown on pl. 4.)

Altitude 8,500 to 12,000 feet.

Homestake Creek joins the Eagle River near Red Cliff. Red Cliff is 24 miles on U. S. 24 north of Leadville. The district shown in Prof. Paper 138 to the south at the head of the stream is in Pitkin County, but small veins are also found farther north along Homestake Creek in Eagle County. The road along Homestake Creek for several miles south of Red Cliff is passable and fair, but the last 5 to 6 miles to the more important prospects farther south is by trail.

The principal values reported are gold with some silver, lead, and zinc, in small veins in pre-Cambrian granite and schist. The amount of production, if any, is not known.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1881.

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.

White River National Forest Map.

Mt. Egley

(Not shown on pl. 4.)

The location of this locality is not known.

A little placer gold was produced in 1932, 1939, and 1941. The total production for these 3 years was 27 fine ounces of gold and 25 fine ounces of silver.

Red Cliff (Battle Mountain, Gilman, Belden)

T. 6 S., R. 80 W. (See pl. 4.)

Altitude 9,000 to 10,500 feet.

Red Cliff is on U. S. Highway 24, 25 miles north of Leadville. The principal operator is the Empire Zinc Company, a subsidiary of the New Jersey Zinc Company, with offices at Gilman, 3 miles northwest of Red Cliff.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 378-87.

White River National Forest Map.

Crawford, Ralph Dixon, and Gibson, Russell, Geology and ore deposits of the Red Cliff district, Colo. Colo. Geol. Survey Bull. 30, 89 pp., 15 figs., 3 pls. (incl. map) (1925).

Elbert County

Gold Creek or Ronk Creek placers

T. 8 S., R. 65 W. (Not shown on pl. 4.)

Altitude 6,400 to 6,500 feet.

These placers are 1 to 1½ miles west and northwest of Elizabeth, and on Gold Creek or Ronk Creek, a tributary of Running Creek (Boxelder Creek on some maps) that parallels Cherry Creek

8 miles to the west. Elizabeth is on State 86, and 40 miles southeast of Denver.

The placers are similar to the Cherry Creek placers in Douglas and Arapahoe Counties.

Castle Rock Quad., 1:125,000, contours 100 ft., ed. 1913.

Elizabeth Quad., 1:62,500, contours 20 ft., ed. 1945.

Elbert County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Total Value
1926	1	7	$ 148
1931	1	2	40
Total 1924-1931	2	9	188
1932	3	28	571
1933	1	11	223
1934	1	10	346
1935	2	7	243
1938	4	17	609
1939	2	23	805
1940	5	27	945
Total 1932-1941	1–5	123	3,742

El Paso County

Blair Athol

T. 13 S., R. 67 W. (See pl. 4.)

Altitude 7,000 feet.

This district is in the foothills 6 miles northwest of Colorado Springs.

This area is pre-Cambrian granite, and a small production of copper is reported, but there is no data on the nature of the occurrence.

Production reported from this area, which also is total county production, is 323 tons in 1913 and 1914 that yielded 13,276 pounds of copper.

Colorado Springs Quad., 1:125,000, contours 100 ft., ed. 1909.

Pike National Forest Map.

Finlay, G. I., Description of the Colorado Springs quadrangle, Colo.: U. S. Geol. Survey Geologic Atlas, Colorado Springs folio no. 203, maps, 1916.

Fremont County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total				
1881-08				3,708		3,708	76,526		76,526	109,078	534,237	591,333	$226,837
1909-23	6,239			217		217	15,286		15,286	558,076	150,748	861,436	194,753
[1]1924-31	183	1		2		2	507		507	801	6,492	42,000	3,398
1932-41	616	1–2	1–13	32	135	167	73	20	93	17,400	2,000		7,268
1942-45	14,113	1–3		245		245	7,328		7,328	97,800	209,000	2,655,300	341,318
CRUDE ORE SHIPPED TO SMELTERS													
1909-23	6,214					217			15,271	558,076	146,157	854,275	
[2]1924-31	26					1			136	801	2,492		
[3]1932-41	98					6			69	17,400	2,000		
1942-45	101					11			793	1,600	12,000	15,000	

Year	Ore (short tons)	Bullion Gold	Bullion Silver	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
ORE TO GOLD AND SILVER MILLS									
1909-23									
1924-31									
1932-41	68	6							
1942-45	13,978	65	400	3,427	169	6,069	95,600	197,000	2,626,000
ORE TO CONCENTRATING MILLS									
1909-23	25			18		15		4,591	7,161
[4]1924-31	157			51	1	371		4,000	42,000
[5]1932-41	450			1	20	4			
[6]1942-45	34			10		66	600		14,300

[1]Production in 1927 and 1928 only.
[2]Production in 1927 only.
[3]Production in 1938 and 1941.
[4]Production in 1928 only.
[5]Production in 1932 only.
[6]Production in 1942 only.

Fremont County

Arkansas River placers

The Arkansas River from the Chaffee County line downstream to Florence. (Not shown on pl. 4.)

Altitude about 5,200 feet at Florence and about 7,000 feet at the Fremont County line.

Prior to 1945 this district produced small quantities of placer gold. The nature of the placers are the same as those described under Arkansas River placers in Chaffee County.

The mine production recorded for 1945 is ore shipped from an old dump at the Florence smelter site.

Canon City Sheet, 1:125,000, contours 25, 50, and 100 ft., ed. 1892. Shows Florence and Arkansas River to west.

San Isabel National Forest Map.

Badger Creek

T. 50 N., R. 10 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 7,500 feet.

Badger Creek joins the Arkansas River about 8 miles southeast of Salida, and the deposits are 4 miles north up Badger Creek. U. S. 50 follows the Arkansas River.

Copper mineralization is said to be present, but the type of occurrence is not known. No production is reported from this area.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Canon City

T. 18 S., R. 70 W. (Not shown on pl. 4.)

Altitude 5,900 feet.

Veins with copper and tungsten are said to occur in pre-Cambrian granite. No production is reported.

Canon City Sheet, 1:125,000, contours 25, 50, and 100 ft., ed. 1892.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 144, 1912.

Cotopaxi

T. 48 N., R. 12 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 6,500 to 7,000 feet.

Cotopaxi is on U. S. 50 and 24 miles southeast of Salida. The old Cotopaxi mine is in a small gulch half a mile northwest of Cotopaxi.

Fremont County

Arkansas River Placers District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932........		2			8	8							$ 167
1933........		2			1	1		2	2				248
1934........		13			61	61		12	12				2,132
1935........		11			43	43		7	7				1,497
1945........	1		101	11		11	793		793	1,600	12,000	15,000	3,922

Cotopaxi District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1943..........................	1	3,284	48	38	20,100		829,600	$93,882
1944..........................	1	2,688	28		16,000		787,500	92,915
1945..........................	1	3,862	84	5,119	41,600	64,000	664,000	94,060

This is a pre-Cambrian deposit consisting of massive chalcopyrite with intimately intergrown dark-brown sphalerite in a gangue of quartz, abundant biotite, reddish garnet, and dark-green amphibole. The deposit probably was a lense of igneous basic ore-bearing rock, now greatly metamorphosed and conformable with the schistosity of the gneiss.

The property is described in 1907 as having been "idle for many years, but it was at one time a considerable shipper of ore."

Rio Grande National Forest Map.

San Isabel National Forest Map.

Lindgren, Waldemar, Notes on copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, pp. 166-167, 1908.

Currant Creek (Parkdale, Micanite)

T. 17 S., R. 72 W. (See pl. 4.)

Altitude 7,000 to 7,500 feet.

Parkdale is 13 miles west of Canon City on U. S. 50, and the mineralized area is about 8 miles to the north on Currant Creek. A secondary road follows Currant Creek.

Zinc, copper, gold, silver, and lead are reported. The general area is pre-Cambrian granite, but the nature of the occurrence is not known.

No production is recorded.

Pikes Peak Quad., 1:125,000, contours 100 feet, reprint 1919.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Grape Creek (Greenhorn)

T. 20 S., R. 71 W. (See pl. 4.)

Altitude 6,500 to 7,500 feet.

The deposit is on Grape Creek, 8 miles southwest of Canon City, and it is about 6 miles on a poor road from U. S. 50.

Some zinc-lead ore has been produced, but the nature of the occurrence is not known.

Canon City Sheet, 1:125,000, contours 25, 50, and 100 ft., ed. 1892. This map covers the area, but the location of deposit is not shown.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hillside

T. 20 S., R. 73 W. (Not shown on pl. 4.)

Altitude 7,250 to 7,750 feet.

Hillside is on Texas Creek, and it is 11 miles by State 69 and 28 miles by U. S. 50 southwest of Canon City. Hillside is 13 miles northwest of Westcliffe.

Fremont County

Grape Creek (Greenhorn) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode		Lode	Lode				
1943	1	1,576	31	741	7,100	70,000	117,400	$20,464
1944	1	1,384	24	436	6,000	40,000	119,500	18,783
1945	1	1,184	20	135	4,800	23,000	108,000	15,842

The nature of the occurrence is not known. A trial shipment of 7 tons of gold ore mined in 1935 yielded about 0.2 ounces of gold per ton.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Red Gulch

T. 49 N., R. 12 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,000 feet.

The Red Gulch district is 9 miles, by an unmapped road, north of Cotopaxi on U. S. 40, and 24 miles southeast of Salida. Red Gulch is shown as Carroll Creek on recent State maps.

Copper deposits occur in red beds of Carboniferous age. Deposition of chalcocite with a little silver is controlled by carbonaceous shales and coal seams. Samples of coal gave $0.114V_20_5$. Narrow seams of barite cut both coal and ore. A nearby fault is barren.

Production seems to be limited to a few cars of high-grade and several cars of low-grade ore shipped at an early date. No production was made in recent years.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Lindgren, Waldemar, Notes on copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, pp. 170-174, 1908.

Whitehorn (Calumet in Chaffee County)

T. 51 N., R. 10 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,000 to 10,500 feet.

This district is east of and continuous with the Calumet area in Chaffee County and the same description applies.

The district is known for small occurrences of gold and silver, but the nature of the occurrence is not known.

No production is recorded.

Gunnison National Forest Map.

Pike National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Garfield County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Total				
[1]1885-08				149		149	156	156				$ 3,185
[2]1909-23	346			670		607	372	372	1,044			14,219
[3]1924-31	66	1		1		1	194	194		10,142		760
[4]1932-41	615	1–4	1	877	2	879	511	511	1,300		7,000	31,741
1942-45	10	1					56	56		400	2,900	337
CRUDE ORE SHIPPED TO SMELTERS												
1909-23	346					670		372	1,044			
1924-31												
[5]1932-41	586					871		428	1,300			
1942-45	10							56		400	2,900	

ORE TO GOLD AND SILVER MILLS		Bullion		Concentrates					
		Gold	Silver	Tons	Gold	Silver	Copper	Lead	Zinc
1909-23									
1924-31									
[6]1932-41	3	6							
1942-45									
ORE TO CONCENTRATING MILLS									
1909-23									
1924-31									
[6]1932-41	26			7		83			7,000
1942-45									

[1]No production from 1885 to 1894 and from 1906 to 1910.
[2]Production from 1910 to 1918.
[3]Production in 1927 only.
[4]No production from 1933 to 1938.
[5]Production from 1938 to 1941.
[6]Production in 1941 only.

Garfield County

Rifle Creek and Elk Creek Districts

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1939	1	199	322	159	600			$11,440
1940	1	213	308	142	100			10,892
1941	4	100	89	142	500		7,000	3,800
1942	1	10		56		400	2,900	337

Garfield County

Rifle Creek and Elk Creek

T. 4 S., Rs. 90 and 92 W. (Shown but not named on pl. 4.)

Altitude 7,000 to 7,500 feet.

These two localities are on the south flank of the White River Plateau, parts of which are almost inaccessible.

More than one prospect is reported on Rifle Creek, but the occurrence known best is in Range 92 on East Rifle Creek 18 miles northeast of Rifle and about 2 miles north of the well-known Vanadium mine.

Sphalerite and some galena occur in narrow north-south fissures in the Leadville (Mississippian) limestone. The cross fissures are related to a nearby east-west fault concealed by alluvium. A minor production is reported from this deposit.

On Elk Creek (R. 90 W.) Forbes describes a 12-inch massive sulfide vein in gneiss carrying gold, and a small production is recorded. Unverified reports tell of lead-silver, and gold mineralization in the sedimentary rocks in the general area north of Glenwood Springs and Newcastle. Indications are that the deposits are small but the occurrence is of interest because it is far removed from the mineralized belt in Colorado.

White River National Forest Map.

Rickard, Forbes, Gold ore near Newcastle: Min. Sci. Press, vol. 99, p. 503, 1909.

Gilpin County

Northern Districts (Perigo, Independence, Pine-Kingston-Apex)

T. 2 S., R. 73 W. (See pl. 4.)

Altitude 9,000 to 10,500 feet.

These districts are separated from the Southern Districts geographically rather than geologically. They cover about half a township 20 to 25 miles southwest of Boulder and 50 to 60 miles northwest of Denver. Access roads U. S. 40 from Denver and State 119 from Boulder are good.

The area is characterized by mineralized veins in pre-Cambrian granite and schist. Local dikes of quartz monzonite are common. Production is maintained by several small producers, although large mines also have produced in the area. The grade of the ore varies from high values to low-grade ore.

Gold and silver are the predominating metals, but some copper, lead, and zinc minerals are present. The large number of veins are favorable for a sustained production in the future.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 314-15.

Gilpin County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Placer	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08..				3,736,784	11,704	3,748,488			8,480,342	18,416,843	25,721,044	79,090	$88,686,519
1909-23..	766,071			320,882	25	320,907	2,042,200	16	2,042,200	6,967,416	9,771,791	250,623	9,724,806
1924-31..	492,173	18–55	2–12	40,805	515	41,320	166,683	93	166,776	399,628	1,114,145	75,400	1,081,302
1932-41..	1,398,491	51–135	50–154	100,087	34,956	135,043	416,575	6,282	422,857	630,100	1,740,700	116,000	4,874,397
1942-45..	27,023	10–24	4–15	7,097	408	7,505	54,277	76	54,353	259,900	636,300	347,000	421,841
CRUDE ORE SHIPPED TO SMELTERS													
1909-23..	123,647					155,264			1,043,510	4,156,453	3,724,229		
1924-31..	3,369					3,757			59,576	89,433	546,913	3,800	
1932-41..	7,057					6,198			85,868	186,427	440,509		
1942-45..	880					1,756			8,124	56,526	55,728		
ORE TO GOLD AND SILVER MILLS													
		Bullion: Gold	Bullion: Silver		Concentrates: Tons	Concentrates: Gold			Concentrates: Silver	Concentrates: Copper	Concentrates: Lead	Concentrates: Zinc	
1909-23..	338,495	48,844	15,032										
1924-31..	470,370	21,253	12,538		7,520	12,498			62,683	275,178	367,914	19,000	
1932-41..	1,333,949	53,374	88,299		32,496	31,914			126,715	209,432	482,119	84,000	
1942-45..	9,313	474	1,260		1,107	1,523			22,967	35,419	383,171	299,374	
ORE TO CONCENTRATING MILLS													
1909-23..	303,929				118,934	116,774			983,642	2,810,963	6,047,562	250,623	
1924-31..	18,434				2,120	3,297			31,886	35,017	199,318	52,600	
1932-41..	57,485				7,956	8,601			115,903	234,241	818,072	32,000	
[1]1942-45..	16,830				2,899	3,344			21,926	167,955	197,401	47,626	

[1]No production in 1944.

Gilpin County

Northern Districts (Perigo, Independence, Pine-Kingston-Apex)

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Total Value
1932..	7	45	1,510	348	70	418	213	10	223			$ 8,690
1933..	16	10	1,034	285	56	341	351	3	354			7,156
1934..	16	45	909	355	121	476	142	14	156			16,718
1935..	19	24	1,089	258	88	346	957	11	968	15,000	100	14,046
1936..	12	15	6,127	1,032	46	1,078	182	5	187	200		37,893
1937..	9	6	8,186	1,711	2,479	4,190	1,943	221	2,164	2,400	150	148,644
1938..	11	11	10,059	1,342	3,270	4,612	1,219	294	1,513	800	20,000	163,389
1939..	17	11	4,417	700	1,975	2,675	519	184	703	1,800	600	94,317
1940..	16	11	4,384	431	98	529	540	7	547	5,200	200	19,502
1941..	8	4	2,735	364	106	470	315	10	325		1,000	16,738
1942..	3		854	152		152	581		581	6,400		6,507
1944..	1		*	8		8	1		1			281
1945..	1	•	2	2		2						70

*Less than ½ ton.

Central City Quad., 1:62,500, contours 100 ft., ed. 1912.

Central City Quad. (7½-minute series), 1:31,680, contours 50 ft., ed. 1944.

Nederland Quad. (7½-minute series), 1:31,680, contours 50 ft., ed. 1944.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 and 100 ft., 1939.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey. Prof. Paper 94, pp. 200-207, maps, 1917.

Southern Districts (Central, Nevada, Gregory, Russell, Quartz Mountain)

T. 3 S., R. 73 W. (See pl. 4.)

Altitude 8,000 to 10,000 feet.

These districts are scattered throughout the township and in places mineralization extends across into adjoining townships. They are 40 to 50 miles west of Denver and 25 to 30 miles southwest of Boulder. The best access to Central City is U. S. 40 and State 279 or State 119. Many secondary roads in the district are poor, and access to a considerable part of the area is difficult.

The veins are larger and more numerous in these areas than in the Northern Districts. The general nature of the occurrences of ore are very similar.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 314-15.

Central City Quad., 1:62,500, contours 100 ft., ed. 1912.

Central City Quad. (7½-minute series), 1:31,680, contours 50 ft., ed. 1944.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Geologic Map of the Front Range Mineral Belt, U. S. Geol. Survey, 1:62,500, contours 50 and 100 ft., 1939.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin Co. and adjacent parts of Clear Creek and Boulder Counties, Colo.: U. S. Geol. Survey Prof. Paper 94, pp. 208-280, maps, 1917.

Gilpin County

Southern Districts (Central, Nevada, Gregory, Russell, Quartz Mountain)

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	47	21	278,905	15,315	147	15,462	24,670	50	24,720	46,000	189,000	84,000	$337,685
1933	53	40	47,437	3,282	530	3,812	7,869	143	8,012	12,500	84,000		85,515
1934	119	102	112,353	6,826	447	7,273	34,762	162	34,924	32,600	165,000		285,480
1935	90	130	356,313	19,951	730	20,681	76,643	213	76,856	44,000	229,900		791,932
1936	64	93	346,317	16,788	4,703	21,491	76,847	913	77,760	31,800	328,700	12,000	831,084
1937	65	92	105,167	8,548	3,091	11,639	43,748	609	44,357	19,600	184,850	20,000	456,246
1938	54	141	40,523	4,487	5,066	9,554	32,291	1,092	33,383	22,200	81,000		361,859
1939	68	91	17,228	4,412	3,807	8,219	49,616	890	50,506	106,200	187,400		341,801
1940	60	119	27,755	5,696	2,991	8,687	47,025	533	47,558	151,800	230,800		366,557
1941	43	76	26,043	7,956	5,134	13,090	16,723	918	17,641	138,000	38,000		489,145
1942	21	13	15,281	4,968	270	5,238	14,546	52	14,598	115,900	112,300		215,259
1943	18	4	6,873	1,365	17	1,382	22,109	3	22,112	95,200	237,000	131,000	108,393
1944	9	5	3,087	421	47	468	14,219	7	14,226	36,800	197,000	170,000	66,604
1945	9	15	926	181	74	255	2,821	14	2,835	5,600	90,000	46,000	24,727

Grand County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total			
1896-08				572		572			303	4,355	690	$12,657
[1]1909-23	21				65	65	3,568	11	3,579	816	2,855	4,510
[2]1924-31	7	1					774		774		800	610
[3]1932-41	95	1–3	1–9	6	33	39	4,570	1	4,571		8,000	4,959
1942-45	7	1–2					817		817		1,000	648
CRUDE ORE SHIPPED TO SMELTERS												
1909-23	21								3,568	816	2,855	
[2]1924-31	7								774		800	
[5]1932-41	82					5			4,048		7,935	
1942-45	4								540		1,000	
ORE TO GOLD AND SILVER MILLS		Bullion			Concentrates							
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	
1909-23												
1924-31												
[6]1932-41	5		426									
1942-45	3		26						251			
ORE TO CONCENTRATING MILLS												
1909-23												
1924-31												
[7]1932-41	8				1	1			96		65	
1942-45												

[1]No production from 1910 to 1914.
[2]Production in 1925 only.
[3]No production in 1933.
[5]Production only in 1939, 1940, and 1941.
[6]Production in 1934 only.
[7]Production in 1939 only.

Grand County

Placers

Small placer operations are reported on Willow Creek north of Granby and on Red Dirt Creek, a tributary of Muddy Creek several miles northwest of Kremmling during the years 1934 to 1937. Kremmling and Granby are on U. S. 40, and elevations on the streams named are 7,500 to 9,500 feet.

The total placer gold production during this period is reported as less than one ounce of fine gold. Willow Creek and Muddy Creek are tributaries of the Colorado River, and small amounts of placer gold that is very fine have been known for many years to be present in the sand in places along the streams in this general area.

The topographic map of the State of Colorado, scale 1:500,000 and dated 1934 shows the location of the streams referred to.

Arapahoe National Forest Map.

Blue Ridge

T. 1 S., R. 79 W. (See pl. 4.)

Altitude 8,000 to 8,500 feet.

Blue Ridge is at Scholl on Battle Creek 10 miles southwest of Parshall (U. S. 40). Scholl is shown on the State Geologic Map but it is not marked on the Ute Peak Quadrangle Topographic Map. The road from Parshall is fair to poor.

No information is available as to the occurrence of the copper found in this locality. The State Geologic Map shows Miocene Tertiary deposits in this area with pre-Cambrian crystalline rocks a few miles to the south.

No production is reported.

Ute Peak Quad., 1:62,500, contours 50 ft., ed. 1937.

Arapahoe National Forest Map.

White River National Forest Map.

Corral Creek

Corral Creek is listed as Parshall station with no other explanatory data in U. S. Geol. Survey Bull. 507. Parshall is on U. S. 40 about 115 miles west of Denver.

Arapahoe National Forest Map.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 143, 1912.

Grand Lake (Wolverine)

T. 3 N., R. 74 W. (Not shown on pl. 4.)

Altitude 10,000 to 11,000 feet.

This area is 7 miles east of Grand Lake, and probably on East Inlet that flows into Grand Lake from the east. Grand Lake is on State 278 that joins U. S. 34 fourteen miles northeast of Granby (U. S. 40).

The only production recorded from this area is a 25-ton shipment in 1939 of lead-silver-gold ore to the Leadville smelter. U. S. Geol. Survey Bulletin 507 (p. 143) lists gold, copper, silver, and lead, and veins in pre-Cambrian complex.

Rocky Mountain National Park, 1:125,000, contours 100 ft., reprint 1922.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 143, 1912.

La Plata (Williams Fork)

T. 3 S., R. 76 W. (Shown but not named on pl. 4.)

Altitude 9,000 to 12,500 feet.

This La Plata is not to be confused with the better known district by the same name in the San Juan area in southwestern Colorado. The La Plata district in Grand County is at the head of Williams River, and it extends a few miles across the Continental Divide (Jones Pass) into the headwaters of West Fork of Clear Creek in Clear Creek County. (In the adjoining township to the west and 3 miles southeast of Leal there are small scattered veins with the same type of mineralization.)

The headwaters of Williams River are 30 miles from Parshall (U. S. 40) over a fair to poor road along the valley. The head of Clear Creek is 18 miles from Empire and 9 miles on a fair to poor road from U. S. 40. Access is difficult from either direction.

The veins in this area are usually conspicuous iron-stained zones resulting from the oxidation of pyrite localized along fissuring and fault zones. A moderate amount of exploration has been done which has encountered small veins of lead and zinc with silver and some gold in local areas.

Shipment of small lots of silver-lead ore from Bobtail Creek at the head of Williams River are reported in 1935, 1940, 1941, 1942, and 1943.

Fraser Quad., 1:62,500, contours 50 ft., ed. 1926.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Monarch (Harmon)

T. 2 N., R. 74 W. (See pl. 4.)

Altitude 8,250 to 9,000 feet.

Monarch is on State 280, a fair to good road, and about 6 miles from U. S. 34, on Arapahoe Creek, a tributary of the Colorado River. It is about 10 miles northeast of Granby (U. S. 40). Monarch is listed on Plate 1 of U. S. Geol. Survey Professional Paper 138, but Harmon is not mentioned. Harmon is listed in U. S. Geol. Survey Bull. 507 as 12 miles east of Granby, and it is not certain that the two localities are the same. In Bull. 507 Harmon is credited with copper veins in pre-Cambrian rock.

Rocky Mountain National Park, 1:125,000, contours 100 ft., reprint 1922.

Arapahoe National Forest Map.

Roosevelt National Forest Map.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 143, 1912.

Red Gorge

T. 1 S., R. 82 W. (Not shown on pl. 4)

Altitude 7,000 to 7,500 feet.

Red Gorge is near Radium and the eastern part of the Yarmony district in Routt County to which reference should be made for description.

Hoklas, W. I., Steamboat Springs, Colorado, Personal communications.

Gunnison County

Box Canyon

T. 50 N., R. 4 E., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 9,500 to 10,500 feet.

Six miles south of Pitkin, and near U. S. 50 about 25 miles east of Gunnison.

The principal mines in this district are the old Independence and Camp Bird mines 3 to 4 miles on roads with steep grades north of Waunita Hot Springs. Waunita Hot Springs is 4 miles on State 328 from U. S. 50 and 16 miles northwest of Sargents.

Production has been from free-milling small quartz lenses in schist. The Roosevelt tunnel on Quartz Creek and 2½ miles southwest of Pitkin was planned to crosscut under the veins at a depth of about 1,500 ft., but the veins were not recognizable or they were not reached by the tunnel.

Considerable production is claimed for early years.

In recent years production was limited to 1932, 1938, and 1939, and a total of 573 tons were produced that yielded 69 ounces gold and 10 ounces silver.

Pitkin Quad., 1:62,500, contours 50 ft., ed. 1945.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colo.: U. S. Geol. Survey Bull. 380, p. 38, 1909.

Cebolla (Vulcan, Domingo, Powderhorn, White Earth)

T. 47 N., Rs. 1 and 2 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,000 to 9,000 feet.

Gunnison County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1873-08				66,432	242	66,674			4,957,845	538,829	35,849,047	768,912	$7,599,819
1909-23	134,969			40,736	465	41,201	479,709	162	479,871	448,278	6,914,912	18,244,638	3,339,930
1924-31	26,666	5–11	2–10	3,420	30	3,450	175,184	7	175,191	44,963	6,874,594	7,014,600	1,191,163
1932-41	68,444	8–25	3–17	15,928	300	16,228	81,859	75	81,934	26,700	699,800	458,000	680,288
1942-45	24,373	5–8		1,497		1,497	85,916		85,916	72,600	2,632,200	2,570,300	621,120
CRUDE ORE SHIPPED TO SMELTERS													
1909-23	48,114					7,852			341,622	385,423	4,558,097	16,866,952	
1924-31	13,991					1,236			112,583	28,579	4,665,591	4,443,600	
1932-41	3,308					920			38,684	22,010	385,528	247,000	
1942-45	881					287			14,005	356	447,892		
ORE TO GOLD AND SILVER MILLS		Bullion		Concentrates									
		Gold	Silver	Tons		Gold			Silver	Copper	Lead	Zinc	
1909-23	66,722	16,514	9,878										
1924-31	3,879	1,860	2,489	69		135			3,650		20,404		
1932-41	59,744	12,600	9,215	903		1,334			23,399	150	73,035		
[1]1942-45	9,848	599	651	843		232			7,309	10,179	261,816	350,978	
ORE TO CONCENTRATING MILLS													
1909-23	20,133			12,086		16,370			128,209	62,855	2,356,815	1,377,686	
1924-31	8,796			5,073		189			56,462	16,384	2,188,599	2,571,000	
[2]1932-41	5,392			743		1,074			10,561	4,540	241,237	211,000	
1942-45	13,644			4,725		379			63,951	62,065	1,922,492	2,219,322	

[1]No production in 1943.
[2]No production in 1932, 1934, 1935, and 1936.

This area is on Cebolla Creek 15 to 18 miles south of Iola on State 149. Iola is on the D. & R. G. W. Railroad and on U. S. 50, and 15 miles west of Gunnison. Cebolla is a village 7 miles west of Iola. The road into the area is satisfactory during the summer.

The principal production at Vulcan has been gold obtained from a pyrite zone referred to as the vein along the schistosity. Much pyrite has little or no gold content. The gold may be later in age than the pyrite. Small shipments of lead, gold-silver, and copper-gold-silver ores are reported from other veins. The veins are in pre-Cambrian schist and possibly also in Cretaceous sediments. However, a report has not been published as to the possible extent or nature of mineralization.

Iron and manganese deposits in this area have been described but no production is recorded.

Production since 1931 was made only in 1932, 1933, 1934 and 1941 and during these years a total of 75 tons was mined which yielded 55 ounces gold, 208 ounces silver, 100 pounds copper, and 100 pounds lead. The bulk of the ore yielded only gold and silver.

Uncompahgre Quad., 1:125,000, contours 100 ft., ed. 1911.

Gunnison National Forest Map.

Harder, E. C., Manganese deposits of the United States: U. S. Geol. Survey Bull. 427, p. 150, 1910.

Leith, C. K., Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, p. 197, 1906.

Cochetopa (Green Mountain, Gold Basin)

T. 48 N., Rs. 1 and 2 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,000 to 8,500 feet.

This area is 3 to 4 miles south of Parlin and extends from Cochetopa Creek to the west 2 to 4 miles. Parlin is on U. S. 50 east of Gunnison 13 miles. The road from Parlin is fair to poor.

A small production has come from free milling gold in quartz veins locally carrying some copper and possibly tellurium. The rocks are red and grey granite and gneiss of pre-Cambrian age.

Cochetopa (Green Mountain, Gold Basin) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Lead (pounds)	Total Value
1932	1	150	48	10		$ 994
1933	2	58	25	1		524
1934	3	210	117	8		4,081
1939	1	326	26	6		914
1940	3	123	45	66	3,100	1,777
1941	2	7	4	7		145

Gunnison National Forest Map.
Rio Grande National Forest Map.
San Isabel National Forest Map.

Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colo.: U. S. Geol. Survey Bull. 380, pp. 37-38, 1909.

Dorchester (Taylor River)

T. 12 S., R. 84 W. (Not shown on pl. 4.)

Altitude 8,000 to 10,000 feet.

Dorchester is in Taylor Park near the head of Taylor River. The best access to Taylor Park is from Almont on State 135 and 9 miles northeast of Gunnison. The distance from Almont to Dorchester is about 40 miles over a fair road except for the last several miles which are poor. The road is closed during most of the winter.

In the rugged area a few miles west of Dorchester, lead-zinc mineralization occurs in faulted and folded limestone and dolomite which is continuous with the ore-producing formation at Aspen 10 miles to the north. In spite of the fact that exploration and some mining occurred at an early date, published reports on the area are lacking and very little is known about the occurrence of the ore. The rock formations and structural conditions known to occur in the area are not unfavorable for ore deposits. Short summer seasons and distance from a railroad have made development difficult in this as well as in other parts of Taylor Park.

Taylor Park Quad., 1:62,500, contours 50 ft., ed. 1937.

Gunnison National Forest Map.

Elk Mountain

T. 13 S., R. 85 W. (See pl. 4.)

Altitude 9,500 to 11,000 feet.

This area includes the ghost town of Gothic about 22 miles north of Crested Butte and is no longer shown on many maps of recent date. State 327 into the area is a fair road but most of the prospects are 1 to 5 or even 10 miles off the road and can be reached only with difficulty by trail or poor road.

The veins show varying proportions of sphalerite, galena, and chalcopyrite with gold and silver content. The high transportation cost is a discouraging factor in prospecting, particularly for occurrences of zinc and lead.

Mineralization is widespread but the veins are small and irregular. The country rock is Mancos shale with dikes, sills, and laccolithic masses of quartz monzonite.

Crested Butte Quad., 1:62,500, contours 100 ft., ed. 1894.

Gunnison National Forest Map.

Emmons, S. F., Description of the Elk Mountains, (Colo.): U. S. Geol. Survey Geologic Atlas, Anthracite-Crested Butte folio no. 9, 1894.

Vanderwilt, J. W., Personal files.

Gunnison County

Elk Mountain District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932		1			1	1		1	1				$ 26
1933	2	2	1		2	2	116	2	118				89
1934	4	2	61	5	6	11	1,623	3	1,626		2,350		1,544
1935	4	1	520	29	3	32	3,637		3,637		650		3,733
1936	4	2	67	19	2	21	430		430		5,600		1,569
1937	3	3	475	82	4	86	4,269	1	4,270	360	17,400		7,367
1938	2	1	50	3	1	4	167		167		1,300		280
1939	4	3	158	7	2	9	1,093		1,093	18,700	6,900	6,000	3,638
1940	2	1	1		4	4	128	4	132		100		239
1943	1		21	1		1	169		169		2,400	3,400	702
1945	1		2	2		2	232		232				235

Gold Brick

T. 50 N., Rs. 3 and 4 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 10,500 feet.

Ohio City is 13 miles on U. S. 50 and 8 miles on State 162 east of Gunnison, and the Gold Brick district is 4 to 6 miles on a fair road north of Ohio City. The rugged topography makes travel difficult away from the roads.

The principal ore is gold-silver-lead occurring in small though relatively rich veins in the pre-Cambrian granite and schist.

The productive veins are concentrated immediately east of Gold Creek over an area 4 miles long and about 1 mile wide. Numerous mines have produced chiefly gold with some silver, lead, and copper.

Production is characterized by relatively small tonnages of fairly high-grade ore. Development is usually confined to a depth of a few hundred feet except in the Carter mine. The Carter mine has a crosscut tunnel and a long raise connecting with workings first developed through a shaft from surface over 1,500 feet higher in elevation than the tunnel. Nearby sedimentary formations lying on the granite and schist have not been productive.

Pitkin Quad., 1:62,500, contours 50 ft., ed. 1945.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colo.: U. S. Geol. Survey Bull. 380, pp. 22-34, 1909.

Crawford, R. D., and Worcester, P. G., Geology and ore deposits of the Gold Brick district, Colo.: Colorado Geol. Survey Bull. 10, 116 pp., maps, 1916.

Gold Brick District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1932...	3	184	42	39			$ 881
1933...	7	328	203	845	460	6,600	4,766
1934...	10	8,618	2,239	5,012	150	22,450	82,339
1935...	13	4,578	1,985	4,345		22,400	73,502
1936...	5	10,735	2,849	5,326		20,400	104,771
1937...	9	4,948	1,006	4,640	440	33,340	40,825
1938...	6	6,349	791	2,571		9,300	29,782
1939...	6	5,890	1,817	2,581	300	8,700	65,787
1940...	6	11,530	2,324	9,225	400	49,700	90,430
1941...	7	9,297	1,822	7,581		26,400	70,666
1942...	4	7,109	1,317	3,492	600	19,700	49,971

Goose Creek (Madera)

T. 48 N., R. 3 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 7,500 to 8,500 feet.

Madera is on Lake Fork 9 miles southwest of Iola (on U. S. 50 and 12 miles west of Gunnison).

Occasional small shipments of lead-silver and gold-silver-copper ore are recorded from this area. The country rock is pre-Cambrian granite and schist overlain by some of the Potosi-Volcanic series.

Production since 1931 was limited to 1939 and 1940 when 30 tons were shipped that yielded 1 ounce of gold, 178 ounces of silver, 400 pounds of copper, and 1,400 pounds of lead.

Uncompahgre Quad., 1:125,000, contours 100 ft., ed. 1911.

Gunnison National Forest Map.

Uncompahgre National Forest Map.

Quartz Creek

T. 51 N., R. 4 E., New Mexico Principal Meridian. (Not named on pl. 4.)

Altitude 10,000 to 11,500 feet.

Pitkin is 13 miles on U. S. 50 and 13 miles on State 162 east of Gunnison. Quartz Creek is 1 to 4 miles northeast of Pitkin and near the road to Tincup.

Quartz Creek district is the southern end of a mineralized area that includes the Tincup district. This area lies within a wide complex faulted zone that extends northwest to Aspen. Rocks in the area are pre-Cambrian granite and schist. Paleozoic dolomite, and quartz monzonite of Tertiary age. The veins carry chiefly silver-lead and gold. Small molybdenite-bearing quartz veins are present in the pre-Cambrian rocks.

Pitkin Quad., 1:62,500, contours 50 ft., ed. 1945.

Garfield Quad., 1:62,500, contours 50 ft., ed. 1945.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colo.: U. S. Geol. Survey Bull. 380, pp. 34-36, 1909.

Quartz Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Total Value
1934	3	466	137	575	575	50	1,550	$5,231
1935	2	25	1	199	199		750	211
1937	3	343	39	49	49		160	1,424
1938	1	46	6	2,189	2,189	100	7,500	1,980
1941	3	15	3	464	464		2,400	572
1943	1	3		305	305		1,200	307

Gunnison County

Rock Creek (Marble) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode		Lode	Lode	Total				
1933	2	14	4	1,078	1,078		300		$ 459
1934	2	65	3	2,286	2,286		200		1,585
1935	1	3		199	199				157
1937	3	25	3	1,519	1,519		100		1,268
1940	1	32	6	1,412	1,412		200		1,224
1941	3	7	2	862	862		200	1,000	769
1944	2	121	1	464	464	600	11,600	16,200	3,221
1945	1	89		180	180	1,600	6,400	8,600	1,883

Rock Creek (Marble)

Tps. 11 and 12 S., R. 87 W. (See pl. 4.)

Altitude 9,000 to 13,000 feet.

Marble, named after nearby white marble, is on the westerly flank of the Elk Mountains and 40 miles on State 133 south of Glenwood Springs. East of Marble 6 miles is Crystal and the central part of the district. Some highway maps show a road into the area from Gunnison, but the last 5 miles of this road are impassable.

The various mines and prospects, many on trails, are within a radius of 1 to 5 miles and 500 to 2,000 feet higher in altitude, and many are difficult to reach. Crystal and the area as a whole is closed during the winter.

For summary see pages 446-51.

Gunnison National Forest Map.

Vanderwilt, J. W., Geology and mineral deposits of the Snowmass Mountain area, Gunnison County, Colo.: U. S. Geol. Survey Bull. 884, 184 pp., 1937.

Ruby

T. 13 S., R. 87 W. (See pl. 4.)

Altitude 10,000 to 10,500 feet.

The Ruby mine was about 10 miles northwest of Crested Butte and a few miles north of State 135. Access to the area is not difficult.

The Ruby was said to have produced rich ruby silver ore at an early date. The vein, which occurred in Mesaverde (Cretaceous) shale was cut off at a relatively shallow depth and lost on a flat fault. No activity has been reported for many years.

Anthracite Quad., 1:62,500, contours 100 ft., ed. 1894.

Gunnison National Forest Map.

Emmons, S. F., Cross, C. W., and Eldridge, G. H., U. S. Geol. Survey Geologic Atlas, Anthracite-Crested Butte, Colo., folio no. 9, p. 2, 1894.

Spring Creek (Spring Gulch)

T. 14 S., R. 83 W. (See pl. 4.)

Altitude 9,500 to 10,000 feet.

Spring Creek is a narrow canyon that joins Taylor River about 7 miles northeast of Almont on State 306. The road along the creek north from State 306 is narrow and rocky throughout the distance of 6 miles to the Doctor mine, the principal mine in that area.

The Doctor mine produced silver-bearing lead carbonate in 1880 and 1890 and at least 17,000 tons zinc carbonate in 1917 and 1918. Later production has been largely hand-sorted dump ore. The zinc carbonate occurs in narrow replacement bodies that have been mined for several hundred feet in the Leadville (Mississippian) dolomite. The dolomite is much altered. Development has reached a depth of about 200 feet and insufficient work has been done to determine whether the oxidized ore represents the roots of an eroded ore body or whether the lead and zinc carbonate are the oxidized parts of a sulfide ore body as yet undiscovered at depth. Sulfides are conspicuous by their absence in the zinc carbonate and older lead carbonate stopes.

The last recorded production was 641 tons of sorted zinc carbonate from the dump in 1937 and 1938 that yielded 203,000 pounds of zinc and 25,900 pounds of lead.

Taylor Park Quad., 1:62,500, contours 50 ft., ed. 1937.

Gunnison National Forest Map.

Taylor Park

T. 13 S., R. 83 W. (unsurveyed). (Not named on pl. 4.)

Altitude 10,500 to 11,500 feet.

Taylor Park is not a well-defined district. It includes the mines on the southeast and northeast slopes of North Italian Mountain about 6 miles west of Dorchester. Prospects west and north of T. 13 S., R. 83 W., have been referred also to this district. The Forest Hill mine 5 miles southeast of Dorchester also is considered in this area. Access to Dorchester, as described under the district by this name, is not easy. Roads and trails out from Dorchester are poor and difficult.

The geology of the area is complex and has not been described in detail. In the valley the veins are in granite. North Italian Mountain is a part of the Sawtooth Range, the core of which is a Tertiary intrusive stock flanked by Paleozoic dolomite in which lead-zinc veins and replacement has occurred. Gold and silver are important locally. Faults are numerous; the Castle Creek fault of Aspen, Colorado, extends into this area.

Taylor Park Quad., 1:62,500, contours 50 ft., ed. 1937.

Gunnison National Forest Map.

San Isabel National Forest Map.

Tincup

T. 15 S., R. 81 W. (See pl. 4.)

Altitude 10,000 to 12,000 feet.

The Tincup district is at the head of Willow Creek, a tributary of Taylor River, and on the extreme southeast side of Taylor Park. The post office of Tincup, shown on most maps, is about 15 miles north of Pitkin on State 162 and 26 miles east of Gunnison. Cumberland Pass between Pitkin and Tincup is a little over 12,000 feet above sea level. The road is fair during the summer but impassable for several months during the winter.

The formations include pre-Cambrian crystalline and Paleozoic sedimentary rocks intruded by dikes and sills. These formations are similar to those occurring in the Leadville and Aspen mining districts except for the Fremont limestone and Harding quartzite found in the Tincup district below the Parting member at the base of the Devonian.

Gunnison County

Taylor Park District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	2	5	7	4	11	15	4	2	6				$ 301
1933		7			61	61		13	13				1,273
1934	2	15	8	7	89	95	14	22	36				3,345
1935	3	12	48	1	37	38	526	7	533		7,000		1,995
1936		13			34	34		9	9				1,197
1937	1	3	15	1	18	19	172	4	176				783
[1]1938	1	3	40	4	5	9							308
[1]1939		5			9	9		3	3				317
[1]1940	3	2	477	40	6	46	2,897	3	2,900	100	94,300	87,000	13,879
[1]1941	3		219	38		38	4,095		4,095	2,900	58,400	28,000	10,013
1942	2		133	2		2	3,774		3,774	2,000	66,300	8,400	8,219
1943	2		219	2		2	3,136		3,136	500	67,800	16,000	9,243
1944	2		144	1		1	2,689		2,689		80,800		8,411
1945	2		267	1		1	4,583		4,583		233,000		23,332

[1]Includes Tincup district, Gunnison County.

The sedimentary formations trend northwesterly and dip 10°-35° N. E. On the east side of the district the beds are cut off by the Tincup fault, a strong thrust fault that strikes rough parallel with the bedding but dips only about 10° N.E. Other faults are present at the southwestern edge of the main district.

The important ore deposits have been silver-lead-gold "blanket" deposits and silver-lead-gold veins. Quartz veins with spotty molybdenite and some hubnerite were worked for molybdenite during the World War in 1917 and 1918. Production was small, and it is doubtful that profitable mining would be possible at the present market price of molybdenum.

The blanket deposits occur at limestone and dolomite contacts and the ore bodies cut off at faults. The veins cut all formations including the pre-Cambrian, but the chief ore bodies were in limestone and dolomite. In places oxidized ores were mined.

The total production from 1901 to 1935 was 1,438 tons of ore that yielded 298 ounces of gold, 26,446 ounces of silver, 177 pounds of copper and 153,820 pounds of lead. Half of the tonnage came from one mine and the balance from seven mines. Production since 1932 has not been large but the amount is not known because for several years it apparently was included with other small production from Taylor Park.

The outlook for the district as summed up by Goddard whose report is the basis for the above data is as follows:

"The ore deposits of the Tincup district are very similar in character and composition to those of the Leadville and Aspen districts, 25 to 30 miles to the north. In each of these districts the chief production has come from lead-silver blanket deposits that occur along certain bedding planes in the Paleozoic sediments at their contact with prominent pre-ore faults. The chief difference between the Tincup district and the larger districts is in the extent and amount of faulting. In the Leadville and Aspen districts there are networks of strong pre-ore faults, which are of great extent and in many places form wide broken zones. These faults furnished large trunk channels for the free circulation of the ore solutions and were undoubtedly important factors in the concentration of ore in large bodies. In the Tincup district the faults and fractures in general are of small extent and displacement and do not appear to form any extensive network. Thus the circulation of ore solutions was confined to narrow channels, and the resulting deposits were small compared with those of the Leadville and Aspen districts. Because of this difference in structural conditions it seems probable that the Tincup district will always be a small district and that there is little possibility of finding ore bodies much larger than those already exploited.

"However, there is a distinct possibility of finding new ore bodies in the Tincup district comparable to those already exploited. In some of the larger mines, such as the Gold Cup and the Tincup group, there has apparently been no exploration of the lower potential ore horizons. It is possible that ore may have been formed at some of these lower horizons along the fault fissures that influenced the formation of ore bodies at the upper horizons. There is also the possibility of finding new ore bodies at favorable horizons along fault fissures that have remained undiscovered or have not shown evidence of being associated with ore bodies. The West Gold Hill ore body apparently showed no surface indication of its existence and the faults with which it was associated were apparently inconspicuous. It is probable that a careful survey of the district will uncover numerous pre-ore fault fissures which at present are unknown or little understood but which may be associated with ore bodies at favorable horizons beneath the surface. Thus future exploration in the Tincup district may be carried on along two lines—(1) exploration of lower favorable horizons along fault fissures known to be associated with ore bodies in upper horizons; (2) exploration for additional pre-ore fault fissures and along known fissures that show no surface indication of ore but may contain ore at favorable horizons at depth. In this exploration diamond drilling and geophysical prospecting would undoubtedly be of considerable aid.

"The future possibilities of the molybdenum-tungsten veins depend largely on metallurgical treatment and on market conditions. The tungsten minerals in these veins seem to be scarce, but molybdenite is consistently present. There seem to be numerous molybdenum veins on the western part of the crest of Gold Hill that as yet have been little explored. Also these veins appear to occupy some of the most extensive fault fissures in the district. If the mining and metallurgical problems could be worked out so as to compete against other producers the Tincup deposits could produce an important quantity of molybdenum."

A small production is recorded for 1932 and 1933. Production for the years 1934 through 1941 and possibly later years is included with Taylor Park.

Garfield Quad., 1:62,500, contours 50 ft., ed. 1945.

Pitkin Quad., 1:62,500, contours 50 ft., ed. 1945.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Goddard, E. N., The geology and ore deposits of the Tincup mining district, Gunnison County, Colo.: Colorado Sci. Soc. Proc., vol. 13, no. 10, pp. 552-595, 1936.

Tomichi (Whitepine)

T. 50 N., R. 5 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,000 to 11,000 feet.

Whitepine is about 10 miles on a fair road north of Sargents. Little trace remains of the old mining camp of Tomichi. The

Gunnison County

Tomichi (Whitepine) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1933	2	302	3	4,577	840	156,000	60,000	$ 10,013
1934	1	79		1,064	300	31,450	33,000	3,309
1935	2	72	3	1,142		36,000		2,352
1937	2	18	2	468	200	3,000		619
1939	1	20		451				306
1940	1	14		360	900	3,600		538
1941	1	92	2	803		32,600	35,000	5,124
1942	2	380	3	1,866	1,000	100,200	108,900	18,394
1943	1	3,941	40	21,597	15,500	567,600	686,000	135,431
1944	2	5,768	67	21,223	32,400	745,600	861,800	179,704
1945	2	6,176	60	22,206	18,400	729,600	860,400	182,067

district is immediately northeast of Whitepine and on the east slope of Tomichi Creek. Sargents is on U. S. 50 and 34 miles east of Gunnison.

The ore deposits are classified as : 1, replacement ores in limestone and dolomite; 2, contact deposits and 3, fissure veins. Some bog iron ore also is present. Although indications are that the continuity of most of the ore shoots is limited, the thick strata of easily replaceable limestone, comparable to Leadville and Aspen districts, connected by faults with a quartz monzonite provides conditions favorable for deposition of metallic minerals. The principal values are in lead, silver, and zinc. Gold is important locally and some copper is present. The iron ores have not been commercial grade.

Garfield Quad., 1:62,500, contours 50 ft., ed. 1945.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Crawford, R. D., Geology and ore deposits of the Monarch and Tomichi districts, Colo.: Colorado Geol. Survey Bull. 4, 1913.

Harder, E. C., The Taylor Peak and Whitepine iron ore deposits, Colo.: U. S. Geol. Survey Bull. 380, pp. 188-198, 1909.

Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colo.: U. S. Geol. Survey Bull. 380, pp. 21-40, 1909.

Leith, C. K., Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, pp. 196-198, 1906.

Hinsdale County

The mining districts of Hinsdale County are concentrated in the area southwest of Lake City between Lake Fork and its tributary, Henson Creek. The several districts, although listed and described separately, have much in common as to geology and ore occurrence. The districts are in the heart of the rugged San Juan Moutains with unsurpassed scenery. However, access is so difficult that prospecting and development are seriously handicapped. Future discoveries of ore comparable to the past are likely as soon as economic conditions are favorable. Zinc and lead production is a possibility if prices become stable at a reasonable level.

Burrows Park (Whitecross)

T. 43 N., R. 5 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,500 to 12,000 feet.

Whitecross is on State 351 near the head of Lake Fork of Gunnison River and about 12 miles by road southwest of Lake City, and centrally located in the White Cross district. Lake City is on State 149 and 54 miles southwest of Gunnison. The road to Whitecross is fair, but the region is famous for its rugged topography and areas off the road are difficult to reach.

Hinsdale County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)		Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Lode	Total	Lode	Total				
1875-08....				67,374	67,374	5,263,361	5,263,361	1,421,395	93,054,779	984,245	$9,715,102
1909-23....	31,009			2,869	2,869	415,332	415,332	1,442,678	4,222,580	119,789	799,820
1924-31....	6,538	2–16		386	386	57,864	57,864	42,767	1,018,840	179,600	143,371
1932-41....	4,889	1–6		451	451	23,633	23,633	32,100	378,100	24,000	55,118
1942-45....	14,143	1–3		69	69	18,408	18,408	20,900	800,600	47,000	81,654
CRUDE ORE SHIPPED TO SMELTERS											
1909-23....	9,688				2,278		363,605	1,363,195	1,543,939	32,167	
1924-31....	1,350				199		29,367	15,701	648,231	22,000	
1932-41....	281				287		6,742	4,475	28,909		
[4]1942-45....	13				2		522	3,200			
ORE TO GOLD AND SILVER MILLS											
		Bullion		Concentrates							
		Gold	Silver	Tons	Gold		Silver	Copper	Lead	Zinc	
1909-23....		92	75								
[1]1924-31....	9	17	7								
[2]1932-41....	15	89	26								
1942-45....											
ORE TO CONCENTRATING MILLS											
1909-23....	21,321			3,610	499		51,652	79,483	2,678,641	87,622	
1924-31....	5,179			637	170		28,490	27,066	370,609	157,600	
[3]1932-41....	4,593			491	75		16,865	27,625	349,191	24,000	
1942-45....	14,130			798	67		17,886	17,700	800,600	47,000	

[1]Production in 1931 only.
[2]Production in 1932 and 1935 only.
[3]No production in 1932, 1933, 1934, and 1936.
[4]Production in 1942 only.

The region has been termed a geological extension of the Silverton mining area that lies 14 miles to the southwest on the Animas River in San Juan County. The road or trail into Animas River Valley is over Cinnamon Pass (altitude 12,600 feet) about 3 miles west of Whitecross.

The district is in an area of interbedded tuffs and flows of Tertiary age with an inlier of pre-Cambrian granite in its central part. Most of the contacts between volcanics and granite are faults. Faults also extend into both kinds of rock. The faults contain the ore deposits.

The veins are filled fissures grading into replacement types. The ore consists of 3 kinds: Chalcopyrite ore, sphalerite-galena ore, and gold-silver ore with small amounts of lead and zinc.

The ore shoots that have been described are small and irregular, but in spite of this the area produced considerable ore. A handicap of the area is distance from market and severe winter weather.

For a summary of the general geology and ore deposits of the Silverton area, with selected bibliography, refer to pages 431-37.

San Cristobal Quad., 1:125,000, contours 100 ft., ed. 1907.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Juan National Forest Map.

Brown, W. H., The mineral zones of the White Cross district and neighboring deposits in Hinsdale County, Colorado: Colorado School of Mines Mag., vol. 15, no. 11, pp. 5-15, March 1926.

Woolsey, L. H., Lake Fork extension of the Silverton mining area, Colo.: U. S. Geol. Survey Bull. 315, pp. 26-30, 1907.

Carson

T. 42 N., R. 5 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 11,500 to 12,500 feet.

Carson is at the head of Wager Gulch, a tributary of Lake Fork of the Gunnison River and about 18 miles southwest of Lake City. Reference should be made to Burrows Park for access to Lake Fork of the Gunnison River for reaching the mouth of Wager Creek. The road along Wager Creek rises 1,800 feet in about three miles. Access and working conditions are difficult.

Mineralization extends south across the divide at the head of Wager Creek and into the head of Lost Trail Creek, a tributary of the Rio Grande River.

The general geology and nature of the veins are probably comparable to the other mining districts in Hinsdale County. The reference given merely lists a few mines at Carson that produced $3,000 to $27,000, but the mines are not described.

The region is one of Tertiary volcanic rocks with the underlying volcanic rocks exposed along the valley of Lake Fork.

Mineralization is confined to the Carson volcanic center where zones of mineralized and decomposed porphyry are numerous along irregular gashes and fractures that are not generally continuous for more than a few hundred feet. Ore minerals occur in partly filled cracks and openings in the decomposed zones. The ore varies in thickness from a few inches to about 18 inches. Ore bodies lack continuity. The chief values are in silver and lead with copper, some gold, and a little zinc. The chief gangue mineral is barite.

The ore is said to be high-grade, averaging as much as $50 to $500 per ton and an early production of about $200,000 is claimed.

San Cristobal Quad., 1:125,000, contours 100 ft., ed. 1907.

Gunnison National Forest Map.

Rio Grande National Forest Map.

San Juan National Forest Map.

Uncompahgre National Forest Map.

Irving, J. D., and Bancroft, H., Geology and ore deposits near Lake City, Colo.: U. S. Geol. Survey Bull. 478, p. 17, 1911.

Larson, E. S., The economic geology of Carson camp, Hinsdale County, Colo.: U. S. Geol. Survey Bull. 470, pp. 30-38, 1911.

Galena (Henson Creek)

T. 44 N., Rs. 4, 5, and 6 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,600 to 12,000 feet.

Henson Creek flowing from the west joins Lake Fork of Gunnison River at Lake City. Lake City is 54 miles on State 149 southwest of Grand Junction.

The road along Henson Creek is fair to good, but as the ridges on either side of the valley rise 2,000 to 3,000 feet above the stream, areas away from the road are accessible only with difficulty. The productive mines are close to Henson Creek.

The district is in the volcanic area of the San Juan Mountains. The ore occurs in fissure veins containing lead-zinc ores with subordinate gold and chalcopyrite; lead-silver-zinc ore with considerable chalopyrite; and gold telluride with silver in which the other metals are subordinate. The ore bodies have been characterized by extreme richness on the one hand and mediocre grades on the other. It is reasonable to conclude that ore comparable to that mined in the past remains hidden in the rugged almost inaccessible parts of the general region.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 439-43.

Lake City Quad., 1:62,250, contours 100 ft., ed. 1905.

Uncompahgre National Forest Map.

Irving, J. D., and Bancroft, H., Geology and ore deposits near Lake City, Colo.: U. S. Geol. Survey Bull. 478, pp. 72-99, 1911.

Hinsdale County

Galena (Henson Creek) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode		Lode	Lode	Total				
1932	1	6		78	78		2,000		$ 89
1934	1	7		577	577		500		399
1935	2	77	1	843	843	400	1,550		741
1938	3	1,183	25	4,908	4,908	5,850	137,000	6,000	11,225
1939	2	1,003	9	2,572	2,572	3,000	62,000	4,000	5,495
1940	4	943	8	3,019	3,019	3,600	79,200	1,000	6,857
1941	3	623	13	1,776	1,776	12,000	11,000		3,761
1942	2	3,680	26	6,608	6,608	5,800	295,600		26,116
1943	1	8,250	34	9,329	9,329	9,700	381,000	33,000	41,224
1944	1	2,200	7	1,949	1,949	2,200	124,000	14,000	13,444

Hinsdale County

Lake Fork (Lake San Cristobal) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	1	14	69	21	21				$1,428
1935	2	20	144	149	149	600	1,650		5,265
1938	1	100	2	588	588	650	4,000		698
1939	1	63	47	77	77				1,697
1940	2	43	11	827	827		1,800	8,000	1,567
1941	2	84	7	4,410	4,410	3,000	4,000		3,963
1942	1	5		190	190	200			159
1945	1	8	2	332	332	3,000			711

Lake Fork (Lake San Cristobal)

T. 43 N., R. 4 W., New Mexico Principal Meridian. (Shown but not named on pl. 4.)

Altitude 9,000 to 11,000 feet.

This district is at the north end of Lake San Cristobal and about 5 miles south of Lake City. This area is well-known because of the Golden Fleece mine that produced high-grade gold telluride ore.

Access and geologic features are the same as for the Galena district also in Hinsdale County to which reference can be made for details.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 439-43.

San Cristobal Quad., 1:125,000, contours 100 ft. ed. 1907.

Gunnison National Forest Map.

Uncompahgre National Forest Map.

Irving, J. D., and Bancroft, H., Geology and ore deposits near Lake City, Colo.: U. S. Geol. Survey Bull. 478, pp. 99-123, 1911.

Park (Sherman)

Sherman is on State 351 on Lake Fork of Gunnison River 4 miles southeast of Whitecross (Burrows Park), also in Hinsdale County, to which reference should be made for access and other data.

The general geologic conditions at Sherman are the same as at Burrows Park.

The principal values produced are gold and silver. High transportation costs are a handicap for shipping other metals.

Huerfano County

La Veta

T. 30 S., R. 68 W. (Not shown on pl. 4.)

Altitude 7,000 to 10,000 feet.

La Veta is 16 miles, 11 miles on U. S. 160 and 5 miles on a surfaced road (State 111), southwest of Walsenburg.

The occurrence of gold and silver is described in Folio 71 as confined to West Spanish Peak immediately south of La Veta. The core of West Spanish Peak is augite-diorite of Tertiary age, and East Spanish Peak about 4 miles to the northeast has a core of granite porphyry of the same age.

Wahatoya (Guajotoyan) Creek, which joins the Cucharas River just east of La Veta, shows a little placer gold. On the east side of West Spanish Peak, the several tributaries of the Apishapa River in Las Animas County also show placer gold. The source of this gold has not been determined.

The lodes contain silver associated with galena, gray copper, chalcopyrite, sphalerite, and siderite. Quartz, calcite and barite are present. Veinlets have been found in the augite-diorite of the mountain, but the richest veins occur in the surrounding zone of metamorphosed sedimentary rocks.

Other intrusive centers similar to those of Spanish Peaks are known to occur in and on the east side of the Sangre de Cristo Mountains several miles northwest of La Veta where comparable occurrences of gold and silver are to be expected, and no information is available regarding reported prospects in these areas.

The total production prior to 1908 was 168 ounces of gold, 1,176 ounces of silver, 92 pounds of copper, and 1,067 pounds of lead. In 1932 and 1934 a few ounces of placer gold were produced.

Walsenburg Quad., 1:125,000, contours 25, 50, & 100 ft., ed. 1892.

San Isabel National Forest Map.

Hills, R. C., Description of the Spanish Peaks quadrangle, Colo.: U. S. Geol. Survey Geologic Atlas Spanish Peaks folio no. 71, p. 7, maps, 1901.

Malachite (Huerfano)

T. 26 S., R. 70 W. (Not shown on pl. 4.)

Altitude 7,300 to 7,800 feet.

This district is in the Sangre de Cristo Mountains on the Huerfano River about 5 miles southwest of Gardner. Gardner is 29 miles west of Walsenburg on State 69 and 150.

In U. S. Geol Survey Bull. 507 the deposits are listed as disseminated copper-silver in Paleozoic Red Beds. The State Geologic Map shows Paleozoic and Cretaceous formations in the general area.

No production is recorded from the area.

Huerfano Quad., 1:125,000, contours 25, 50 & 100 ft., ed. 1892.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Hill, J. M., The mining districts of the western United States: U. S. Geol. Survey Bull. 507, p. 146, maps, 1912.

Jackson County

Jackson County is virtually coextensive with North Park which has important coal and oil deposits. The metalliferous deposits have not been regarded as important and very little is known about them. In addition to the districts listed, several "abandoned mines" are shown on the geologic map (plate II) that accompanies Bull. 596 referred to under Teller and other mining districts.

Prior to 1906 production is combined with that of Larimer County but the totals are small. From 1909 to 1917 the production was 229 tons of lode ore that yielded 19 ounces of gold, 591 ounces of silver, and 23,723 pounds of copper. Since 1931 only placer gold was produced from the Independence Mountain area.

Jackson County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Total Value
1932	1	3	$ 67
1933	2	5	100
1934	3	9	326
1935	7	19	650
1937	1	5	175
1938	1	1	42
1939	1	2	70
1940	1	9	315

Independence Mountain

T. 11 N., R. 81 W. (Not shown on pl. 4)

Altitude 8,500 to 9,000 feet.

Placer gold is reported on Independence Mountain 6 to 8 miles northwest of Northgate on State 125. Maps do not show roads into this area, but the mountain slopes are rugged. Water is not plentiful.

Early operations (prior to 1915) found less gold than was anticipated and the project was abandoned as unprofitable.

Independence Mountain is a granite area bounded on the south by faulted Tertiary sedimentary rocks.

Plate II, Bull. 596. (See reference below).

Routt National Forest Map.

Beekly, A. L., Geology and coal resources of North Park, Colo.: U. S. Geol. Survey Bull. 596, p. 117, pl. II, 1915.

Pearl

T. 12 N., Rs. 81 and 82 W. (See pl. 4.)

Altitude 8,500 feet.

Pearl is about 18 miles northwest of Cowdrey on State 125. The road from Cowdrey to Pearl is unimproved and fair to poor.

The country rock is pre-Cambrian granite, cut by small dikes of pegmatite, and larger independent masses of hornblende gneiss.

The ore minerals encountered in prospects are chalcopyrite and dark sphalerite. Gold and silver are present locally. These minerals occur in small irregular veins that parallel the schistosity or in vein-like masses formed by segregation accompanying the general metamorphism which produced the banding of the country rock. Veins also cross the banding of the rock. Beekly describes intermittent prospecting along the crystalline rocks of Independence Mountain and eastward fully 10 miles from Pearl, but the character of mineralization probably changes from place to place as is suggested by the presence of some placer gold on the south side of Independence Mountain.

No production is recorded.

Hahn's Peak Quad. 1:125,000, contours 100 ft., ed. 1913.

Routt National Forest Map.

Beekly, A. L., Geology and coal resources of North Park, Colo.: U. S. Geol. Survey Bull. 596, p. 117, pl. II, 1915.
Spencer, A. C., Reconnaissance examination of the copper deposits at Pearl, Colo.: U. S. Geol. Survey Bull. 213, pp. 163-169, 1903.

Rand

T. 6 N., R. 78 W. (Not shown on pl. 4.)

Altitude 8,500 feet.

Rand Post Office on State 125 is 23 miles south of Walden.

Though listed in Professional Paper 138 there is no further data on mineral deposits of the area. Tertiary sedimentary formations underlie the region. Beekly in U. S. Geol. Survey Bull. 596 mentions various old mining areas in North Park, but Rand is not included.

Plate XII, U. S. Geol. Survey Bull. 596, 1915, shows the geology but not the topography of the area.

Arapahoe National Forest Map.

Routt National Forest Map.

Teller

T. 5 N., R. 77 W. (Not shown on pl. 4.)

Altitude 9,000 to 10,000 feet.

Teller is on Jack Creek 9 miles southeast of Rand, and Rand is 23 miles on State 125 south of Walden. The road from Rand to Teller is not shown on regular highway maps, and local inquiries are recommended as the general area is mountainous.

The mining camp was active in the early eighties. The country rock is pre-Cambrian granite or schist, and the ore is described as rich in silver and copper, though small in quantity. Mention is made of the possibility of very low-grade ore, some of which may be mined profitably in the future with improved transportation facilities. Records of early production, if any, are lacking.

Plate XII of Bull. 596 listed below shows the geology but not the topography.

Arapahoe National Forest Map.

Routt National Forest Map.

Beekly, A. L., Geology and coal resources of North Park, Colo.: U. S. Geol. Survey Bull. 596, p. 117, pl. II, 1915.

Jefferson County

Evergreen

T. 5 S., R. 71 W. (See pl. 4.)

Altitude 7,000 to 7,500 feet.

Evergreen is on State 74 and 12 miles west of Morrison.

Evergreen is an important recreational center in the Rocky Mountain Parks system rather than a mining district. In Bull. 507 Evergreen is listed with Malachite, but Professional Paper 138 lists it separately.

Copper related to basic schists extends to Evergreen as described under Malachite, but no production is recorded from the Evergreen area.

A very different deposit, the Agusta Lode, occurs on Cub Creek, half a mile above Evergreen. The ore of the Agusta Lode is a quartz-fluorite vein in red granite. The ore minerals are yellow sphalerite and chalcocite and limited quantities were shipped for their copper and silver content.

Two shipments are reported from this area in 1943 described as containing gold, silver, copper, lead, and zinc. The grade of the ore is not reported.

Denver Mountain Parks, 1:62,500, contours 100 ft., ed. 1924.

Arapahoe National Forest Map.

Pike National Forest Map.

Lindgren, Waldemar, Notes on copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, p. 170, 1908.

Golden placers

T. 3 S., Rs. 69 and 70 W. (See pl. 4.)

Altitude 5,200 to 5,700 feet.

Placer gold along Clear Creek has been known for many years. East of Golden the gold is fine and production has been small. In recent years sand and gravel plants have been recovering a little gold as a by-product.

Immediately west of Golden the canyon is narrow which limits the yardage of gravel. A traction dry-land dredge operated from 1935-1937 on Clear Creek several miles west of Golden.

Geophysical studies have been made of a part of the placers on Clear Creek.

The combined lode and placer gold production for the county prior to 1918 was only 1,585 ounces, indicating that placer operation was not large up to 1918. The placer gold shown in the following table is total county production, most of which came from the placers along Clear Creek.

Golden Quad., 7½-minute Series, 1:31,680, contours 10 ft., ed. 1944.

Arvada Quad., 7½-minute Series, 1:31,680, contours 10 ft., ed. 1944.

Roosevelt National Forest Map.

Wantland, Dart., A comparison of the geophysical surveys and the results of operations at the Roscoe placer of the Humphreys Gold Corporation, Jefferson County, Colo.: Colorado School of Mines Quart., vol. 32, no. 1 pp. 85-115, 1937.

Jefferson County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
Total 1885-1908..					1,585	1,585			7,049	19,695	10,863		$ 70,400
Total 1909-1918..			24	1		1	9		9	1,000			272
1931..		1			2	2							33
Total 1924-1931..		1			2	2							33
1932..		5			12	12							240
1933..		6			354	354		51	51				7,329
1934..		48			2,562	2,562		388	388				89,797
1935..		48			4,623	4,623		640	640				162,270
1936..		34			106	106		22	22				3,734
1937..		32			90	90		20	20				3,151
1938..		35			72	72		14	14				2,522
1939..		58			154	154		31	31				5,411
1940..	1	47	1,764	93	147	240	1,149	31	1,180	114,000			22,121
1941..	1	26	4,624	151	428	579	1,959	80	2,039	192,000			44,371
Total 1932-1941..	2	5–58	6,388	244	8,547	8,791	3,108	1,277	4,385	306,000			340,946
1942..		7			432	432		73	73				15,172
1943..	1	4	14	1	137	138	31	24	55	500	200	2,000	5,165
1944..		2			6	6		1	1				211
1945..		5			55	55		14	14				1,935
Total 1942-1945..	1	2–7	14	1	630	631	31	112	143	500	200	2,000	22,483

Malachite

T. 4 S., R. 70 W. (Shown but not named on pl. 4.)

Altitude 7,000 feet.

The Malachite mine is on the divide between Bear Creek and Mount Vernon Canyon and about 3 miles west of Morrison. The mine can be reached by following State 74 west from Morrison about 2 miles to Starbuck and thence north 1½ miles over a secondary road with steep grades. Access also is possible from Mt. Vernon Canyon.

The Malachite mine produced a small quantity of copper ore in the eighties and it has attracted some attention during each period that copper prices were relatively high.

The Front Range in this area is pre-Cambrian granite with much gneiss and schist. Copper mineralization is found in or near a zone of amphibolite that extends from 2 or more miles south to 5 miles northwest of Evergreen. The sulfides are regarded as pre-Cambrian age. Somewhat similar mineral occurrences, some of which contain nickel, are found still farther north and south along the Front Range.

The ore in the Malachite mine is massive chalcopyrite with dark sphalerite, and pyrrhotite. The gangue minerals are feldspar (labradorite) and augite partly altered with hornblende. The ore body is an irregular vein-like lenticular mass probably paralleling the schistosity of the enclosing amphibolite rock.

The deposit was diamond drilled in 1942, but the results of the drilling have not been made public.

The only reported lode production is from this area, and the county production for 1940 and 1941 shows a total of 6,388 tons of ore shipped that yielded 3,100 ounces of silver, and 306,000 pounds of copper. A few tons of similar ore were shipped in 1943.

Denver Mountain Parks, 1:62,500, contours 100 ft., ed. 1924.

Arapahoe National Forest Map.

Lindgren, Waldemar, Notes on copper deposits in Chaffee, Fremont, and Jefferson Counties, Colo.: U. S. Geol. Survey Bull. 340, pp. 167-170, 1907.

Lake County

Alicante (Birdseye)

T. 8 S., R. 79 W. (Shown but not named on pl. 4.)

Altitude 10,500 to 11,500 feet.

This area is in the valley of the Arkansas River 10 to 12 miles north of Leadville. State 91 follows the valley and is not over 1 to 3 miles from the prospects in the area.

The north part of the area is about 1 mile southeast of Climax, where small veins with gold, lead, silver, and zinc occur in pre-Cambrian granite on both sides of the valley. A small production is reported.

Birdseye, 4 miles farther south, is on the east side of the Arkansas Valley, and covers the drainage area of Birdseye

Lake County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total				
1859-08.....				1,411,001	298,302	1,709,303			195,248,190	68,468,798	16,661,138,057	471,343,280	$306,954,537
1909-23.....	5,337,920			736,112	30,616	766,728	35,225,150	9,147	35,234,297	31,631,034	259,150,068	763,574,754	118,830,013
1924-31.....	1,142,291	29–55	2–6	128,691	3,516	132,207	4,007,628	1,076	4,008,704	1,509,757	92,929,236	47,907,000	20,908,315
1932-41.....	815,964	18–82	11–35	121,043	12,559	133,602	1,004,563	3,270	1,007,833	501,400	20,595,200	11,571,000	6,776,276
1942-45.....	1,984,104	24–29	3	86,220	31	86,251	1,537,183	10	1,537,183	1,107,300	38,142,700	48,517,000	12,572,295
CRUDE ORE SHIPPED TO SMELTERS													
1909-23.....	4,317,140					674,328			32,188,561	31,215,853	181,538,618	497,397,186	
1924-31.....	703,247					78,651			3,074,647	1,114,934	63,144,975	61,792,000	
1932-41.....	216,355					75,115			725,749	278,264	16,563,586	9,137,519	
1942-45.....	74,235					8,746			253,259	83,698	6,338,198	124,149	
ORE TO GOLD AND SILVER MILLS													
		Bullion			Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23.....	41,404	37,800	11,506										
1924-31.....	17,426	32,721	31,940		215	54			698	1,600	48,984	67,000	
1932-41.....	392,565	18,268	28,014		12,951	14,809			110,317	143,448	1,033,804	9,000	
1942-45.....	1,515,104	20,760	35,508		54,564	20,218			731,907	711,517	9,144,763	18,101,098	
ORE TO CONCENTRATING MILLS													
1909-23.....	979,376				714,410	23,984			3,025,083	415,181	77,611,450	266,177,568	
1924-31.....	421,618				154,259	17,265			900,343	393,223	29,735,277	86,048,000	
[1]1932-41.....	207,044				15,516	12,851			139,983	79,688	2,997,810	2,424,481	
1942-45.....	394,765				62,114	36,496			516,499	312,085	22,659,739	30,291,753	

[1]No production in 1932, 1933, and 1934.

Gulch, where occurrences of gold are reported; the nearby projected intersection of the Mosquito Fault and the London Fault add interest to the area.

A small production of high-grade gold ore is reported as having been mined in early days from Little Corinne mine near the top of Mosquito Range a short distance south of the intersection of the two faults. A few tons of gold-silver-lead silver ore shipped in 1935 is the only production reported in recent years.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Pike National Forest Map.

San Isabel Forest Map.

White River National Forest Map.

Box Creek

T. 10 S., R. 80 W. (Shown but not named on pl. 4.)

Altitude 9,400 to 9,700 feet.

Box Creek joins Herrington Creek, a tributary of the Arkansas River, one mile west of Hayden Ranch. Hayden Ranch is on U. S. 24 about 10 miles south of Leadville.

During the interval from 1916 to 1924 a bucket dredge operated successfully and continuously in Box Creek Valley, beginning about a mile west of its junction with the Arkansas River and thence for a distance of about 1½ miles up the valley. This was known as the Derry Dredge listed in the Bureau of Mines records. Since that time, a land dredge has operated intermittently. These operations probably accounted for practically all placer production in Lake County since 1916.

Mt. Elbert Quad., 1:62,500, contours 50 ft., ed. 1939.

Leadville Quad., 1:125,000, contours 50 ft., ed. 1891.

Gunnison National Forest Map.

San Isabel National Forest Map.

White River National Forest Map.

Buckeye Gulch

T. 8 S., R. 79 W. (Not shown on pl. 4.)

Altitude 10,500 to 11,000 feet.

Buckeye Gulch is a tributary on the west side of the Arkansas River about 6 miles north of Leadville. State 24 follows the valley. Access is relatively easy, only to the lower part of the gulch.

Small sluicing operations have been conducted in the gulch for many years. The quantity of gold produced is not known.

Small veins with gold are reported near the head of the gulch in the Pennsylvanian sedimentary rocks, but no lode production is recorded.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Lake County

Granite District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total	
1932	1	1	5	20	2	22	7		7	$ 455
1933	2	3	47	62	12	74	66	2	68	1,552
1934	2	2	44	85	7	92	6		6	3,219
1935	1	7	34	54	21	75	32	3	35	2,659

Colorado Creek (Gulch)

T. 9 S., R. 81 W. (Not shown on pl. 4.)

Altitude 10,000 to 11,000 feet.

Access roads are the same as in the St. Kevin-Sugar Loaf district.

Colorado Creek or Gulch is the south boundary of the Sugar Loaf district. The gravels of the stream were worked for placer gold at an early date.

Sugar Loaf-St. Kevin Mining District, 1:24,000, contours 50 ft., surveyed 1930.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

San Isabel National Forest Map.

White River National Forest Map.

Granite

A small part of the Granite district extends into Lake County. For descriptions see Granite in Chaffee County.

Homestake

T. 9 S., R. 81 W. (Not shown on pl. 4.)

Altitude 9,500 to 12,000 feet.

This area is at the head of the west branch of the Tennessee fork of the Arkansas River near Homestake Peak. Although only 12 miles west of Leadville, access to the area is difficult as 6 miles are over steep trails.

Small veins with gold and silver occur in the pre-Cambrian crystalline rocks. Similar veins are reported west of the divide near the head of both the Frying Pan drainage to the west and the Eagle River drainage to the north.

It is probable that this district extends across the Divide into Eagle County and covers the area around Gold Park. See Leadville Quadrangle map.

The principal production is from the Homestake mine which at an early date produced high-grade lead-silver ore. The vein was unusual in the fact that it contains a small quantity of nickel sulfide.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

San Isabel National Forest Map.

White River National Forest Map.

Henderson, C. W., Mining in Colorado, a history of discovery, development, and production: U. S. Geol. Survey Prof. Paper 138, p. 134, 1926.

Leadville (California, Evans, Iowa, Empire)

T. 9 S., R. 79 W. (See pl. 4)

Altitude 10,200 to 11,000 feet.

Leadville in the broad open valley of the Arkansas River is on U. S. 24. The main line of the Denver & Rio Grande Western Railroad follows the valley of the Arkansas.

Lake County

Leadville (California, Evans, Iowa, Empire) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	15	9	4,339	6,182	52	6,234	16,738	11	16,749	6,000	152,000	126,000	$ 142,292
1933	27	10	18,298	10,345	153	10,498	35,507	24	35,531	15,000	1,009,700	2,492,000	372,427
1934	42	32	28,433	14,282	293	14,576	83,573	36	83,609	90,400	1,047,800	1,029,000	653,710
1935	41	19	58,164	13,812	340	14,152	109,504	82	109,586	61,000	2,575,000	1,848,000	763,451
1936	47	3	116,971	13,324	1,429	14,753	120,027	226	120,253	43,000	3,100,900	1,742,000	843,200
1937	62	4	173,365	16,037	1,182	17,219	172,481	213	172,694	89,000	4,200.100	3,352,000	1,212,702
1938	58	8	45,474	10,045	14	10,058	101,472	3	101,475	56,800	2,444,900	193,000	544,939
1939	73	10	53,006	7,409	35	7,444	129,376	9	129,385	11,400	2,176,800	344,000	469,749
1940	50	8	67,484	8,115	93	8,208	72,796	24	72,820	25,200	1,588.400	343,000	442,940
1941	38	14	240,219	19,037	309	19,346	114,016	87	114,103	101,800	2,224,300	95,000	904,172
1942	25	1	364,641	27,114	1	27,115	241,301		241,301	130,300	6,696,400	6,688,000	2,207,026
1943	24		458,702	23,150		23,150	379,513		379,513	282,000	9,901,000	11,023,000	3,049,845
1944	23		686,548	20,149		20,149	496,634		496,634	351,000	11,505,000	15,968,000	3,846,514
1945	25		473,812	15,706		15,706	417,427		417,427	344,000	10,032,000	14,838,000	3,462,109

The mineralized area extends from the eastern part of Leadville east to the Mosquito Range, a distance of 3 to 5 miles. The distance from north to south is also about 3 to 5 miles. The area is mountainous, but numerous roads that served the old mines of the area make the greater part of the district easily accessible.

Leadville is one of the leading metal-producing areas in the United States.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 350-70. This summary reviews the possibilities relative to drainage tunnels, including the "Leadville Drainage Tunnel" which remains an uncompleted war project.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Geologic Map of West Slope of Mosquito Range in vicinity of Leadville, Colorado, 1:12,000, contours 50 ft., ed. 1939.

St. Kevin-Sugar Loaf

T. 9 S., Rs. 80 and 81 W. (See pl. 4.)

Altitude 10,000 to 11,000 feet.

St. Kevin lies north and Sugar Loaf south of Turquoise Lake on Lake Fork about 4 miles west of Leadville. These two areas combined have also been known as the Independent mining district. Access roads to the area are good.

These districts were early producers of silver, chiefly from oxidized ores. Locally, gold was important. The veins are in much altered pre-Cambrian granite. The old dumps show considerable dark brown sphalerite, galena, and pyrite with quartz and some pink carbonate.

Production from a few mines in these districts continued until comparatively recent times.

Leadville Quad., 1:125,000 contours 100 ft., ed. 1891.

Sugar Loaf-St. Kevin Mining Districts, 1:24,000, contours 25 feet, surveyed 1930, U.S.G.S.

Sandberg, A. E., Notes on ore minerals from the Sugar Loaf district, Lake County, Colorado: Colorado Sci. Soc. Proc., Vol. 13, no. 8, pp. 496-504, 1935.

St. Kevin-Sugar Loaf District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Silver (fine ounces) Total	Lead (pounds)	Total Value
1933	1	7	10	336	336	300	$ 328
1934	2	264	82	2,911	2,911	400	4,760
1935	2	342	96	4,423	4,423	2,000	6,609
1944	1	3	4	45	45		172
1945	1	6	7	90	90	1,000	395

Tennessee Pass (Harrington, East Tennessee)

T. 8 S., R. 80 W. (See pl. 4.)

Altitude 10,200 to 10,300 feet.

Tennessee Pass is on U. S. 24, 9 miles northwest of Leadville.

Two districts are referred to Tennessee Pass; one to the south in Lake County is the East Tennessee district, and one just north of the pass in Eagle County is the Tennessee Pass district.

East Tennessee occupies a valley of a creek flowing southwesterly and joining Tennessee Pass Creek about 2 miles south of Crane Park. (See Leadville Quadrangle.) The district in Eagle County is on the east side of Piney Creek.

Gold is found in small veins in the Leadville blue limestone (Mississippian) in both places.

The only recorded production since 1931 was 89 tons in 1935, that yielded 80 ounces of gold and 64 ounces of silver.

A little placer gold has been produced by sluicing along Tennessee Creek about 5 miles north of Leadville.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Twin Lakes (Lackawanna Gulch)

T. 11 S., Rs. 81 and 82 W. (See pl. 4.)

Altitude 9,500 to 12,000 feet.

Twin Lakes Post Office is on State 82, 22 miles southwest of Leadville and 5 miles west of Granite on U. S. 24. Access to the area is relatively easy, but prospects only a few miles from the highway may be 1,000 to 2,500 feet higher in elevation and difficult to reach.

The district is usually considered as including all of Lake Creek drainage west of Twin Lakes. Lackawanna Gulch is a short tributary near the head of the drainage system where the Mt. Champion mine is located. The Red Mountain district in Chaffee County is in the southwest part of Lake Creek drainage.

The general area is known for high-grade gold samples, but overall production has been small and limited to a few places. Lead, silver, and zinc are present in places. The veins are small and occur in pre-Cambrian granite and quartz monzonite, probably of Tertiary age.

Lackawanna Gulch is mentioned as a producer only in 1935 when 33 tons of ore yielded 180 ounces of gold and 50 ounces of silver.

The exact place in the Twin Lakes district of the production listed below is not known.

Mt. Elbert Quad., 1:62,500, contours 50 ft., ed. 1939, (Eastern part of Lake Creek).

Lake County

Twin Lakes (Lackawanna Gulch) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Lead (pounds)	Total Value
1932	2	1	7	8	11	19	7	3	10		$ 395
1933	1	1	4	5	141	146	11	43	54		3,034
1934	6	1	50	200	224	424	139	73	212	1,300	14,998
1935	1	2	15	40	1,355	1,394	135	441	576	3,100	49,359

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911, (Western part of Lake Creek).

Gunnison National Forest Map.

San Isabel National Forest.

Howell, J. V., Twin Lakes district of Colorado (Lake and Pitkin Counties): Colorado Geol. Surv. Bull. 17, 1919.

Chapman, E. P., The quartz monzonite batholithic intrusions of Twin Lakes and Clear Creek districts, Lake and Chaffee Counties, Colo.: Colorado Sci. Soc. Proc., vol. 13, no. 8, pp. 481-493, 1935.

Weston Pass

The Weston Pass district is located in both Lake and Park Counties. For location and other details see description of Weston Pass under Park County.

La Plata County

Animas River

Tps. 36 and 37 N., R. 9 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 7,000 to 7,500 feet.

The gravels along the Animas River north of Durango carry placer gold, but so far as is known adequate sampling has never been done. Sluicing by individuals has been reported from time to time, but the only production recorded in recent years was 7 ounces of gold in 1938. The area has been considered too small for large floating dredges; however, recent developments in smaller dry land or floating scow and dragline operations give renewed interest to placers of this type.

Durango Quad., 1:62,500, contours 100 ft., ed. 1898.

Montezuma National Forest Map.

San Juan National Forest Map.

California (La Plata, Oro Fino, May Day)

Tps. 36 and 37 N., Rs. 10, 11, and 12 W., New Mexico. Principal Meridian. (See pl. 4.)

Altitude 9,000 to 11,500 feet.

This district consists of an area around the town of La Plata on the La Plata River in the heart of the La Plata Mountains and an area at the head of Junction Creek on the east flank of these mountains. The two areas are but a few miles apart but they are separated by a high divide crossed by a trail over Eagle Pass at an altitude of 11,700 feet.

La Plata is 9 miles north of Hesperus and Hesperus is 11 miles on U. S. 140 west of Durango. The altitude of the central area is 9,200 feet in the valley and 11,000 to 12,000 only 2 to 3 miles to the east and west on the ridges and peaks that flank the valley.

The eastern part of the district, which includes Oro Fino, is at the head of Junction Creek on the east side of the La Plata Mountains and about 14 miles northwest of Durango. The road

La Plata County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total			
[1]1878-08				94,316		94,316	1,077,540		1,077,540	13,641	186,623	$2,676,220
1909-23	46,322			78,650		78,650	676,510		676,510	258,791	72,797	361,230
1924-31	31,678	2–14		12,683		12,683	158,607		158,607	585	137,177	525,619
1932-41	73,095	3–15	1–4	13,825	36	13,861	110,571	1	110,572	300	325,800	31,947
1942-45	120	1–3		878		878	1,152		1,152	1,100	3,400	
CRUDE ORE SHIPPED TO SMELTERS												
1909-23	41,922					77,453			670,179	258,563	72,797	
1924-31	3,914					4,392			60,682	585	2,577	
1932-41	1,040					4,284			18,264	100	11,840	
1942-45	120					878			1,152	1,100	3,400	
ORE TO GOLD AND SILVER MILLS		Bullion		Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	
1909-23	4,100	955	477									
1924-31	780	1,675	8,468									
1932-41	1,191	1,917	6,253		5	59			69	200	1,700	
1942-45												
ORE TO CONCENTRATING MILLS												
1909-23	300				145	242			5,854	228		
[2]1924-31	26,984				1,077	6,616			89,457		134,600	
1932-41	70,864				1,916	7,565			85,985		312,260	
1942-45												

[1]La Plata and Montezuma Counties combined for this period only.
[2]Production in 1928, 1929, and 1930.

into this area is along the narrow steep-walled canyon of Junction Creek that joins the Animas River at Durango.

The roads along the valleys are fair to poor with numerous steep grades. Mines and prospects on adjoining slopes are commonly not easily accessible. Much snow falls during the winter.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 416-19.

Durango Quad., 1:62,500, contours 100 ft., ed. 1898 (East part of district).

La Plata Quad., 1:62,500, contours 100 ft., ed. 1908.

Montezuma National Forest Map.

San Juan National Forest Map.

Cross, C. W., assisted by Spencer, A. C., Description of the La Plata quadrangle, Colo.: U. S. Geol. Survey Geologic Atlas La Plata folio no 60, maps, 1899.

Emmons, W. H., The neglected mine and nearby properties, Durango quadrangle: U. S. Geol. Survey Bull. 260, pp. 121-127, 1905.

Cave Basin (or Mount Runlett)

T. 37 N., R. 6 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 8,000 to 10,500 feet.

The mineralized area is near the La Plata-Hinsdale County line in the northeast 4 sections of the township and between Los Pinos River and its tributary Vallecito Creek, about 20 miles north and east of Bayfield. Bayfield on U. S. 160 is about 16 miles east of Durango. State 284 follows the valley of Los Pinos River about 15 miles north of Bayfield, and the road for the remaining distance to the area is probably fair.

Prospects are referred to as being on Mt. Runlett, but this mountain is not shown on the topographic maps.

Unverified reports indicate that mineralization resembles that found on Bear Creek in San Juan County. A small production is reported in 1913.

The extreme northeast and northwest parts respectively of: Ignacio Quad., 1:125,000, contours 100 ft., ed. 1908.

Pagosa Springs Quad., 1:125,000, contours 100 ft., ed. 1927.

San Juan National Forest Map.

Needle Mountains (Tacoma, Florida River, Vallecito)

Tps. 38 and 39 N., R. 7 W. (See pl. 4.)

Altitude 11,000 to 12,000 feet.

The main part of the district is in Chicago Basin at the head of Needle Creek. Some mineralization extends south into the headwaters of Florida River, and also to the southeast into Vallecito Basin.

Chicago Basin is 6 miles east of Needleton, a flagstop about 25 miles north of Durango, on the Durango Silverton Railroad. The road along Needle Creek rises from an altitude of 8,100 feet

La Plata County

California (La Plata, Oro Fino, May Day) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Total Value
1932	12	2	3,041	1,466	2	1,469	6,968		6,968		7,000	$ 32,532
1933	12	1	7,801	1,951	3	1,954	14,760		14,760	200	9,700	45,944
1934	10	1	13,663	2,455	3	2,458	16,748		16,748		7,900	97,011
1935	14	4	11,578	2,149	13	2,162	16,925		16,925	•	23,400	88,776
1936	11		13,109	1,195		1,195	11,050		11,050		13,300	50,981
1937	3	3	17,940	2,147	4	2,151	31,845	1	31,846		257,000	115,067
1938	6		2,996	222		222	1,935		1,935	100	1,900	9,125
1939	8		2,604	674		674	5,999		5,999		4,600	27,878
1940	6		167	714		714	2,423		2,423		1,000	26,763
1941	6	1	134	744	3	747	1,914		1,914			27,506
1942	3		66	390		390	377		377			13,918
1943	3		42	250		250	578		578	1,100	3,400	9,559
1944	1		8	163		163	107		107			5,781
1945	2		4	75		75	90		90			2,689

at Needleton to 11,000 feet in the lower part of the Basin. Except for the railroad the only access to the area is by trail.

The veins are in pre-Cambrian crystalline rocks. Chief values are gold, silver, and copper. Pyrite, chalcopyrite, and galena are usually present. The gangue minerals are quartz, rhodochrosite, fluorite, chalcedonic silica, and locally a little barite and calcite.

The mineralization as described by Irving and Emmons is of particular interest. The difficult access is a drawback.

Production from the Needle Mountain district in recent years is recorded only in 1934 when 49 tons were shipped that yielded 80 ounces of gold. Vallecito is credited with 13 tons in 1935 and 1936 that yielded 29 ounces of gold and 4 ounces of silver.

Needle Mountains Quad., 1:62,500, contours 100 ft., ed. 1902.

San Juan National Forest Map.

Irving, J. D., and Emmons, W. H., Economic geology (of the Needle Mountains quadrangle, Colo.): U. S. Geol. Survey Geologic Atlas Needle Mountains folio no. 131, pp. 12-13, 1905.

Larimer County

Drake

T. 3 S., R. 71 W. (See pl. 4.)

Altitude 7,000 to 7,500 feet.

Drake is on U. S. 34 about 15 miles west of Loveland.

Copper-gold ore is reported. No other data are available.

Mt. Olympus Quad., 1:62,500, contours 100 ft., ed. 1907.

Roosevelt National Forest Map.

Empire (Howes Gulch)

T. 7 N., R. 70 W. (Shown but not named on pl. 4.)

Altitude 6,000 to 6,500 feet.

The Empire mine is 3 miles southwest of Bellvue, which is on U. S. 287 six miles northwest of Ft. Collins.

Poorly defined veins with cupriferous pyrite, some chalcopyrite, and possibly a little gold are found in pre-Cambrian granite and schist. Small shipments are reported.

Ft. Collins Quad., 1:62,500, contours 20 ft., ed., 1908.

Livermore Quad., 1:125,000, contours 100 ft., ed. 1909.

Roosevelt National Forest Map.

Home

T. 8 N., R. 74 W. (See pl. 4.)

Altitude 7,500 to 7,600 feet.

Home is on State 14 on La Poudre River about 50 miles west of Ft. Collins.

Larimer County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short) tons)	Mines Producing Yearly Lode	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Zinc (pounds)	Total Value
[1]1895-08			401	775	1,176		1,701	204,851		$55,239
[2]1909-23	98		9		9	11	11		30,722	
1924-31										
1932-41	754	1–6	340		340	1,478	1,478			12,812
1942-45	7	1	8		8	3	3			282
CRUDE ORE SHIPPED TO SMELTERS										
1909-23	48								30,722	
1924-31										
1932-41	39				46		1,200			
1942-45										
ORE TO GOLD AND SILVER MILLS										
		Bullion Gold	Bullion Silver	Concentrates Tons	Concentrates Gold		Concentrates Silver			
1909-23	50	9	11							
1924-31										
1932-41	715	289	277	1	5		1			
[3]1942-45	7	8	3							

[1]Larimer and Jackson Counties combined for this period only.
[2]No production from 1917 to 1932.
[3]Production in 1942 only.

Two small veins with gold and copper in pre-Cambrian granite-gneiss. Considerable exploration has been done but attempts at mining have not been successful.

Home Quad., 1:125,000, contours 100 ft., ed. 1920.

Roosevelt National Forest Map.

Manhattan

T. 9 N., R. 78 W. (See pl. 4.)

Altitude 8,400 to 8,500 feet.

Manhattan is 3 to 4 miles north, on a steep mountain road, off State 14 about 45 miles west of Ft. Collins.

Placer ground was worked intermittently near Manhattan, but the total production is believed to be small. Ore shipped in 1932, 1935, 1936, 1940, and 1941 from small veins totaled 16 tons that yielded 27 ounces of gold and 9 ounces of silver.

Home Quad., 1:125,000, contours 100 ft., ed. 1920.

Roosevelt National Forest Map.

Masonville

T. 6 N., R. 70 W. (See pl. 4.)

Altitude 5,300 to 5,400 feet.

Masonville is on Buckhorn Creek, a tributary of Thompson River, 6 miles west of Loveland on State 16 and U. S. 34 and thence 5 miles northwest on State 186.

Small somewhat discontinuous stringer in pre-Cambrian rocks carry gold and silver values.

Production in recent years, limited to 1935, 1936, 1940, 1941, and 1943, totaled 63 tons shipped that yielded 93 ounces of gold and 83 ounces of silver.

Loveland Quad., 1:62,500, contours 20 ft., ed. 1908.

Roosevelt National Forest Map.

Steamboat Rock (Gray Rock)

This district is listed in U. S. Geological Survey Bulletin 507. It is described as northwest of Ft. Collins and probably is in the same general area as the Home district.

The area is said to have small veins with copper and gold mineralization in the pre-Cambrian rock.

(Native copper in red sandstone)

Native copper is rather widespread in the red rocks in T. 12 N., Rs. 74 and 75 W. and across the state line into Wyoming. These deposits have not been designated or referred to as a district.

Attractive specimens are obtained from time to time, but the deposits are low-grade. Attempts to exploit them have been unsuccessful.

Mesa County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
		Lode	Lode	Placer	Total	Lode	Placer	Total			
[1]1885-08			42	195	237			4,677	29,595		$12,099
[2]1909-23	22			1	1	257		257	5,685	20	1,134
[3]1924-31	3	1				110		110	2,095		353
1932-41	58	1		29	29	262	1	263	10,800		2,232
[4]1942-45	11	2				59		59	2,100		296
CRUDE ORE SHIPPED TO SMELTERS											
1909-23	22							257	5,685	20	
[3]1924-31	3							110	2,095		
1932-41	58							262	10,800		
[4]1942-45	11							59	2,100		

[1]No production from 1886 to 1894.
[2]Production in 1911 and 1912.
[3]Production in 1927 and 1928.
[4]Production in 1942.

Las Animas County

Shipments totaling 4 tons of lead-silver ore are reported in 1934 and 1935 from West Spanish Peak, 18 miles west of Aguilar. This is the area described under La Veta district in Huerfano County. (See page 118.)

Mesa County

The districts from which the above production came is not clear. The only area mentioned in the Minerals Yearbook since 1933 is Sinbad Valley, at the Missouri Girl and Copper River mines. It is not certain, however, that all production came from this locality. Sinbad Valley is southwest of the Gateway area and could well be called a part of it.

The source of the placer gold also is indefinite as sluicing operations are referred merely to the Gunnison and Colorado Rivers.

Gateway (Calamity, Maverick, and others)

T. 51 N., R. 19. W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 5,000 to 6,000 feet.

Gateway is on State 141 about 60 miles south of Grand Junction. The road to Gateway is good, but access roads to many surrounding areas are usually passable but not always safe.

The map (pl. 4) very properly shows this as "Gateway area;" the boundaries are indefinite. Copper-silver mineralization along fissures and faults in sandstone have been prospected in several localities on the west flank of the Uncompahgre Plateau in Mesa and Montrose Counties and in areas south to the New Mexico line. These areas are well-known for their vanadium-uranium deposits that are not related to or associated with the copper mineralization.

The copper-bearing veins are relatively small and are apparently characterized by spotty values. Occasional small shipments of 10 to 20 percent copper with 15 to 20 ounces of silver per ton have been reported in earlier years. No copper or silver production is reported in recent years from the Gateway area.

Uncompahgre National Forest Map.

Sinbad

T. 49 N., R. 19 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 6,000 to 7,000 feet.

The Town of Sinbad is in Montrose County. The area referred to, however, is Sinbad Valley, in Mesa and Montrose Counties, and the production that has been reported in recent years is from Mesa County. The Valley is 12 to 15 miles south of Gateway and 6 to 8 miles from the main road State 141. The road into Sinbad Valley is usually passable.

Fault fissures cutting sandstone beds carry copper with some silver. The occurrences are similar to those found in the Gateway area to the north and on La Salle Creek, Montrose County, to the south. Considerable prospecting has been done, but production has never been large. In recent years production occurred only in 1940 and 1942, and the 30 tons shipped contained 9 percent copper and 4 ounces of silver per ton in recovered metals. (See page 491.)

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, map, p. 220, 1920.

Unaweep

T. 13 S., R. 101 W. (See pl. 4.)

Altitude 6,500 to 7,000 feet.

The Unaweep district is on East Creek in Unaweep Canyon 15 miles southwest of Whitewater on State 141. Whitewater is 10 miles southeast of Grand Junction on U. S. 50.

The chief metal is copper with some gold and silver found in fissure veins. The veins cut both pre-Cambrian granite and the overlying Triassic red sandstone and shale. Some veins are along the walls of basic dikes.

The prevailing minerals are calcite, quartz, and a little fluorite with pyrite, chalcopyrite, and in places hematite is conspicuous. Considerable prospecting has been done, but the ore encountered has been spotty and too small in volume for profitable production.

No production is reported from the district.

Grand Mesa National Forest Map.

Butler, B. S., Notes on the Unaweep copper district, Colo.: U. S. Geol. Survey Bull. 580, pp. 19-23, 1914.

Mineral County

Creede (King Solomon, Sunnyside)

T. 42 N., Rs. 1 E. and 1 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 11,000 feet.

Creede is at the end of State 149, 41 miles northwest of Del Norte. Access to Creede and much of the surrounding area is not difficult, but, as is common in a rugged mountainous country, individual mines and prospects may be hard to reach.

The ore deposits are silver-lead veins in extensive fault fissures in rhyolite and fractured zones of silver ore in shattered rhyolite. The veins carry sphalerite, argentiferous galena, gold, pyrite, and chalcopyrite in a gangue of quartz (amethystine) chlorite, barite, and fluorite. Secondary enrichment was important in places.

Mineral County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly	Gold (fine ounces)		Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
		Lode	Lode	Total	Lode	Total				
1891-08			99,051	99,051	37,382,453	37,382,453	54,402	153,503,529	20,833,264	34,008,937
1909-23	519,164		32,685	32,685	7,184,586	7,184,586	220,686	44,473,772	6,780,143	8,220,122
1924-31	39,174	1–7	419	419	2,962,902	2,962,902		1,565,148	49,000	1,870,538
1932-41	194,111	6–10	2,774	2,774	4,550,754	4,550,754	43,500	4,575,500		3,537,820
1942-45	115,770	6–9	1,791	1,791	2,387,492	2,387,492	323,000	3,768,600	37,000	2,092,292
CRUDE ORE SHIPPED TO SMELTERS										
1909-23	280,894			7,990		6,824,322	142,622	12,323,210	99,131	
1924-31	31,435			230		2,511,014		1,507,748	49,000	
1932-41	45,391			503		2,440,209		2,279,976		
1942-45	10,717			536		294,294	11,074	853,858		

Year	Ore	Bullion		Concentrates					
		Gold	Silver	Tons	Gold	Silver	Copper	Lead	Zinc
ORE TO GOLD AND SILVER MILLS									
1909-23	200	18	2,060						
[1]1924-31	7,739	161	410,395	106	28	41,493		57,400	
[2]1932-41	618		23,636						
1942-45									
ORE TO CONCENTRATING MILLS									
1909-23	238,070			38,828	24,677	358,204	78,064	32,150,562	6,681,012
1924-31									
[3]1932-41	148,102			6,666	2,271	2,086,909	43,500	2,295,524	
1942-45	105,053			8,699	1,255	2,093,198	311,926	2,914,742	37,000

[1]No production in 1924, 1925, and 1926.
[2]Production in 1934 only.
[3]Production from 1937 to 1941.

Creede is the only mining district in Mineral county. The production record illustrates the importance of the area. The persistence of veins with strong mineralization that produced medium to rich ore bodies are factors favorable for continued mining in the future.

Creede and vicinity, 1:24,000, contours 50 ft., ed. 1912.

Creede Quad., 1:125,000, contours 100 ft., ed. 1916.

Rio Grande National Forest Map.

Gunnison National Forest Map.

Emmons, W. H., and Larsen, E. S., Geology and ore deposits of the Creede district, Colo.: U. S. Geol. Survey Bull. 718, 198 pp., 1923.

Larsen, E. S., Recent mining developments in the Creede district, Colo.: U. S. Geol. Survey Bull. 812 pp. 89-112, 1929.

Lunt, H. F., Ore deposition at Creede, Colo.: Eng. and Min. Jour. Press, vol. 117, no. 24, p. 973, 1924.

Moffat County

Douglas Mountain

T. 7 N., R. 102 W. (See pl. 4.)

Altitude 7,200 to 8,000 feet.

The Douglas Mountain district is about 10 miles southwest of Greystone, and access is not easy. The nearest road, State 318 from Maybell to Dinosaur National Monument, is about 8 miles north of Greystone. Greystone is about 30 miles west of Maybell on U. S. 40 and Craig is 31 miles farther east.

In spite of its relative inaccessibility, one mine (Bromide shaft) in T. 7 N., R. 101 W., shipped considerable copper ore during the first World War when copper prices were high. Mineralization is in a small fissure vein in sedimentary beds of Mississippian or Pennsylvanian age. The ore consists of chalcocite with some silver and galena. It is generally high-grade but irregular in occurrence.

The area is difficult to prospect because of soil cover and lack of roads.

Production in recent years (1933, 1935, 1937) was a total of 25 tons that averaged 10 percent copper and 2.1 ounces of silver in recovered metals.

Dinosaur National Monument, 1:62,500, contours 50 ft., ed. 1945. (Only part of area shown).

Fourmile Creek (and Timberlake Creek)

Tps. 10, 11 and 12 N., Rs. 91 and 92 W. (See pl. 4.)

Altitude 6,200 to 6,600 feet.

Timberlake Creek is a tributary of Fourmile Creek, and both streams are close to State Highway 13 about 35 miles north of Craig. Baggs, Wyoming, is about 5 miles to the north.

The placer deposits in this area are similar to the deposits north of Lay (see p. 146). Gold-bearing gravel beds cover the dry rolling plain along the west base of the Elk Mountains from the Little Snake River, near the Colorado-Wyoming line, to the

Moffat County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total			
[1]1873-08.........				753	16,046	16,799			17,505	7,823	131,922	$464,122
[2]1909-23.........	104				1,855		185	204		38,444		
1924-31.........	112	1–2	1–5	1	62	63	227		227	44,000		7,193
1932-41.........	25	1	5–13		2,231	2,231	53	112	165	7,100		77,590
1942-45.........												
CRUDE ORE SHIPPED TO SMELTERS												
1909-23.........	104								185	38,444		
[3]1924-31.........	112					1			227	44,000		
[4]1932-41.........	25								53	7,100		
1942-45.........												

[1]For Routt and Moffat Counties. No production from 1875 to 1881.
[2]Placer gold and silver includes Routt and Moffat Counties.
[3]Production in 1929, 1930, and 1931.
[4]Production in 1933, 1935, and 1937.

Yampa River in Colorado. The overall area is about 30 by 40 miles. The gravel, more properly called sand, is 0 to 30 feet thick and uniform over large areas. The reported gold content averages $0.10 to $1.00 per yard (gold $20) over relatively wide areas.

The gold deposits lie unconformably on the sandstones and shales of the Vermillion Creek series, and they were deposited before the present drainage channels formed. Relatively little concentration of gold has taken place along existing creek beds. The grade of the gold is 885 to 935 fine, and about 1,000 colors are required for 1 cent (gold $20).

Early attempts at hydraulic mining were for the most part unsuccessful due chiefly to extreme fine-grain of the gold and insufficient water.

Individual sluicing operations and the use of power equipment are reported from 1933 through 1940.

Craig Quad., 1:125,000, contours 100 ft., ed. 1916.

Hoover, H. C., Geology of the Fourmile placer mining district, Colo.: Eng. and Min. Jour., vol. 63, p. 510, 1897.

Snow, E. P., The Fourmile placer fields of Colorado and Wyoming: Eng. and Min. Jour., vol. 60, pp. 102-104, 1895.

Fourmile Creek and (Timberlake Creek) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1932	11	46	2	$ 956
1933	7	19		393
1934	6	55	3	1,912
1935	8	123	7	4,314
1936	10	211	13	7,379
1937	5	932	44	32,668
1938	11	641	31	22,441
1939	8	149	9	5,221
1940	5	10		350

Lay

Tps. 8, 9, and 10 N., Rs. 92 and 93 W. (See pl. 4.)

Altitude 6,200 feet.

Lay is 19 miles on U. S. 40 west of Craig, and the latest reported operation was 6 to 10 miles to the north on Lay Creek.

Gold placer deposits have been known for many years, northwest of Craig, on and around the divide that separates the drainage of the Little Snake River to the north and the Yampa River to the south. North of Lay the richest gold is in a bed of sand and gravel in terraces 20 to 100 feet above the present creek bottom. The deposits extend northeast along Timberlake Creek and Fourmile Creek (see p. 144) near the State Line.

A well-defined bedrock is lacking. Assays range in value from 1.6 to 63.7 cents (gold $20) per cubic yard. The gold is 885 to 935 in fineness and it occurs in rounded grains averaging about 1,000 to the cent. The gold-bearing gravel seems to have been deposited on an old land surface similar to the present surface, but preceding the present stream channels. The modern drainage channels as a rule do not show important concentrations of gold.

Lack of water has handicapped development, but in spite of this a moderate production was obtained at an early date. The most recent activity in the area was during 1933 to 1936. The total production for the 4 years was 26 fine ounces of gold.

Craig Quad., 1:125,000, contours 100 ft., ed. 1916.

Gale, H. S., Gold placer deposits near Lay, Routt County (now Moffat County), Colo.: U. S. Geol. Survey Bull. 340, pp. 84-95, 1908.

Round Bottom

T. 6 N., R. 92 W. (Not shown on pl. 4.)

Altitude 6,000 feet.

Round Bottom is on the north side of the Yampa River about 12 miles southwest of Craig. The locality is 7 miles from U. S. 40, and it is served only by ranch roads.

Reports of small placer operations in this area were made in 1932, 1933, and 1934, during which time 14 ounces of gold were produced. The character of the placer is not described, but it probably is like the other placers in Moffat County. Maps:

Monument Butte Quad., 1:62,500, contours 50 ft., ed. 1915.

Skull Creek (and Blue Mountain)

T. 4 N., R. 102 W. (See pl. 4.)

Altitude 7,400 to 7,600 feet.

Skull Creek (see pl. 4) is 80 miles west of Craig and within 5 miles of U. S. 40.

Blue Mountain (not shown on pl. 4) is in T. 5 N., R. 102 W., and the two are listed together because they are in the same general area.

Copper and vanadium are reported on Skull Creek but the nature of the occurrences is not known. In all probability the vanadium occurs as a bedded deposit in sandstone and the copper in veins as in the Douglas Mountain district about 20 miles to the northwest.

No information is available regarding Blue Mountain. Both areas are in sedimentary rocks. No production is reported.

Montezuma County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Total Value
[1]1878-08......				94,316		94,316	1,077,540	1,077,540	13,641	186,623	$2,676,220
1909-23......	673			651		651	713	713	6,059	286	
[2]1924-31......	20	1		7		7					151
1932-41......	8,402	1–3	1–3	10,321	13	10,334	14,148	14,148	8,100	100	370,029
[4]1942-45......	1,619	2		218		218	741	741			8,157
CRUDE ORE SHIPPED TO SMELTERS											
1909-23......	545					579		686	5,962	286	
1924-31......											
1932-41......	1,464					4,338		11,857	8,100	100	
[4]1942-45......	19					42		20			
ORE TO GOLD AND SILVER MILLS											
		Bullion: Gold	Bullion: Silver		Concentrates: Tons	Concentrates: Gold		Concentrates: Silver	Concentrates: Copper		
1909-23......		1	1								
[2]1924-31......	20	7									
1932-41......	6,438	5,868	1,724		24	84		564			
[4]1942-45......	1,600	134	49		16	42		672			
ORE TO CONCENTRATING MILLS											
1909-23......	128				64	71		26	97		
1924-31......											
[3]1932-41......	500				82	31		3			
1942-45......											

[1]For La Plata and Montezuma Counties combined.
[2]Production in 1929 only.
[3]Production in 1934 only.
[4]Production in 1942 only

Montezuma County

Montezuma County has yielded gold from small but relatively high-grade veins. Small amounts of placer gold are found in stream channels in the western approaches to the La Plata Mountains at the eastern boundary of the county. Placer production has been intermittent and small. The veins with one exception have been small but with sufficient high-grade gold specimens to attract the prospector. The exception referred to is the Red Arrow vein described in the East Mancos district, which was discovered about 1932. The Red Arrow received considerable publicity because of the high-grade native gold that it produced. The area in which the veins are found is in sedimentary formations, a large part of which is Mancos shale. Outcrops are few. Access to many areas is very difficult so that the discovery of the small isolated rich veins is largely a matter of chance. It is more than likely that additional veins will be discovered from time to time in this area by the prospector who has the courage to devote the necessary time, which may require several seasons.

The summary of the general geology under La Plata district (see pp. 416-19) applies also to the La Plata Mountains in the eastern part of Montezuma County.

Bear Creek

T. 38 N., R. 12 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 8,000 to 8,500 feet.

Bear Creek, a tributary of the Dolores River, is about 15 miles southwest of Rico on State 145.

This locality, as listed in U. S. Geol. Survey Professional Paper 138, is a few miles up Bear Creek from its junction with the Dolores River. Rico Folio No. 130 shows the canyon of Bear Creek in massive white sandstone with calcareous shale and thin limestone of the La Plata formation. The Morrison sandstone and shales and the Dakota sandstone also are present. A quartz monzonite dike, apparently from the La Plata center of eruption to the southeast, crosses Bear Creek at a small angle, but the presence of mineral deposits in the vicinity is not mentioned in Folio No. 130. However, where the dikes traverse the sandstone, small chalcocite ore bodies are said to occur in the Shinarump sandstone at the top of the Cutler formation of Permian age. The ore bodies are small, thin, and tabular. No production is reported.

Rico Quad., 1:62,500, contours 100 ft., ed. 1897.

Montezuma National Forest Map.

San Juan National Forest Map.

Cross, C. W., and Ransome, F. L., Description of the Rico quadrangle (Colo.): U. S. Geol. Survey Geologic Atlas Rico folio no. 130, maps, 1905.

East Mancos River (Red Arrow mine)

T. 36 N., Rs. 11 and 12 W., New Mexico Principal Meridian. (Red Arrow mine on pl. 4.)

Altitude 8,000 to 9,500 feet.

The East Mancos River district, described in some reports as a part of the La Plata district, is 8 to 14 miles east of Mancos. The Mancos River heads in the La Plata mountains 4 to 6 miles to the north and east.

U. S. 160 leaves the valley of the Mancos River about 6 miles east of Mancos beyond which the mountain roads are poor.

The area is known for a little placer gold in the streams and isolated fissure veins carrying gold with silver. The most recent deposit, known as the Red Arrow vein, was discovered in 1932 or 1933 and produced a little over 6,000 tons with a gross value of $330,000. This is the largest and richest production on record from this area. The vein is in the upper member of the La Plata sandstone. For the area as a whole the veins are small and values are spotty, but very rich pockets of gold and silver ore have been discovered. Copper is a characteristic associating metal, but economically unimportant. Lead and zinc are present in minor quantities.

Prospecting is made difficult by an extensive cover of soil, wooded areas, and heavy vegetation. Therefore, the chances are that in the future discoveries may be made comparable to those of the past.

Red Arrow Mine

Year	Ore	Gold	Silver	Copper	
1933	21 tons	170 oz.	129 oz.		
1934	124	435	828		
1934		265	50		(high-grade gold ore and nuggets)
1935	81	270	562		
1936	216	1,593	3,414	2,000 lbs.	
1937	214	1,929	2,383	1,945	
1938	638	1,744	3,447	2,500	
1939	839	943	1,102	500	(includes small production from adjoining property)
1940	3,000	1,355	295		(mill ore)
	39	179	585		(ore shipped)
1941	2,524	1,053	1,152		(mill ore and 24 tons of ore shipped)
1942	1,600	210	735		
1943	no production				
1944	no production				

Production for Montezuma County as presented by the U. S. Bureau of Mines has not been separated into districts. However, from year to year the production of individual mines is given. Inasmuch as the principal production has come from the Red Arrow mine it is possible to adjust the figures for this mine as given above. The figures are believed to be within 5 percent accurate.

La Plata Quad., 1:62,500, contours 100 ft., ed 1908.

Montezuma National Forest Map.

San Juan National Forest Map.

Cross, C. W., assisted by Spencer, A. C., Description of the La Plata quadrangle (Colo.): U. S. Geol. Survey Geologic Atlas La Plata folio no. 60, maps, 1899.

Root, A. P., Jr., and Simmons, J. E., The Red Arrow discovery: Eng. and Min. Jour., vol. 135, no. 6, pp. 260-261, June, 1934.

Vanderwilt, J. W, Personal files.

Stoner

T. 39 N., R. 13 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 7,200 to 7,700 feet.

Stoner on State 145 is 15 miles northeast of Dolores and 21 miles southwest of Rico.

Stoner is listed in U. S. Geol. Survey Professional Paper 138. Some float of unknown character is said to have been picked up near Stoner many years ago, but the dumps of the few prospect holes in the area show neither gold nor base metals. The State Geologic Map shows this to be an area of Cretaceous shale and sandstone.

Montezuma National Forest Map.

Montrose County

La Sal Creek

T. 47 N., R. 19 W., New Mexico Principal Meridian. (See Cashin mine on pl. 4.)

Altitude 5,500 feet.

The Cashin mine and Cliff Dweller mine make up the district on La Sal Creek, a tributary of the Dolores River. The mines are about 6 miles from Paradox on State 90. Paradox is about 100 miles south of Grand Junction and 85 miles west of Montrose. Roads into the area are fair but distances from shipping points are a disadvantage.

The ore of the Cashin and Cliff Dweller mine is along two intersecting fault fissures in the Dolores formation. Chalcocite impregnates sandstone adjoining the fissures, and native copper with some native silver is found in breccia zones. The copper sulfides usually occur higher in the fissures than the metallic copper.

The fissures have been prospected by tunnels several hundred feet long together with a number of winzes. Ore shipped prior to

Montrose County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly		Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
		Lode	Placer	Lode	Placer	Total	Lode	Placer	Total			
[1]1886-08......				909	1,121	2,030			180,616	218,541		$184,842
[2]1909-23......	897			2	2,249	2,251	32,264	63	32,327	314,051		93,550
1924-31......			1–4		78	78		22	22			1,622
1932-41......	849	1–3	15–58	7	1,405	1,412	15,507	410	15,917	118,600		69,909
1942-45......	16,456	1	1–5	90	20	110	44,030	4	44,034	940,600	700	161,323
CRUDE ORE SHIPPED TO SMELTERS												
1909-23......	897					2			32,264	314,051		
1924-31......												
[3]1932-41......	849					7			15,507	118,600		
1942-45......	16,456					90			44,030	940,600	700	

[1]No production from 1888 to 1894.
[2]No production from 1907 to 1912.
[3]Production 1937-1941.

Montrose County

La Sal Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total			
1934		5			56	56		11	11			$ 1,956
1935		23			123	123		28	28			4,311
1936		13			85	85		18	18			2,982
1937	3	5	156	1	37	38	698	7	705	24,000		4,779
1938	2	3	119	2	40	42	549	11	560	13,600		3,165
1939	2	6	97		83	83	75	19	94	15,000		4,529
1940	2	4	207	2	49	51	467	21	488	19,000		4,279
1941	1		270	2		2	13,718		13,718	47,000		15,371
1942	1		138	1		1	2,759		2,759	16,600		4,006
1943	1	1	2,044	15	3	18	5,271	1	5,272	129,000		21,149
1944	1		7,687	47		47	23,722		23,722	403,000	700	72,975
1945	1		6,587	27		27	12,278		12,278	392,000		62,596

1920 contained 35 to 50 percent copper with 8 to 10 ounces of silver per ton; a copper content of about 20 percent or more was required for profitable mining.

The source of the placer gold reported from the La Sal Creek district is not known.

Paradox Valley Quad., 1:125,000, contours 100 ft., ed. 1922.

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, map, p. 220, 1920.

Naturita

T. 46 N., R. 15 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 5,000 to 5,500 feet.

Gold is present in sand and gravel bars on benches above the water level along the San Miguel and Uncompahgre Rivers in a number of places, and along the Dolores River below its junction with the San Miguel River. The San Miguel and Dolores River placers are accessible from State 141.

Remnants of old water ditches used for former placer operations are plentiful. These efforts, as in recent years, were mostly by individuals sluicing on a small scale with mediocre results.

Production of placer gold has been credited annually for several years to Naturita on the San Miguel River along which placer gold occurs in places beginning near Pinon (see pl. 4) about 9 miles southeast of town along the valley to its junction with the Dolores River, a distance of 25 to 30 miles. The gravels at Pinon are reported to have been washed with some success at an early date. However, it is not known just where the placer gold produced in recent years has come from.

The only production of placer gold reported in recent years from the Uncompahgre River was a few ounces in 1933. No production is reported from the Dolores River for many years although reports of sluicing operations have been made.

Naturita District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1932	18	100	28	$2,069
1933	34	197	62	4,096
1934	40	191	67	6,704
1935	35	179	54	6,286
1936	32	76	26	2,694
1937	11	20	6	705
1938	12	26	8	901
1939	12	30	9	1,056
1940	13	59	17	2,077
1941	18	54	17	1,902
1942	5	14	3	492
1945	1	3		105

The gold is fine and average values are said to be low, but there is little evidence that sampling on an engineering basis has been done. An inadequate water supply makes efficient operation difficult. The source of the gold undoubtedly is from eroded deposits of the San Juan Mountains to the southeast.

Uncompahgre National Forest Map.

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, p. 224, 1920.

Sinbad

Sinbad Valley, the area referred to, is in Mesa and Montrose Counties. See Sinbad, Mesa County (pages 141-42) for description, maps, and references.

Tabequatche Basin

T. 48 N., R. 13 W. (Not shown on pl. 4.)

Altitude 7,000 to 7,500 feet.

Tabequatche Creek flows west and joins the San Miguel River about 3 miles southeast of Uravan (State 141). The Basin is about 18 miles up Tabequatche Creek, well up on the Uncompahgre Plateau. The road along Tabequatche Creek is difficult in places and local inquiries are advisable.

The area is of interest because of the occurrence of conglomerate boulders, impregnated with azurite, that are found on a bench on the north side of the basin at a place known as the Copper King prospect. Attempts to locate the source of the boulders do not seem to have been successful.

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, map, p. 220, 1920.

Ouray County

The mining districts in Ouray County are within a radius of 10 to 15 miles of Ouray in the southern part of the county, and the area as a whole has been referred to as the Ouray district. The several districts listed are characteristic localities; each is so isolated from the other by the extremely rugged topography as to justify the subdivision.

In addition to the topographic maps listed under each district a number of special purpose maps on a scale of 1:12,000 have been prepared of certain areas in connection with the cooperative geologic program. Inquiries as to these maps should include the locality that may be in question and be addressed to the U. S. Geological Survey, Washington 25, D. C.

Ouray County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1878-08..				1,091,443		1,091,443	31,845,006		31,845,006	16,976,697	127,338,632	114,067	$54,581,383
1909-23..	1,406,106			609,949		609,949	9,890,423		9,890,423	5,950,753	34,355,422	1,076,583	23,351,722
1924-31..	94,800	7–19	3	52,489	5	52,494	520,149		520,149	702,411	2,839,496	310,000	1,712,133
1932-41..	381,745	7–19	2–11	109,144	126	109,270	1,806,958	110	1,807,068	3,192,600	7,196,000	173,000	5,438,694
1942-45..	141,166	10–19		18,057		18,057	553,341		553,341	617,300	5,613,300	3,574,600	1,939,987
CRUDE ORE SHIPPED TO SMELTERS													
1909-23..	107,621					27,457			2,149,938	2,765,661	7,468,226	634,285	
1924-31..	6,035					7,088			195,164	488,042	956,643		
1932-41..	6,112					7,398			177,200	67,902	484,023	22,000	
1942-45..	1,795					123			19,421	21,694	282,104		
ORE TO GOLD AND SILVER MILLS													
		Bullion			Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23..	829,815	378,226	282,854										
1924-31..	47,387	28,586	11,128		2,887	13,448			51,086	135,666	519,939		
1932-41..	261,641	66,023	19,423		25,125	33,929			745,458	2,419,176	3,655,638		
1942-45..	117,864	10,973	3,149		9,229	6,354			379,655	476,467	3,189,265	2,519,779	
ORE TO CONCENTRATING MILLS													
1909-23..	468,670				149,612	204,266			7,457,631	3,185,092	26,887,196	442,298	
1924-31..	41,378				5,192	3,367			262,771	78,703	1,362,914	310,000	
1932-41..	113,992				6,742	1,794			864,877	705,522	3,056,339	151,000	
1942-45..	21,507				3,666	607			151,116	119,139	2,141,931	1,054,821	

Ouray County

Red Mountain District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	2	2	18	15	4	19	60	60		3,000		$ 503
1935	1		19				60	60	200	4,800	5,000	472
1936	1		350	51		51	1,224	1,224	5,700	10,000		3,710
1937	6		15,284	492		492	26,950	26,950	214,200	208,200	25,000	77,885
1938	2		22,517	700		700	37,363	37,363	348,000	281,400		95,695
1939	5		2,452	80		80	9,809	9,809	40,500	87,700	13,000	18,468
1940	7		626	60		60	6,210	6,210	2,800	38,000	10,000	9,362
1941	3		37				246	246	100	13,200	4,000	1,239
1942	7		1,447	54		54	3,119	3,119	4,900	88,000	168,900	26,305
1943	7		1,619	37		37	5,393	5,393	27,600	170,000	106,000	32,916
1944	7		2,007	93		93	16,176	16,176	40,400	337,800	172,500	66,901
1945	6		1,586	74		74	8,325	8,325	28,000	282,500	177,600	57,009

Red Mountain

T. 43 N., Rs. 7 and 8 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,500 to 11,500 feet.

The Red Mountain district is on U. S. 550, 12 miles south of Ouray and one mile north of Red Mountain Pass.

The portal of the Treasury tunnel (Idarado Mining Co.) is located in this district and mining through this tunnel is generally referred to the Red Mountain district. In reality the Treasury tunnel extends westerly about 3½ miles to develop the Black Bear vein and eventually other veins better known, as in the Telluride area.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 428-31.

Ouray Special, 1:62,500, contours 100 ft., ed. 1904.

Silverton Quad., 1:62,500, contours 100 ft., ed. 1902.

San Juan National Forest Map.

Uncompahgre National Forest Map.

Ridgway

T. 45 N., R. 8 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 7,500 to 8,500 feet.

Ridgway is on U. S. 550, 13 miles north of Ouray and 23 miles southeast of Montrose.

Gold placering on the Uncompahgre River is credited to "near" Ridgway. No other record is available regarding the placer deposits.

Montrose Quad., 1:125,000, contours 100 ft., ed. 1911.

Uncompahgre National Forest Map.

Ridgway District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1932	1	3		$ 56
1934	11	42	14	1,492
1935	8	22	7	776
1936	3	9	3	324
1939	3	6	3	212

Ouray County

Sneffels (Imogene Basin) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	7		17,966	11,703		11,703	34,415		34,415	88,700	276,000		$265,500
1933	5	2	15,135	8,045	5	8,050	46,035	2	46,037	160,100	265,100		202,568
1934	5		21,567	7,498		7,498	60,695		60,695	204,000	319,650		329,433
1935	4		27,047	11,415		11,415	81,280		81,280	226,400	429,700	1,000	493,967
1936	3		21,557	8,376		8,376	64,227		64,227	200,300	354,000		377,622
1937	4		25,140	9,428		9,428	68,547		68,547	250,200	397,200		436,699
1938	3		25,118	11,509		11,509	92,537		92,537	362,000	402,300		516,605
1939	3		29,100	11,749		11,749	80,866		80,866	301,200	362,600		514,473
1940	6		37,936	10,956		10,956	120,905		120,905	376,000	434,400		533,645
1941	3		37,884	10,422		10,422	120,773		120,773	242,500	447,800		504,793
1942	4		33,789	6,569		6,569	110,295		110,295	130,400	625,600	539,700	416,232
1943	7		32,860	4,834		4,834	80,924		80,294	112,500	749,000	511,000	352,724
1944	1		25,804	2,980		2,980	99,952		99,952	110,800	954,000	752,500	352,440
1945	1		25,947	2,963		2,963	96,563		96,563	123,000	884,000	722,400	348,077

Ouray County

Uncompahgre (Upper Uncompahgre, Ouray) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	3		1,588	753		753	13,305		13,305	1,300	35,000	8,000	$ 20,694
1933	4	2	990	1,199	7	1,206	7,285	1	7,286	1,400	15,300		28,129
1934	6		10,895	619		619	49,144		49,144	7,700	111,350		58,137
1935	6		16,348	1,083		1,083	144,836		144,836	26,400	422,700	16,000	161,810
1936	3	2	19,604	525	27	552	340,713	80	340,793	44,500	1,046,000		335,482
1937	6		7,676	257		257	86,892		86,892	18,600	356,600		99,487
1938	8		6,784	543		543	83,479		83,479	13,500	168,300		82,036
1939	6		4,159	751		751	68,120		68,120	16,700	204,100		83,854
1940	6		7,721	549		549	122,815		122,815	26,200	325,600	57,000	129,382
1941	11		6,227	368		368	38,167		38,167	13,400	176,000	34,000	54,184
1942	8		3,369	159		159	27,997		27,997	6,000	85,700		31,942
1943	4		2,044	66		66	5,362		5,362	3,900	160,000	37,000	22,626
1944	5		4,251	139		139	27,197		27,197	12,800	652,200	143,000	94,411
1945	3		6,443	89		89	72,038		72,038	17,000	624,500	244,000	138,404

Sneffels (Imogene Basin)

T. 43 N., R. 8 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,500 to 11,000 feet.

This district is 8 miles west-southwest of Ouray and 1,500 to 3,000 ft. higher in altitude, but the road to the mine camp is well kept. Sneffels is on State 361.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 421-24.

Ouray Special, 1:62,500, contours 100 ft., ed. 1904.

Silverton Quad., 1:62,500, contours 100 ft., ed. 1902.

San Juan National Forest Map.

Uncompahgre National Forest Map.

Uncompahgre (Upper Uncompahgre, Ouray)

T. 44 N., R. 7 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 7,500 to 9,500 feet.

The Uncompahgre district is on the east side of the valley immediately north of Ouray. The mines are only a few miles off the main highway (U. S. 550) but the grades are steep.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 409-14.

Ouray Quad., 1:62,500, contours 100 ft., ed. 1904.

Uncompahgre National Forest Map.

Park County

The major part of lode production has come from the northwest part of the County. The districts commonly recognized from north to south and on the east side of the Mosquito Range are: 1, Consolidated Montgomery; 2, Buckskin; 3, Mosquito; 4, Sacramento; and 5, Horseshoe. The Leadville district is just west of the divide that forms the crest of the Mosquito Range. The first 3 districts are also referred to collectively in some reports as the Alma district.

The gold in Alma and Fairplay placers came from the foregoing districts. Beaver Creek and Tarryall Creek, also with gold placers, drain the south and east slopes of Mt. Silverheels 10 miles north of Alma.

The other localities listed in Park County represent scattered isolated districts.

Alma placers

T. 9 S., Rs. 77 and 78 W. (Shown but not named on pl. 4.)

Altitude 9,200 to 9,300 feet.

The Alma placers are one-quarter to one-half a mile northeast of Alma and on the east side of the South Platte River.

Park County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Placer	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08..				243,257	152,604	395,861			6,261,428	1,705,904	31,881,987		$16,316,387
1909-23..	78,297			89,972	19,043	109,015	689,818	3,599	693,417	338,354	9,298,369	2,243,532	3,444,633
1924-31..	35,482	8–15	1–2	92,723	6,669	99,392	100,733	1,455	102,188	85,828	1,695,459	22,000	2,204,753
1932-41..	1,128,574	18–40	19–136	556,799	58,158	614,957	504,429	10,912	515,341	686,400	13,950,600	1,331,000	19,932,868
1942-45..	182,839	8–10	2–20	29,082	27,560	56,642	70,622	4,971	75,593	235,400	1,205,600	3,933,000	2,577,735
CRUDE ORE SHIPPED TO SMELTERS													
1909-23..	61,942					88,985			612,570	327,479	9,095,943	2,243,532	
1924-31..	18,476					74,998			88,917	69,884	1,554,917	22,000	
1932-41..	35,669					106,486			112,563	57,023	2,271,761	6,000	
1942-45..	1,695					1,663			6,757	27,362	59,138		
ORE TO GOLD AND SILVER MILLS		Bullion			Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23..	3,296	882	388										
1924-31..	15,366	13,269	8,297		508	4,094			3,054	15,707	129,357		
1932-41..	159,357	65,426	59,454		6,644	34,084			53,188	103,390	1,008,938		
1942-45..	4,340	240	578		597	507			6,479	15,388	102,018	389,127	
ORE TO CONCENTRATING MILLS													
1909-23..	13,059				881	105			76,860	10,875	202,426		
[1]1924-31..	1,640				79	362			465	237	11,185		
1932-41..	933,548				85,799	350,803			279,224	525,987	10,669,901	1,325,000	
1942-45..	176,804				13,675	26,672			56,808	192,650	1,044,444	3,543,873	

[1]Production in 1927 and 1930.

Rich concentrations of coarse gold occur in medium to coarse gravel near a shale bedrock over a relatively small area. The gravels are generally regarded as glacial outwash. However, the large nuggets (weights of an ounce to several ounces were not uncommon) near bedrock are suggestive of stream gravels which somehow escaped being removed by the ice.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 348.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Pike National Forest Map.

San Isabel National Forest Map.

Alma Placers District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Placer	Gold (fine ounces) Placer	Silver (fine ounces) Placer	Total Value
1932	5	37	7	$ 773
1933	4	84	19	1,738
1934	1	1,046	208	36,693
1935	1	3,007	612	105,700
1936	74	2,272	457	79,860
1937	59	2,321	472	81,593
1938	61	3,213	662	112,897
1939	49	3,154	663	110,840
1940	18	2,013	426	70,758
1941	10	2,699	568	94,869
1942	2	413	83	14,514
1943	1	6	1	211
1945	2	4	1	141

Beaver Creek

T. 9 S., R. 77 W. (Shown but not named on pl. 4.)

Altitude 10,000 to 10,500 feet.

Beaver Creek joins the South Platte River at Fairplay. Fairplay is on U. S. 285 in the west central part of South Park 90 miles from Denver.

Beaver creek drains the south and west stopes of Silverheels Mountain, a high peak about 10 miles north of Fairplay.

The placers on Beaver Creek are outwash gravels from Wisconsin moraines from the South Platte glacier. Thus the gold was derived from the South Platte Valley.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 341-42.

Pike National Forest Map.

San Isabel National Forest Map.

Patton, H. B., et al, Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, pp. 189-190, 1912.

Singewald, Q. D., Stratigraphy, structure, and mineralization in the Beaver-Tarryall area, Park County, Colo.: U. S. Geol. Survey Bull. 928 a, p. 41, 1942.

Park County

Beaver Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Total Value
1932....	1	3	2	4	11	15	4	3	7	$ 309
1933....		2			5	5				104
1934....		8			22	22		3	3	754
1935....		5			44	44		4	4	1,551
1936....		4			462	462		93	93	16,239
1937....		6			336	336		71	71	11,808
1938....		6			403	403		87	87	14,161
1939....		7			4,300	4,300		903	903	151,113
1940....		4			5,459	5,459		1,170	1,170	191,897
1941....		3			3,313	3,313		713	713	116,462
1942....		4			1,936	1,936		422	422	68,060
1944....		1			2	2				70
1945....		1			19	19		6	6	669

Buckskin

T. 9 S., R. 78 W. (Shown but not named on pl. 4.)

Altitude 10,500 to 12,000 feet.

This district is along Buckskin creek that heads in the Mosquito Range about 2 to 6 miles northwest of Alma. The creek joins the South Platte River at Alma. A good road along the valley affords access to the area.

The sedimentary formations are exposed about 2 miles northwest of Alma, beyond which the valley is in pre-Cambrian granite and schist, with the sedimentary formations on each of the flanking ridges.

Small veins occur in the crystalline rocks but the larger mines have been in the sedimentary formations. The ore occurs in veins and along beds. The principal ores are gold, gold-silver, and lead-silver. Some of the deposits carry appreciable quantities of zinc. Present placer possibilities along Buckskin Creek must take into account not only early operations that worked over much of the gravel deposits, but also the effect of mill tailings that have been discharged into the stream from each of the mills that operated in the past. Some of the tailings from inefficient mills of an early date were moderately high in metal content.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 336-41.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Leadville Quad., 1:125,000, contours 25, 50, and 100 ft., ed. 1891.

Pike National Forest Map.

San Isabel National Forest Map.

White River National Forest Map.

Patton, H. B., et al, Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, pp. 129-132, 1912.

Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, maps, 1941.

Consolidated Montgomery

T. 8 S., R. 78 W. (Shown but not named on pl. 4.)

Altitude 11,500 to 13,500 feet.

The Montgomery district is at the head of Platte River (also known as Montgomery Gulch) 5 to 10 miles north of Alma. The lower mile of the area is easily accessible but the last 4 miles does not have a consistently maintained road.

The valley of the Platte River has cut deeply into the pre-Cambrian granite and schist. Paleozoic quartzite and limestone are confined to the higher slopes of Mt. Lincoln to the south and the North Star Range to the north. Considerable early production came from the schist, but in recent years the Cambrian quartzites on North Star Range have yielded the ore. The chief values are gold found in veins and fractured zones. Zinc mineralization has

Park County

Buckskin District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932......	3	3	68	21	1	22	39		39				$ 454
1933......	5		116	79		79	220		220	1,000	1,800		1,836
1934......	5	6	8,924	1,178	8	1,186	5,052		5,052	19,100	100		46,250
1935......	8	8	867	350	17	367	1,017	3	1,020		4,750		13,758
1936......	7		136	114		114	1,437		1,437	400	1,700		5,219
1937......	8	2	1,069	545	13	558	2,305	3	2,308	1,800	26,900		23,113
1938......	5	4	608	304	9	313	993	1	994	150	20,400		12,558
1939......	4	6	56	22	16	38	408	3	411	700	6,800		2,002
1940......	11	9	6,342	1,112	15	1,127	6,594	3	6,597	26,400	75,000	711,000	95,662
1941......	6	6	4,676	1,059	15	1,074	6,584	3	6,587	21,600	81,600	614,000	95,524
1942......	2	1	5,741	1,445	2	1,447	9,696		9,696	27,800	118,200	906,600	153,137
1943......	3		6,203	1,762		1,762	11,676		11,676	42,000	163,000	941,900	189,383
1944......	3		5,614	1,467		1,467	12,008		12,008	35,400	121,000	886,000	175,347
1945......	4		6,536	1,041		1,041	9,682		9,682	24,600	98,400	707,000	136,408

Park County

Consolidated Montgomery District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	2	1	299	106	2	108	14		14				$ 2,238
1933	5		1,560	428		428	1,551		1,551	100	900		9,434
1934	8	1	93	64	2	66	2,337		2,337	500	6,500		4,099
1935	7		1,072	447		447	1,312		1,312		3,800		16,731
1936	3		277	157		157	400		400	400	3,800		6,003
1937	4	1	3,798	288	4	292	16,194	1	16,195	100	5,240		23,047
1938	2	2	5,929	278	39	317	29,007	8	29,015				29,866
1939	4	1	2,784	929	8	937	3,129	3	3,132	500	1,000		35,020
1940	7		7,352	1,093		1,093	7,972		7,972	3,700	400		44,362
1941	7	1	3,700	402	5	407	1,727	3	1,727	1,500	800		15,696
1942	2		885	735		735	4,306		4,306	18,400	1,800		31,134
1943	2		996	359		359	2,416		2,416	4,400	15,000	21,100	18,259
1944	1		577	193		193	1,042		1,042	5,000	1,000	10,600	9,459

been found where the veins in the schist intersect the overlying sedimentary formations.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 336-41.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Leadville Quad., 1:125,000, contours 25, 50, and 100 ft., ed. 1892.

Pike National Forest Map.

San Isabel National Forest Map.

White River National Forest Map.

Patton, H. B., et al, Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, p. 142, 1912.

Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, maps, 1941.

Fairplay

Tps. 9 and 10 S., R. 77 W. (See pl. 4.)

Altitude 10,250 to 10,500 feet.

The Fairplay placer refers to the area southeast of the town. The area along the Platte River just west of Fairplay was known as the Cincinnati when it was worked 40 or more years ago.

The gravels and the gold contained in the valley represent glacial outwash chiefly from the east slopes of the Mosquito Range. A large dredge began operation in this area in 1941.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 348.

Pike National Forest Map.

San Isabel National Forest Map.

Patton, H. B., et al, Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, p. 188, 1912.

Singewald, Q. D., Stratigraphy, structure, and mineralization in the Beaver-Tarryall area, Park County, Colo.: U. S. Geol. Survey Bull. 928 a, p. 40, 1942.

Guffey (Freshwater)

T. 15 S., R. 73 W. (See pl. 4.)

Altitude 8,000 to 8,500 feet.

Guffey on Currant Creek is about 35 miles northwest of Canon City. State 9 to Guffey joins U. S. 50 thirteen miles west of Canon City. Guffey can be reached also by a branch road that joins State 143 sixteen miles northwest of Cripple Creek. The general area is mountainous.

Very little is known about the Guffey area, but it is probably the northwest extension of the Currant Creek district only a short distance to the southeast in Fremont County. The metals reported are copper with gold and silver in veins and fractured zones in pre-Cambrian crystalline rocks. No production from the district is recorded.

In the Minerals Yearbook of 1945 a Freshwater district is listed in Park County as having produced 64 tons from two mines

Park County

Fairplay District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Placer	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Total Value
1932		23		63		15	15			$ 1,312
1933		7		119		21	21			2,465
1934		8		142		28	28			4,984
1935		25		601		128	128			21,142
1936		20		149		31	31			5,252
1937		17		123		27	27			4,333
1938		18		167		36	36			5,868
1939	1		7		50		50	100	1,000	91
1940		36		1,165		246	246			40,950
1941		46		10,171		2,022	2,022			357,423
1942		11		13,853		2,738	2,738			486,802
1943		1		8		3	3			282
1944		1		2						70
1945		3		7,338		1,284	1,284			257,743

that yielded 1 ounce of gold, 83 ounces of silver, 5,600 pounds of copper, 100 pounds of lead, and 2,600 pounds of zinc.

A reference to a Freshwater district is not found in any earlier reports and its exact location is not known, but as the shipper used the Guffey Post Office address, Freshwater is believed to be in the general vicinity of Guffey.

Pike National Forest Map.

Halls Gulch

T. 6 S., R. 76 W. (Shown but not named on pl. 4.)

Altitude 11,000 to 12,000 feet.

Halls Gulch is shown on the Montezuma Quadrangle as Hall Valley, and it flows easterly into the North Fork of the South Platte River 13 to 14 miles west of Bailey. Bailey is 48 miles southwest of Denver. The mines are 8 to 10 miles on a branch road from U. S. 285 that follows North Fork. The upper few miles of the branch road are usually not passable with an automobile.

Halls Gulch is in pre-Cambrian schist and gneiss. The principal values have been gold, silver, lead, copper, and a little zinc. The gangue minerals are barite, quartz, and dolomite in varying proportions. Some of the veins are characterized by bismuth, silver, tetrahedrite, chalcopyrite with a varying gold content. One of the mines produced chiefly a silver-lead ore low in gold. The veins are a few inches to several feet wide and the small ore shoots tend to be irregular though high-grade.

Montezuma Quad., 1:62,500, contours 100 ft., ed. 1926.

Arapahoe National Forest Map.

Pike National Forest Map.

Lovering, T. S., Geology and ore deposits of the Montezuma quadrangle, Colo.: U. S. Geol. Survey Prof. Paper 178, pp. 87-89, 113-114, 1935.

Halls Gulch District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1933	1	129	18	3,580	11,500	2,600	$2,454
1934	1	9	1	127			114
1937	1	3		172		1,200	204
1938							
1939	1	7		50	100	1,000	91
1940	1	3		21		1,200	75
1941	1	27	1	111	900	200	231

Horseshoe

T. 10 S., Rs., 78 and 79 W. (Shown but not named on pl. 4.)

Altitude 11,500 to 12,500 feet.

Horseshoe is at the head of Fourmile Creek about 12 miles west by south of Fairplay. The road from Fairplay to Horseshoe is fairly good for the first 6 miles but in the higher elevations of Fourmile Creek the grades are steep and the road is not kept in repair so as to be safe.

The head of Fourmile Creek is a glacial cirque. The sedimentary beds that form the rim of the cirque have the appearance from a distance of a giant horseshoe.

The London fault and related folding and fracturing is the outstanding geologic feature in the area. Mineralization is similar to that on Sacramento Creek immediately to the north.

The principal ores have been lead-silver with varying quantities of gold, copper, and zinc. Veins occur in the pre-Cambrian granite, but the ore has come from veins and replacements in the Paleozoic dolomites that were productive in the Leadville area.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 336-41.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Pike National Forest Map.

San Cristobal National Forest Map.

Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, pp. 66-67, map, 1941.

Horseshoe District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Lead (pounds)	Total Value
1932	1	4	12	12	28	28	300	$265
1933	1	1			9	9	1,000	40
1938	1	11			147	147	3,000	240
1940	1	23			114	114	2,000	181

Mosquito

T. 9 S., R. 78 W. (See pl. 4.)

Altitude 10,500 to 12,500 feet.

This area covers Mosquito Creek and its tributaries. The eastern part of the area is 2 miles west of Alma and easily accessible, but 3 to 5 miles farther west on the high and rugged slopes of the Mosquito Range access is difficult.

Park County

Mosquito District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	11		41,784	125,440		125,440	63,103		63,103	60,300	1,614,700		$2,663,115
1933	19		60,837	59,375		59,375	35,120		35,120	69,400	1,313,000		1,292,705
1934	24	1	119,932	82,658	1	82,659	53,698		53,698	52,500	2,619,200		3,024,735
1935	16	2	119,775	66,330	16	66,346	59,125		59,125	92,000	1,899,950		2,448,263
1936	14	3	120,012	52,663	20	52,683	47,844	4	47,848	24,200	1,628,500		1,958,078
1937	12	3	144,045	44,443	20	44,463	42,053	6	42,059	65,100	1,238,660	6,000	1,670,065
1938	10	1	123,557	33,526	18	33,544	25,887	4	25,891	54,850	814,600		1,233,618
1939	15		125,894	33,638		33,638	33,317		33,317	67,700	1,069,200		1,257,238
1940	13	1	118,331	26,731	4	26,735	32,680		32,680	54,900	843,400		1,007,338
1941	5		104,386	22,940		22,940	18,924		18,924	55,000	655,400		860,205
1942	6		86,658	15,009		15,009	9,152		9,152	32,200	423,600	5,400	564,602
1943	3		60,741	6,298		6,298	7,501		7,501	21,200	222,000	161,400	262,601
1944	4		4,923	622		622	2,776		2,776	3,800	36,000	106,400	39,267
1945	1		1,344	128		128	284		284	200	3,500		5,010

The drainage of Mosquito Creek is separated from Buckskin Creek by a high divide (Loveland Mountain) but the general geology is similar in the two areas. Veins are widespread in both the pre-Cambrian crystalline and Paleozoic sedimentary rocks of the area, but production has come chiefly from the sedimentary formations.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 336-41.

Pike National Forest Map.

San Cristobal National Forest Map.

Patton, H. B., et al, Geology and ore deposits of the Alma district, Park County, Colo.: Colorado Geol. Survey Bull. 3, pp. 95-129, 1912.

Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, 1941.

Pulver

T. 12 S., R. 73 W. (Not shown on pl. 4.)

Altitude 9,000 to 10,500 feet.

Pulver is 10 miles west of Lake George, which is on U. S. 24 36 miles northwest of Colorado Springs.

The rock in the area is pre-Cambrian granite and schist. Data are not available as to the nature of the occurrence.

The only recorded production in recent years was in 1943, 1944, and 1945 when one mine shipped 2,557 tons that averaged 2.5 to 4.5 percent zinc and 0.25 to 0.5 percent copper with a minor quantity of lead and gold.

Pike National Forest Map.

Sacramento

T. 9 S., R. 78 W. (Shown but not named on pl. 4.)

Altitude 11,500 to 12,500 feet.

Sacramento Creek is south of Mosquito Creek and north of Fourmile Creek (Horseshoe) about 12 miles southwest of Fairplay. The mines are near the head of the streams where grades are steep and the roads usually are not passable. The first 5 to 8 miles of road out from Fairplay are fairly good.

The London fault dominates the structure of the area. Veins are found in pre-Cambrian and sedimentary rocks, but as is common in the adjoining districts the best prospects are in the Leadville (Mississippian) limestone.

Early production was moderate and none is reported from this district in recent years.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 336-41.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Pike National Forest Map.

San Cristobal National Forest Map.

White River National Forest Map.

Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, pp. 63-66, map, 1941.

Tarryall Creek

T. 8 S., Rs. 76 and 77 W. (See pl. 4.)

Altitude 9,750 to 11,000 feet.

The head of Tarryall Creek is on the east slope of Silverheels Mountain west of Como, and the stream flows southeasterly across South Park. Como, on U. S. 285, is 10 miles northeast of Fairplay and 82 miles southwest of Denver. Como and Tarryall Creek for several miles to the northwest are readily accessible but the general area is very rugged and difficult to prospect.

Silverheels Mountain consists of a great thickness of alternating beds of coarse conglomerate and shale with a few thin beds of limestone of Permian and Pennsylvanian age. The series is prevailingly gray in the lower part and red in the upper part. Numerous sills of quartz monzonite are present. A large stock lies along the northeast side of the area and the top of a small stock apexes in Montgomery Gulch north of Silverheels Mountain. The regional dip of the beds is eastward with interruptions due to local folding and faulting that accompanied igneous intrusion.

Sulfide mineralization coincides with an extensive area of metamorphism related to the Montgomery Gulch stock. Pyrite and quartz were deposited throughout the metamorphosed area. A little gold accompanied the pyrite but very little lead or zinc was deposited. The ore-forming solutions spread into innumerable small fissures and fractures and thus formed numerous scattered small deposits. No lode production is recorded from the area.

Tarryall Creek has important placer gold deposits; the gold extends some miles southeast of Como. Placer operations suspended during the war, are expected to be resumed.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 347-49 for lode deposits and pages 341-42 for placer deposits.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Pike National Forest Map.

San Cristobal National Forest Map.

White River National Forest Map.

Muilenburg, G. A., Geology of the Tarryall district, Park County, Colo.: Colorado Geol. Survey Bull. 31, 64 pp., map, 1925.

Singewald, Q. D., Stratigraphy, structure, and mineralization in the Beaver-Tarryall area, Park County, Colo.: U. S. Geol. Survey Bull. 928 a, maps, 1942.

Tarryall Springs

T. 12 S., R. 72 W. (See pl. 4.)

Altitude 8,500 to 10,000 feet.

Tarryall Springs is about 8 miles northwest of Lake George, which is on U. S. 24, 36 miles northwest of Colorado Springs. The area is near State 77 but data as to an access road are not available.

Tungsten is reported in pre-Cambrian granite or schist.

Platte Canyon Quad., 1:125,000, contours 25, 50, & 100 ft., ed. 1893.

Pike National Forest Map.

Park County

Tarryall Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total	
1932		3			53	53		7	7	$ 1,088
1933		6			39	39		6	6	805
1934	2	20	19	10	737	747		57	57	26,132
1935	2	36	26	8	1,122	1,130		93	93	39,605
1936		35			431	431		36	36	15,124
1937		39			642	642		53	53	22,525
1938		25			730	730		59	59	25,595
1939	2	30	12	8	729	737	22	56	78	25,848
1940	1	12	9	6	814	820	4	90	94	28,767
1941	2	9	10	13	5,064	5,077		578	578	178,106
1942		2			3,977	3,977		433	433	139,503

Weston Pass

Tps. 10 and 11 S., R. 79 W. (See pl. 4.)

Altitude 11,400 to 12,500 feet.

Weston Pass is at the crest of the Mosquito Range and on the boundary between Lake and Park Counties. The distances by road are 19 miles to Leadville to the northwest and 22 miles to Fairplay to the southeast. The district can be reached from either the east or west. The last several miles of road on either side are usually poor and much of the time the road over the divide is not passable.

The district extends into both Lake and Park Counties but mining has been confined to within a mile on either side of Weston Pass.

The sedimentary formations are essentially those described for the Leadville district. The average dip is 25° easterly. A fault zone to the northeast has elevated pre-Cambrian granite to the level of the Paleozoic sedimentary beds. The ore is a replacement body confined to a limited stratigraphic horizon in the Leadville Blue limestone. Principal values are lead with low silver and some zinc. During the first World War oxidized lead-zinc ores were produced. High silver-lead values probably were a product of surface enrichment. A moderate production is indicated but none is recorded for recent years.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1893.

Pike National Forest Map.

San Cristobal National Forest Map.

Behre, C. H., Jr., The Weston Pass mining district, Lake and Park Counties, Colo.: Colorado Sci. Soc. Proc., vol. 13, no. 3, map, 1932.

Pitkin County

Ashcroft

T. 11 S., R. 84 W. (See pl. 4.)

Altitude 9,400 to 13,000 feet.

Ashcroft is a ghost town on Castle Creek 10 miles north of Aspen, and Aspen on State 82 is 42 miles southeast of Glenwood Springs. The area is in the heart of a very picturesque, rugged part of the Elk Mountains. Maintenance of the Castle Creek road ends at Ashcroft, and access to the surrounding areas where the prospects are located is by steep and even poor trails. The Montezuma mine shown on the map is at an altitude of 13,000 feet and the road to the mine is little more than a trail.

The principal geologic features are a large quartz monzonite stock, to the west of the ghost town that makes Hayden Peak, flanked by Paleozoic sedimentary rocks, and the Castle Creek fault to the east. The ore-making dolomite and limestones (Leadville) of the Aspen district are present along the Castle Creek fault. Iron-stained outcrops are widespread; the stain resulted from oxidation of pyrite that is plentiful. Magnetite in metamorphosed

Pitkin County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1880-08......				27,829		27,829	89,556,879	89,556,879	844,345	565,555,316	13,176,766	$85,366,416
1909-23......	1,545,969			131		131	8,051,343	8,051,343	284,118	168,310,361	3,665,236	15,591,291
1924-31......	146,930	7–10		95		95	1,075,493	1,075,493	1,000	14,329,963	2,285,000	1,846,305
1932-41......	209,226	2–6	1	118	9	127	1,680,041	1,680,041	7,300	5,225,300	1,546,000	1,486,225
1942-45......	67,731	4–5		8		8	793,111	793,111	4,800	2,116,800	1,245,000	858,353
CRUDE ORE SHIPPED TO SMELTERS												
1909-23......	552,135					43		5,965,574	99,638	77,252,598	3,349,215	
1924-31......	100,439					88		921,527	1,000	12,354,763	1,948,000	
1932-41......	102,126					111		673,150	378	1,943,984		
1942-45......	13,004					1		56,154		275,508	14,600	
ORE TO GOLD AND SILVER MILLS												
		Bullion Gold	Bullion Silver		Concentrates Tons	Concentrates Gold		Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc	
1909-23......		72	5,262									
[1]1924-31......		7	1									
[2]1932-41......		6										
1942-45......	4,825		69		85			1,046		26,349	41,000	
ORE TO CONCENTRATING MILLS												
1909-23......	993,834				248,539	16		2,080,507	184,480	91,057,763	316,021	
1924-31......	46,491				8,658			153,965		1,975,200	337,000	
1932-41......	107,100				6,193	1		1,006,891	6,922	3,281,316	1,546,000	
1942-45......	49,902				3,278	7		735,842	4,800	1,814,943	1,189,400	

[1]Production in 1931 only.
[2]Production in 1932, 1934, and 1936.

beds attracted early attention. Gold has been found in small relatively rich pockets in fissure veins, and lead-silver ores with zinc have been prospected. Mining costs are high because of the distances from transportation and the short working season.

Production has been small.

Aspen Quad., 1:62,500, contours 100 ft., ed. 1895.

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.

Gunnison National Forest Map.

Leith, C. K., Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, pp. 196-198, 1906.

Avalanche

T. 10 S., Rs. 87 and 88 W. (Not shown on pl. 4.)

Altitude 8,500 to 10,000 feet.

The junction of Avalanche Creek and Crystal River is on State 133 twelve miles south of Carbondale, which is fifteen miles on State 82 southeast of Glenwood Springs. The mineral deposits are several miles up Avalanche Creek. The general area is the north side of Mount Sopris, which is characterized by steep slopes with trails as the only means of access.

Mt. Sopris is the high point on a quartz monzonite stock. To the north in Avalanche Creek the Pennsylvanian limestone, shale, and gypsiferous beds dip steeply to the north, having been dragged into this position by the intrusion. Galena with silver and some gold is found along some of the limestone beds. Relatively low metal concentrations are indicated, but the work is insufficient to determine whether the scattered outcrops represent isolated concentrations or parts of a larger continuous mineraiization.

Production from the area, if any, has been small, and none has been reported since 1936.

Gunnison National Forest Map.

White River National Forest Map.

Vanderwilt, J. W, Personal files.

Frying Pan (Homestake)

T. 8 S., Rs. 82 and 83 W. (Not shown on pl. 4.)

Altitude 9,500 to 11,000 feet.

The Frying Pan district is given in U. S. Geol. Survey Bull. 507 as Nast station on the long since abandoned Colorado Midland Railroad on the Frying Pan Creek. State 104 follows the old railroad grade and Nast is 25 miles east of Basalt, which in turn is 23 miles on State 82 southeast of Glenwood Springs.

Scattered and small veins are present in an area that extends from the head of Frying Pan Creek across the high divide into the head of Homestake Creek, a tributary of the Eagle River to the north, and into the head of Lake Fork, a tributary of the Arkansas to the southeast. Thus, in addition to access by way of Frying Pan Creek, the area can be reached by way of Homestake Creek from Red Cliff and by way of Colorado Creek west of Leadville. Each of the three routes have long steep grades on trails that make access difficult.

The principal metals are gold and silver found in small and scattered veins in the pre-Cambrian granite. No production is recorded.

Leadville Quad., 1:125,000, contours 100 ft., ed. 1891.

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.

San Cristobal National Forest Map.

White River National Forest Map.

Independence

T. 11 S., R. 83 W. (See pl. 4.)

Altitude 11,400 to 11,500 feet.

Independence is a ghost town on the Roaring Fork, a tributary of the Colorado River, 32 miles on State 82 southeast of Aspen. Independence Pass, the highest highway pass in the State, is 4 miles farther east and impassable during the winter on account of heavy snow.

A vein of relatively limited extent on the north side of the valley was responsible for a moderate production prior to 1900. At a relatively shallow depth the vein was interrupted by a fault or an intrusive contact related to the volcanic rocks found in abundance to the south.

Gold was produced. Relatively high gold values are indicated by the fact that stope pillars in 1932 yielded 38 tons that averaged 2.3 ounces per ton; in 1934 a shipment of 14 tons averaged 1 ounce per ton, and in 1940 the last recorded production, 2 tons, averaged 3.5 ounces. The silver content was about 2 ounces per ton.

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.

Gunnison National Forest Map.

San Cristobal National Forest Map.

Lincoln Gulch

Tps. 11 and 12 S., Rs. 82 and 83 W. (See pl. 4.)

Altitude 11,000 to 12,500 feet.

Lincoln Gulch joins Roaring Fork 15 miles southeast of Aspen. The mineralized area is at the head of the gulch and the 10 miles from the main highway (State 82) is narrow, rough, and generally poor.

The head of Lincoln Gulch faces north and the Red Mountain district in Chaffee County lies to the east; Red Mountain, a conspicuous iron-stained peak, is on the divide between these two areas. A small but high-grade production of silver-lead ore came from the Ruby vein on the west side of Red Mountain. The northerly part of the Lincoln Gulch area is a much pyritized iron-stained rock, probably of volcanic origin, in which small stringers with galena and sphalerite are common. Occasional molybdenite flakes also are present in the pyritized rock. The western and southern parts of the area are granite and schist with small veins carrying lead, silver, and occasional small though rich lenticular bodies of chalcopyrite with gold.

In 1938 and 1939 a total of 6 tons were shipped that averaged 15 percent lead, 8 ounces of silver, and about 0.7 ounce of gold per ton in recovered metals.

Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.

Gunnison National Forest Map.

Vanderwilt, J. W. Personal files.

Roaring Fork (Aspen, Richmond Hill, Lenado)

T. 10 S., R. 84 W. (See pl. 4.)

Altitude 7,800 to 10,000 feet.

Aspen is 42 miles on State 82 southeast of Glenwood Springs, and the principal mines are located within a mile of the town in the valley of Roaring Fork. Richmond Hill, 4 miles to the south, and Lenado (T. 9 S., R. 84 W.) on Woody Creek, 6 miles to the northeast, are generally considered as parts of the Aspen district.

The Paleozoic sedimentary formations, striking north to northeast and dipping westerly, rest on pre-Cambrian granite and schist of the Sawatch Range to the east. The Castle Creek fault striking north to northwest is to the west. The relative displacement on the east or Aspen side of this fault was up fully 5,000 feet. Related folding and faulting played an important role in controlling later localization of ore bodies.

Spurr interpretated the ore parallel to bedding as being in contact veins. The contacts he regarded as bedding faults along which large displacement had occurred. More recent studies indicate that folding, faulting, and brecciation probably related to the movement on the Castle Creek fault played an important part in creating the openings that were necessary for ore deposition.

Aspen is famous for its rich silver production. Important quantities of lead have also been produced and zinc is conspicuous throughout the district, but pyrite is not plentiful. Minor quantities of gold are present. The chief gangue mineral is barite and dolomite.

The total production has been about $105,000,000, and 95 to 98 percent of this amount has come from the Aspen district alone. This production came from several stratigraphic horizons but relatively the important horizon was the contact of the Leadville (Mississippian) dolomite and overlaying "Weber" (Pennsylvanian) shale to the north of the valley and Leadville dolomite and overlying Leadville limestone on the south side of the valley. In recent years the biggest production has come from Richmond Hill, where silver-lead ore occurs in the Weber shales close to a porphyry sill east of the Castle Creek fault. Second in importance has been lime-fluxing ore with silver and lead taken from old stopes in the mines south of Aspen and shipped to Leadville.

Pitkin County

Roaring Fork (Aspen, Richmond Hill, Lenado) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Total				
1932	1	1	4,100		2	2	45,901	45,901		228,000		$ 19,833
1933	2	1	3,677	1	7	8	68,860	68,860		178,000		30,849
1934	5		9,784				121,094	121,094	900	411,000	233,000	103,581
1935	3		15,880				174,208	174,208		543,300	250,000	157,944
1936	2		26,692				198,311	198,311		666,000	200,000	194,228
1937	6		35,437				165,404	165,404	700	832,000	105,000	183,938
1938	4		27,934				190,569	190,569	500	440,000	160,000	151,165
1939	4		24,083				210,138	210,138	1,200	530,200	176,000	176,835
1940	4		37,483				266,614	266,614	2,000	585,000	168,000	229,652
1941	5		24,088				238,773	238,773	2,000	807,000	254,000	235,079
1942	5		16,842	1		1	286,131	286,131	1,000	629,800	284,000	272,236
1943	4		17,746	2		2	302,386	302,386	2,600	686,000	408,000	310,952
1944	5		14,625	5		5	126,232	126,232	1,200	465,000	352,000	167,430
1945	5		18,518				78,362	78,362		336,000	201,000	107,735

Aspen Quad., 1:62,500, contours 100 ft., ed. 1910.
Mt. Jackson Quad., 1:125,000, contours 100 ft., ed. 1911.
Gunnison National Forest Map.
White River National Forest Map.

Emmons, S. F., Preliminary notes on Aspen, Colo.: Colorado Sci. Soc. Proc., vol 2, pp. 251-277, 1888.

Rohlfing, D. P., The Colorado mineral belt and the Aspen mining district, Pitkin County, Colo.: Colorado Min. Assoc. Min. Year Book 1937, vol. 25, pp. 16-17, 62-64, 90, 1938.

Spurr, J. E., Geology of the Aspen mining district, Colo.: U. S. Geol. Survey Mon. 31, XXXV, 260 pp., atlas, 1898.

Spurr, J. E., Ore deposition at Aspen, Colo.: Econ. Geology, vol. 4, pp. 301-320, 1909; Min. World, vol. 31, pp. 749-752, 1909.

Vanderwilt, J. W, Revision of structure and stratigraphy of the Aspen district, Colo., and its bearing on the ore deposits: Econ. Geology, vol. 30, no. 3, pp. 223-241, 1935.

Snowmass

Tps. 10 and 11 S., R. 86 W. (Not shown on pl. 4.)
Altitude 10,000 to 12,000 feet.

Snowmass Creek heads in the precipitous slopes on the north side of Snowmass Mountain and flowing northerly it joins Roaring Fork at Snowmass Post Office 15 miles northwest of Aspen on State 82. Ranch roads follow the first several miles of the valley, but the last 4 or 5 miles where the prospects are at the head of the creek can be reached only by trail.

Mineralization at the head of Snowmass Creek is probably related to the quartz monzonite stock, of which Snowmass Mountain is the high point; Hagerman Peak and Capital Peak are parts of this stock. Not only on Snowmass Creek but in adjoining streams the sedimentary rocks near the monzonite are metamorphosed to some extent, and locally small veins with lead, zinc, and copper are present. No production is reported.

Gunnison National Forest Map.

Rio Grande County

Embargo (see Saguache County)
Jasper (Decatur)

T. 37 N., R. 5 E., New Mexico Principal Meridian. (See pl. 4.)
Altitude 9,000 to 9,500 feet.

The prospects and mines are about half a mile west of Jasper. Jasper is on Alamosa Creek about 30 miles southwest of Monte Vista. The county road from Alamosa Creek joins State 15 fourteen miles south of Monte Vista (on U. S. 160 and 285.) The Jasper road is fair to good.

Jasper is in the north part of an area that includes Stunner, Platoro, and Lake Fork in Conejos County, throughout which the general geology is the same.

The rocks are varieties of latite and andesite of the San Juan volcanic series. Much pyrite has been deposited over extensive areas and partial oxidation of the pyrite has produced iron-

Rio Grande County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Total Value
1870-08.........				111,542		111,542	174,581	174,581	93,459	43,588	$2,526,401
1909-23.........	1,692			2,862		2,862	1,620	1,620	30,546	3,422	30,508
1924-31.........	5,751	1–4		25,901		25,901	7,957	7,957	5,392	62,837	544,749
1932-41.........	273,161	1–2	1	101,701	6	101,707	229,724	229,724	298,000	1,400	3,749,639
1942-45.........	21,045	1–2	1	11,498	2	11,500	10,485	10,485	127,800	1,500	425,926
CRUDE ORE SHIPPED TO SMELTERS											
1909-23.........	193					425		1,311	30,546	3,422	
1924-31.........	76					5,462		233		1,600	
[1]1932-41.........	1,313					2,845		1,765		200	
1942-45.........	8					47		64		700	
ORE TO GOLD AND SILVER MILLS											
		Bullion Gold	Bullion Silver		Concentrates Tons	Concentrates Gold		Concentrates Silver	Concentrates Copper	Concentrates Lead	
1909-23.........	1,499	745	309								
[2]1924-31.........	1,045	19,663	1,083		5	32		75			
1932-41.........	271,848	52,223	125,916		10,003	46,633		102,043	298,000	1,200	
1942-45.........	21,037	4,299	1,605		1,562	7,152		8,816	127,800	800	
ORE TO CONCENTRATING MILLS											
1909-23.........											
[3]1924-31.........	4,630				109	744		6,566	5,392	61,237	
1932-41.........											
1942-45.........											

[1]Production in 1933, 1935, and 1938.
[2]No production for 1924, 1925, and 1926.
[3]Production for years 1925, 1929, and 1930.

stained outcrops. The pyrite is not accompanied by economic metals. Quartz stringers and veins of considerable size carry erratic concentrations of gold, lead with silver, and lead with zinc. The minerals in the veins are chiefly quartz and pyrite with some enargite, galena, and sphalerite.

Relatively little production is credited to the area.

Conejos Quad., 1:125,000, contours 100 ft., ed. 1922.

Rio Grande National Forest Map.

Patton, H. B., Geology and ore deposits of the Platoro-Summitville mining district, Colo.: Colorado Geol. Survey Bull. 13, pp. 105-108, map, 1918.

Summitville

T. 37 N., R. 4 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 11,000 to 12,000 feet.

Summitville is at the head of Whightman Fork, a tributary of Alamosa Creek. The shortest road to the district is about 26 miles southwest from Del Norte, but the longer route, about 43 miles, by way of State 15 from Monte Vista to a highway following Alamosa Creek is generally used.

The Summitville district is characterized by numerous north-northwest, south-southeast trending veins, or vein zones, and some cross veins, cutting thick quartz latite porphyry flows, occurring along the contacts, and cutting later latite porphyry dikes. Vein walls are not always sharp, and, in places, broad, mineralized shear zones permit the use of opencut stopes 20 to 40 feet, or more, in width. The potash feldspar crystals of the latite are often partly, or entirely dissolved out, and intense silicification has occurred; small quartz and barite crystals commonly line the cavities formerly filled with feldspar. The known ore exposures and veins extend throughout one and a half miles from north to south and for about a mile from east to west on both sides of South Mountain. Gold is the principal metal, and the highest concentrations often occur where the veins cross the contacts of these porphyry dikes, or in the vicinity of vein junctions.

The most productive zone, to date, has been the oxidized interval from the surface down to between 300 and 450 feet. In this oxidized zone free gold with traces to several ounces of silver are characteristic, and phenomenally rich free gold ore in substantial quantities was produced.

The free gold ores gradually change to sulfide ores that consist of quartz impregnated with varying amounts of copper-bearing sulfide minerals carrying gold with a slightly greater content of silver. Cupriferous pyrite, enargite and covellite are the chief copperbearing minerals, although chalcopyrite and chalcocite are locally present. The copper content in the sulfide ores varies from 0.5 percent to 10 percent or higher, while the gold content varies from about 0.1 to 1.0 ounce per ton; locally, the ore carries several ounces in gold.

Rio Grande County

Summitville District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Total			
1932	2	1	2	5	4	9	7	7			$ 188
1933	2	1	27	186	2	188	28	28		200	3,920
1934	2		5,702	1,201		1,201	2,393	2,393	6,000		44,004
1935	1		34,946	8,119		8,119	12,423	12,423	45,000		296,829
1936	1		49,459	12,989		12,989	25,271	25,271	70,000		480,632
1937	1		36,440	15,369		15,369	34,053	34,053	29,000	1,200	567,849
1938	2		37,207	19,769		19,769	50,855	50,855	10,000		725,757
1939	1		43,039	14,445		14,445	53,460	53,460			541,863
1940	1		39,026	12,637		12,637	37,215	37,215	130,000		483,449
1941	1		27,313	16,979		16,979	14,019	14,019	8,000		605,178
1942	1	1	14,970	5,497	2	5,499	7,186	7,186	93,400	800	208,930
1943	1		3,350	3,287		3,287	1,402	1,402	17,000		118,252
1944	2		1,777	2,154		2,154	1,222	1,222	15,000	700	78,340

The Jack Pickens-Judge Wiley Lease, just prior to July 1, 1931, produced $501,261.42 in gross smelter returns from 864 tons of shipping ore, with an average value of $580.16 for each ton shipped, with gold at $20 per ounce.

The camp is connected with a high tension power line and is well-equipped, including a modern combination amalgamation, flotation and cyanide milling plant with a capacity of between 200 and 250 tons per day. In addition there is a gold retort plant for reducing the gold amalgam, and gold zinc precipitates, to bullion for direct shipment to the U. S. Mint.

Summitville Quad., 1:125,000, contours 100 ft., ed. 1915.

Rio Grande National Forest Map.

Emmons, W. H., The enrichment of sulphide ores: U. S. Geol. Survey Bull. 529, pp. 226-227, 1913.

Patton, H. B., Geology and ore deposits of the Platoro-Summitville mining district, Colo.: Colorado Geol. Survey Bull. 13, pp. 65-88, 1918.

Garrey, G. H. Private communication.

Routt County

Copper Ridge

T. 7 N., R. 84 W. (Not shown on pl. 4.)

Altitude 7,500 to 8,000 feet.

This area is 4 to 7 miles north of Steamboat Springs. Maps do not show a road into the district; slopes are steep so that access probably is not easy.

Copper mineralization is said to occur in the Dakota sandstone that crops out in a north-trending hogback.

No production is reported.

Hahns Peak Quad., 1:125,000, contours 100 ft., ed. 1913.

Hoklas, W. I., Steamboat Springs, Colorado, Personal communication.

Hahns Peak (Columbine)

T. 10 N., R. 85 W. (See pl. 4.)

Altitude 8,500 to 10,500 feet.

Hahns Peak Post Office is 22 miles on State 129 north of Steamboat Springs and Columbine is 4 miles farther north. The general area is characterized by heavy wooded steep slopes, and access is difficult to areas away from the main road. Snowfall is heavy.

Laccoliths of rhyolite, latite, and andesite porphyry with sill-like extensions occur in the Dakota sandstone and Mancos shale of Cretaceous age. Elevation, folding, and faulting of the beds accompanied the intrusions. Beneath the Cretaceous formations are beds of red sandstone and shale (Carboniferous) and Morrison (Jurassic) beds resting on pre-Cambrian granite and schist that crop out to the east. Dikes extending from the laccoliths are common, and a few miles north of Columbine an unusual distribution of basalt dikes occur in the Tertiary beds. An irregular mass of diorite crops out in the pre-Cambrian rocks several miles east

Routt County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Placer	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
[1]1873-08				753	16,046	16,799			17,505	7,823	131,922		$464,122
[2]1909-23	950			159	1,855		11,047	204		32,303	7,614		
1924-31													
1932-41	23	1	2–20	6	230	236	1,063	104	1,167	400	8,600	3,000	9,417
1942-45	1,784	1		11		11	2,226		2,226	13,400	46,000	348,800	46,866
CRUDE ORE SHIPPED TO SMELTERS													
1909-23	594					74			8,356	32,303	7,614		
1924-31													
[3]1932-41	9					2			444	200	3,600		
1942-45													
ORE TO GOLD AND SILVER MILLS		Bullion: Gold	Bullion: Silver		Concentrates: Tons	Concentrates: Gold			Concentrates: Silver	Concentrates: Copper	Concentrates: Lead	Concentrates: Zinc	
1909-23	50	38	12										
1924-31													
[4]1932-41	2	2	76										
1942-45													
ORE TO CONCENTRATING MILLS													
1909-23	306				41	47			2,679				
1924-31													
[5]1932-41	12				8	2			543	200	5,000	3,000	
1942-45	1,784				449	11			2,226	13,400	46,000	348,800	

[1]For Routt and Moffat Counties. No production from 1875 to 1881.
[2]Placer gold and silver includes Routt and Moffat Counties.
[3]Production in 1936 only.
[4]Production in 1934 only.
[5]Production in 1937 only.

Routt County

Hahns Peak (Columbine) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1933		2			8	8		3	3				$ 174
1934	1	20	2	2	47	49	76	23	99				1,772
1935		8			32	32		8	8				1,126
1936	1	11	9	2	28	30	444	9	453	200	3,600		1,587
1937	1	9	12	2	23	25	543	12	555	200	5,000	3,000	1,832
1938		4			41	41		19	19				1,447
1939		7			24	24		13	13				849
1945	1		494	4		4	696		696	3,600	14,000	126,000	16,815

of Hahns Peak. Metamorphism consists chiefly of varying degrees of induration of the sandstone and shale.

Mineralization is concentrated in the porphyry in small irregular veins and impregnations. The ores consist of galena with silver and gold with some copper. High values are required for profitable operation and therefore emphasis has been on gold. Some rich ore has been shipped in small quantities.

Placer gold is found in extensive deposits of gravel along several streams south of Hahns Peak (see pl. 4), and certain areas have been worked intermittently on a small scale since an early date. The problems encountered are low-grade values, small size of gold particles, water supply, and tailings disposal.

Hahns Peak Quad., 1:125,000, contours 100 ft., ed. 1913.

Routt National Forest Map.

Gale, H. S., The Hahns Peak gold field, Colo.: U. S. Geol. Survey Bull. 285, pp. 28-34, map, 1906.

George, R. D., and Crawford, R. D., The Hahns Peak region, Routt County, Colo.: Colorado Geol. Survey 1st Rept. 1908, pp. 189-229, map (1909).

Oak Creek

T. 4 N., R. 85 W. (Not shown on pl. 4.)

Altitude 7,000 to 7,500 feet.

Oak Creek is about 20 miles, on State 131, southwest of Steamboat Springs.

Shale and sandstone of Cretaceous age cover the area. Copper is reported, but the nature of its occurrence is not known.

White River National Forest Map.

Rock Creek (Gore Range)

Tps. 1 and 2 N., Rs. 82 and 83 W. (Not shown on pl. 4.)

Altitude 9,500 to 11,000 feet.

This area is 16 miles east of Yampa, and this coincides with the head of Rock Creek in the Gore Range. The road (State 84) crosses Rock Creek about 10 miles east of Toponas and the head of the stream is about 5 miles north of the road.

The Gore Range is pre-Cambrian granite and schist. Prospecting has been done in various places; unconfirmed reports are that small amounts of lead, zinc, and copper have been found. Also unconfirmed is a legend of lost mines and "Spanish diggings." No production is reported and data are lacking as to the nature of the occurrences.

Arapahoe National Forest Map.

Routt National Forest Map.

Slater (or Three Forks)

T. 12 N., R. 86 W. (Not shown on pl. 4.)

Altitude 6,500 feet.

This district is near the junction of South Fork, Independence Creek, and Little Snake River near the Colorado-Wyoming

State line about 40 miles northwest of Steamboat Springs. Access to the area is over State 129.

Tertiary sedimentary formations cover most of the area, with the underlying pre-Cambrian granite and schist cropping out in the northerly part near the State line and farther north in Wyoming.

According to unpublished reports, northwest-trending veins one to three feet wide with steep dips occur in the schist. The principal metals are lead and silver with some copper and gold.

No production is reported.

Routt National Forest Map.

Slavonia

T. 10 N., R. 83 W. (See pl. 4.)

Altitude 9,000 to 10,000 feet.

Slavonia is at the head of Elk River in the Park Range east of Hahns Peak. The road (State 129) from Steamboat Springs to Hahns Peak follows Elk River about 18 miles. A road is not indicated for the remaining 10 to 12 miles to Slavonia but most likely some of this distance is by trail. Local inquiries should be made at Steamboat Springs and Hahns Peak.

The district is in pre-Cambrian gneiss that grades into gneissoid granite and schist. Acid dikes cut the older rocks.

Quartz lenses and stringers, related to zones of movement and shearing, to some extent parallel to schistosity, carry chalcopyrite, galena, and sphalerite. Some silver and gold are present. Production is limited to trial shipments.

Routt National Forest Map.

George, R. D., and Crawford, R. D., The Hahns Peak region, Routt County, Colo.: Colorado Geol. Survey 1st Rept. 1908, p. 227, map, 1909.

Spring Creek (Steamboat Springs)

T. 6 N., R. 84 W. (Not shown on pl. 4.)

Altitude 7,000 to 7,500 feet.

This is in the vicinity of Steamboat Springs. Considerable prospecting was done at a fairly early date, but the presence of metal sulfides has not been confirmed.

Hoklas, W. I., Steamboat Springs, Colorado, Personal communication.

Yarmony

T. 1 S., R. 83 W. (See pl. 4.)

Altitude 7,000 to 7,500 feet.

This area is 3 to 5 miles north of State Bridge. State Bridge is 14 miles north of Wolcott on U. S. 24 and 6 about half-way between Glenwood Springs and Leadville.

Occurrences of copper (carbonate) are reported to the north and south for several miles of Yarmony as shown on plate 4, and also to the east about 6 miles in the vicinity of Radium (Red Gorge district) in the adjoining township in Grand County.

The area is in the approaches to the west flank of the Gore Range where faulting is common, and green copper stain and nodules of malachite are found in a fractured zone in Paleozoic beds. Considerable prospecting has been done.

Near what is known as Copper Spur on the Denver and Rio Grande Railroad is a copper refinery that operated about 1915 to 1920. Ore was obtained about 3 miles to the northeast from pockets of azurite with some chalcopyrite found in sandstone. In addition to this attempted production, occasional small shipments of copper ore have been reported.

Although mineralization in the granite of the Gore Range has not been reported, such occurrences would not be surprising.

Arapahoe National Forest Map.

Saguache County

Blake (Mirage, Cotton Creek)

T. 45 N., R. 11 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 11,000 feet.

The Blake area is at the head of Cotton Creek in the west slopes of the Sangre de Cristo Range, 10 miles northeast of Mirage. Mirage is about 14 miles in a straight line due east of Saguache in San Luis Valley and a few miles east of State 17. The last half of the road to the area is not dependable.

The geologic conditions at Blake are comparable to those described for the Crestone area also in Saguache County several miles to the southeast, to which reference can be made for a description. The quality of the veins at Blake are reported as somewhat less than at Crestone.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Blake (Mirage, Cotton Creek) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1934	2	111	41	65	300	1,000	$1,543
[1]1935	1	20	8	•			264
[2]1936	1	5	6	17	140	370	239
[1]1938	2	7	2	3	500		114
[1]1939	1	3	1	1	200		57

[1]Blake district only.
[2]Music district only.

Saguache County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Gold (fine ounces) Lode	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1880-08			9,473	9,473	1,235,131	1,235,131	296,237	4,863,088	404,504	$1,434,471
1909-23	82,899		3,400	3,400	726,370	726,370	1,125,780	5,976,771	667,644	1,342,083
1924-31	477,810	2–12	4,050	4,050	3,168,831	3,168,831	12,485,037	23,282,397	1,963,400	5,298,421
1932-41	29,980	5–13	1,869	1,869	335,287	335,287	1,639,300	1,903,200	104,000	576,920
1942-45	28,569	6–10	422	422	152,228	152,228	245,900	2,898,900	2,836,600	680,428
CRUDE ORE SHIPPED TO SMELTERS										
1909-23	16,406			2,942		460,794	618,302	2,522,898	148,543	
1924-31	978			90		23,978	34,182	278,228	14,400	
1932-41	17,472			458		325,301	1,617,283	1,763,445		
1942-45	3,250			71		48,724	114,975	947,866	132,101	

ORE TO GOLD AND SILVER MILLS

Year	Ore (short tons)	Bulion Gold	Bulion Silver	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
1909-23	21	18	2						
[1]1924-31	26	87	61						
1932-41	10,301	344	457	181	1,042	473	600	1,110	
1942-45	10,757	56	1,294	1,201	159	17,494	23,352	389,906	527,217

ORE TO CONCENTRATING MILLS

Year	Ore (short tons)	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
1909-23	66,472	11,108	440	265,574	507,478	3,453,873	519,101
1924-31	476,806	81,708	3,873	3,144,792	12,450,855	23,004,169	1,949,000
[2]1932-41	2,207	501	25	9,056	21,417	138,645	104,000
1942-45	14,562	4,561	136	84,716	107,573	1,561,128	2,177,282

[1]Production for 1928, 1929, 1930, and 1931.
[2]Production from 1937-1941.

Cochetopa Creek

T. 48 N., R. 2 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,250 to 8,750 feet.

Mineralization referred to Cochetopa Creek begins 2 miles south of Parlin in Gunnison County to about 8 miles in Saguache County. Parlin on U. S. 50 is 13 miles east of Gunnison. The road up Cochetopa Creek is poor.

Scattered veins are found over an area 2 to 4 miles wide and about 6 miles along Cochetopa Creek. The country rock is pre-Cambrian granite and schist. The veins are relatively small and contain primarily gold. A small production is reported.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Crestone (Baca Grant)

T. 43 N., R. 12 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 7,500 to 8,000 feet.

Crestone is 15 miles east of Moffat, and Moffat on State 17 is 39 miles north of Alamosa. The road from Moffat to Crestone is usually good.

Crestone is in a band 3 to 6 miles wide of pre-Cambrian rocks on the western side of the Sangre de Cristo Range. Gravels of San Luis Valley cover these rocks to the west, and Paleozoic sedimentary rock are present at the crest of the range several miles to the east. Scattered occurrences of gold mineralization occur in areas in this belt. Crestone seems to be at the center of such an area that extends several miles to the northwest and southeast. The Blake area on Mirage Creek and the Music or Liberty area, both listed in Saguache County have gold mineralization similar in type to that at Crestone.

Crestone (Baca Grant) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Total Value
1932	3	17	14				$ 294
1934	1	3	2	1			63
1935	1	4,431	729	256	300		25,724
1936	2	3,658	297	183	140	610	10,559
1937	2	1,590	156	40			5,495
1938	2	361	97	31			3,429
1939	1	39	42	22			1,485

The veins in the Crestone area are along shear zones roughly parallel to the schistosity and in irregular fractures. The chief value is in free gold with considerable pyrite. Minor amounts of chalcopyrite, sphalerite, and galena are present.

Considerable mining was effected prior to 1900. With one or two exceptions the ore bodies have been small, although in places quite rich.

Rio Grande National Forest Map.

San Isabel National Forest Map.

Crystal Hill

T. 42 N., R. 6 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,000 to 8,300 feet.

This locality is on Carnero Creek about 2 miles west of La Garita. La Garita is 13 miles on a good county road (State 375) northeast of Del Norte (U. S. 74).

The rocks of the area are volcanic flows common to the San Juan region. Scattered minor veins are present. Crystal Hill is a local brecciated area, possibly in the form of a chimney or pipe, with small quantities of free gold. Considerable development has been done but only a minor production is reported.

Del Norte Quad., 1:125,000, contours 100 ft., ed. 1917.

Gunnison National Forest Map.

Rio Grande National Forest Map.

Embargo Creek

T. 41 N., R. 4 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 8,500 to 9,000 feet.

Mineralization along Embargo Creek extends a few miles on either side of the Saguache-Rio Grande County line. Embargo Creek joins the Rio Grande at Granger 9 miles on U. S. 160 west of Del Norte. Mineralization occurs over an interval of about 4 miles beginning about 3 miles north of Granger.

The Embargo Creek area consists of andesites and latites in the Potosi volcanic series that occur over large areas in the San Juan Mountains. It is reported that the prospects show gold with silver, lead, and copper, presumably in veins. No production is reported in recent years.

Creede Quad., 1:125,000, contours 100 ft., ed. 1916.

Rio Grande National Forest Map.

Kerber Creek (Bonanza)

Tps. 46 and 47 N., R. 8 E., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,500 to 10,000 feet.

Bonanza is on Kerber Creek in the Cochetopa Hills at the northwest end of San Luis Valley. The road along Kerber Creek joins Villa Grove on U. S. 285. Villa Grove is 20 miles northeast

Saguache County

Kerber Creek (Bonanza) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	1	4	3	21				$ 68
1933	4	105	3	1,490	3,000	68,000		3,293
1934	3	8		147		1,000		136
1935	5	199	2	4,384	17,700	61,500		7,146
1936	4	928	13	16,130	64,720	277,720		31,684
1937	8	5,002	122	94,146	481,000	361,000	16,000	157,628
1938	7	7,989	159	124,791	735,500	227,000		168,752
1939	8	2,504	46	48,771	247,800	240,000		71,766
1940	13	1,528	30	27,059	62,000	345,000	26,000	46,186
1941	8	1,414	24	17,678	26,000	319,600	62,000	39,346
1942	8	4,793	60	41,292	36,400	878,600	663,600	156,448
1943	10	11,434	216	36,464	50,500	796,000	891,000	195,983
1944	6	5,311	70	27,149	45,000	625,000	500,000	134,831
1945	6	7,030	76	47,302	114,000	599,000	782,000	193,131

of Saguache and 27 miles by road south of Salida. The road into the area is fair to good, but the general area is mountainous and access to specific localities may be difficult.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 443-46.

Gunnison National Forest Map.

San Isabel National Forest Map.

Burbank, W. S., Geology and ore deposits of the Bonanza mining district, Colo.: U. S. Geol. Survey Prof. Paper 169, 166 pp., map, 1932.

Patton, H. B., Geology and ore deposits of the Bonanza district, Saguache County, Colo.: Colorado Geol. Survey Bull. 9, 136 pp., maps, 1916.

Music (Liberty)

T. 25 S., R. 73 W. (See pl. 4.)

Altitude 8,000 to 9,000 feet.

This area is on Arena Creek, and access probably is by way of ranch roads from Crestone. Crestone is about 15 miles east of Moffat on State 17 and about 45 miles northeast of Alamosa.

Music is in reality the southeast part of, and the geologic conditions are similar to, the Crestone area to which reference can be made for the limited information that is available.

Rio Grande National Forest Map.

San Isabel National Forest Map.

San Juan County

Animas

T. 41 N., Rs. 6 and 7 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,300 to 13,000 feet.

The Animas district covers both sides of the Animas River valley immediately northeast of Silverton. Silverton on U. S. 550 known as the "million-dollar highway" is 52 miles north of Durango and 34 miles south of Ouray. U. S. 550 passes through a rugged mountainous territory, and the highway is characterized by sharp curves and somewhat narrow cuts along precipitous slopes bordering the valley. Snowfall is heavy during the winter through March and even April. The road along the valley of the Animas River east of Silverton is good, but many of the mines and prospects, not in the immediate valley, may be 500 to 2,000 feet on steep slopes above the level of the valley and therefore difficult to reach.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 431-33.

Silverton Quad., 1:62,500, contours 100 ft., ed. 1902.

Rio Grande National Forest Map.

San Juan National Forest Map.

Uncompaghre National Forest Map.

San Juan County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold: Placer	Gold: Total	Silver (fine ounces): Lode	Silver: Placer	Silver: Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1873-08...				823,423		823,423	20,952,685		20,952,685	34,958,775	196,825,083	2,982,186	$45,404,953
1909-23...	1,885,923			275,325		275,325	7,698,892		7,698,892	15,065,723	119,601,210	49,372,498	24,976,938
1924-31...	2,330,005	9–17		161,177		161,177	6,291,315		6,291,315	14,054,520	128,754,802	153,033,000	27,591,867
1932-41...	2,294,523	9–33	1–5	207,595	378	207,973	4,212,301	186	4,212,487	10,931,700	38,325,500	18,224,000	13,086,923
1942-45...	772,305	11–19	1	88,756	1	88,757	1,261,156		1,261,157	1,887,000	19,659,000	4,736,000	6,288,728
CRUDE ORE SHIPPED TO SMELTERS													
1909-23...	78,712					30,268			3,304,797	3,913,761	18,540,167	1,475,295	
1924-31...	2,563					974			105,515	76,372	1,126,344		
1932-41...	4,820					7,972			123,854	55,217	1,278,228	2,000	
1942-45...	700					78			5,474	5,447	125,741	2,380	
ORE TO GOLD AND SILVER MILLS													
		Bullion			Concentrates								
		Gold	Silver		Tons	Gold			Silver	Copper	Lead	Zinc	
1909-23...	600,181	63,624	24,507										
[1]1924-31...		648	333										
1932-41...	690	988	463										
1942-45...	5,259	42	894		1,457	136			14,190	25,910	481,526	706,040	
ORE TO CONCENTRATING MILLS													
1909-23...	1,207,030				186,812	181,433			4,369,588	11,151,962	101,061,043	47,897,203	
1924-31...	2,327,442				350,737	159,555			6,185,467	13,978,148	127,628,458	153,033,000	
1932-41...	2,289,013				119,696	198,635			4,087,984	10,876,483	37,047,272	18,222,000	
1942-45...	766,346				29,551	88,500			1,240,589	1,855,643	19,051,733	4,027,580	

[1]Production in 1930 and 1931.

San Juan County

Animas District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	8		191,023	28,275		28,275	491,177		491,177	1,568,000	1,239,000		$ 858,966
1933	10	5	199,611	23,443	12	23,455	389,630	2	389,632	1,184,000	1,198,400		741,331
1934	11	3	210,421	16,268	21	16,289	301,233	6	301,239	819,200	2,048,000		905,349
1935	13	3	177,262	14,679	6	14,685	276,978	3	276,981	624,000	2,415,500		861,453
1936	22		203,972	21,540		21,540	425,831		425,831	991,300	3,082,400		1,316,692
1937	16		219,849	22,504		22,504	379,188		379,188	868,000	4,242,000	188,000	1,448,482
1938	17	2	219,194	20,640	5	20,645	377,366		377,366	1,360,600	1,992,600	263,000	1,204,152
1939	14		198,036	15,278		15,278	268,769		268,769	995,000	1,915,300	1,147,000	970,310
1940	17		224,668	15,034		15,034	301,895		301,895	703,400	4,942,800	2,787,000	1,243,076
1941	17		264,246	17,105		17,105	527,490		527,490	868,000	6,090,300	1,663,000	1,548,075
1942	12	1	197,048	17,077	1	17,078	391,794		391,794	572,900	4,248,000	757,000	1,300,677
1943	11		201,295	21,188		21,188	323,706		323,706	492,600	5,313,800	948,500	1,536,782
1944	7		175,117	28,450		28,450	228,015		228,015	337,000	4,472,000	1,153,000	1,692,591
1945	7		194,862	21,870		21,870	301,957		301,957	453,400	5,225,000	1,590,200	1,673,607

Bear Creek

T. 40 N., R. 6 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 11,000 to 13,000 feet.

This district is shown in Prof. Paper 138 on the Continental Divide at the head of Vallecito Creek, a tributary of Los Pinos River to the south, and the head of Bear Creek, a tributary of the Rio Grande River to the northeast.

The area is in a very rugged part of the San Juan Mountains, 19 miles east of Silverton mostly by trail and 50 miles west of Creede on State 149 in Mineral County. Vallecito Creek is accessible only by trail and although the topographic maps show a road up Bear Creek west from Creede, the end of a road is indicated on standard highway maps at Roosevelt Reservoir some 10 to 15 miles east of the area. The best road and trail information probably can be obtained at Creede.

Narrow white quartz fissure veins with gold and silver telluride (probably petzite) and minor quantities of other sulfides occur in faulted, closely-folded pre-Cambrian schist, slate, and quartzite. San Juan andesite tuffs and flows rest upon and partly cover a very irregular eroded surface of the pre-Cambrian rocks. The volcanic rocks have undergone very little noticeable change since their deposition.

It is estimated that the entire area produced about $200,000 in high-grade telluride ores prior to 1905. Production was derived chiefly from rich though small streaks in the veins.

Needle Mountains Quad., 1:62,500, contours 100 ft., ed. 1917.

Rio Grande National Forest Map.

San Juan National Forest Map.

Irving, J. D., and Emmons, W. H., Economic geology (of the Needle Mountains quadrangle, Colo.): U. S. Geol. Survey Geologic Atlas Needle Mountains folio no. 131, pp. 12-13, 1905.

Prosser, W. C., The Bear Creek sylvanite camp (near Silverton), Colo.: Eng. and Min. Jour., vol. 91, p. 712, 1911.

Eureka (Cement Creek, Mineral Creek, Animas Forks)

T. 42 N., Rs. 6 and 7 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,800 to 13,000 feet.

The conditions of access for the Eureka district are the same as described for the Animas district also in San Juan County, which it joins on the northeast. The town Eureka is on the Animas River 10 miles northeast of Silverton.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 435-37.

Silverton Quad., 1:62,500, contours 100 ft., ed. 1902.

Rio Grande National Forest Map.

San Juan National Forest Map.

Uncompaghre National Forest Map.

San Juan County

Eureka (Cement Creek, Mineral Creek, Animas Forks) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	1		28	93		93	18		18				$ 1,923
1933	2		1	20		20	10		10				409
1934	5		68	303		303	1,773		1,773	100	3,000	2,000	11,945
1935	2	1	111	1,109	334	1,443	5,262	175	5,437		2,700		54,535
1936	2	1	172	581	2	583	4,036		4,036	100	2,500		23,637
1937	4		64,010	2,595		2,595	105,174		105,174	234,000	2,438,000	3,668,000	582,760
1938	3		112,358	5,841		5,841	267,953		267,953	660,000	5,982,700	8,286,000	1,115,269
1939	4		442	781		781	6,298		6,298	6,800	28,400	19,000	34,640
1940	13		5,358	917		917	42,369		42,369	17,000	154,600	93,100	77,740
1941	7		967	279		279	5,172		5,172	2,000	48,600	12,000	17,349
1942	3		288	8		8	2,039		2,039	1,400	39,200	23,400	6,701
1943	7		741	26		26	3,084		3,084	4,900	78,800	53,000	15,374
1944	3		1,376	60		60	3,527		3,527	8,000	92,500	92,000	23,576
1945	4		1,062	39		39	2,915		2,915	10,600	117,500	86,000	24,956

San Juan County

Ice Lake Basin District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Silver (fine ounces) Lode	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1938	1	173	3[illegible]	2,393	400	35,700		$ 4,264
1939	2	793	93	11,083	11,200	148,300		18,913
1940	3	1,604	147	18,398	18,600	280,600	90,900	40,087
1941	1	19		69	•	6,100	5,000	772
1942	1	68	8	824	700	9.800	3,600	1,943
1943	1	64	3	308	500	4,400	2,500	989
1944	1	202	13	1,485	3,000	29,500	13,000	5,758
1945	1	182	14	1,502	2,000	28,500	13,000	5,774

Ice Lake Basin

T. 41 N., Rs. 8 and 9 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 11,500 to 12,500 feet.

Ice Lake Basin is in a very rugged mountainous area at the head of South Fork of Mineral Creek about 7 miles west of Silverton. About 5 miles to the north and across a high divide is the Ophir district in San Miguel County. A poor road follows South Fork to the ghost town of Bandora, but the trail from the valley up to Lake Basin is steep. Not only is access to the Basin difficult but the area itself is hard to prospect.

Telluride Quad., 1:62,500, contours 100 ft., ed. 1904.

San Juan National Forest Map.

Uncompaghre National Forest Map.

San Miguel County

Klondyke

T. 43 N., R. 16 W., New Mexico Principal Meridian. (Not shown on pl. 4.)

Altitude 6,000 to 6,500 feet.

The Klondyke area is at the head of Gypsum Valley north of Cedar on State 161 and a few miles south of State 80. Cedar is a small community but it is shown on most maps. For details as to access local inquiries are necessary. The area is isolated and has a sparce population.

Klondyke, commonly referred to as a basin, lies southeast of a gypsum plug. The prevailing rocks are Dakota sandstone with overlying Mancos shale and underlying Morrison shale. The general area is best known for the vanadium that occurs in the Morrison formation. Copper minerals occur intermittently along faults that traverse the area, and native copper replacing limestone has been observed at several places. Relatively little prospecting has been done.

In 1939 a trial shipment of 5 tons yielded 68 ounces of silver and 1,700 pounds of copper. No other production is recorded.

Montezuma National Forest Map.

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, p. 221, 1921.

Lower San Miguel (Placerville, Sawpit, Newmire)

T. 43 N., Rs. 10 and 11 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 7,300 to 8,500 feet.

Placerville is 14 miles northwest of Telluride. Sawpit and Newmire are between the two, and all are in the valley of the San Miguel River. The valley itself is easily accessible, but places even short distances away from the valley may be difficult to reach.

San Miguel County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
[illegible]...				1,439,193	9,105	1,448,298			24,989,430	4,834,938	74,169,265	970,086	$51,906,251
[illegible]...	6,610,527			1,427,859	21	1,427,880	17,693,289	4	17,693,293	11,846,775	102,643,924	17,171,096	52,252,030
[illegible]...	1,904,960	10–23	4	291,469	11	291,480	5,071,735		5,071,735	1,375,253	46,697,001	1,404,000	12,872,924
[illegible]...	1,149,072	15–36	2–30	146,892	532	147,424	2,607,820	242	2,608,062	999,700	15,275,500	86,000	7,732,520
[illegible]...	681,342	4–9	2	79,958	19	79,977	970,785	7	970,782	1,400,800	14,439,700	7,776,000	5,648,854
CRUDE ORE SHIPPED TO SMELTERS													
[illegible]...	14,810					5,469			680,464	379,841	6,276,203	98,030	
[illegible]...	3,995					5,212			276,180	64,300	1,902,554		
[illegible]...	7,700					5,558			98,360	48,385	632,343	33,000	
[illegible]...	19					5			917		3,900		

ORE TO GOLD AND SILVER MILLS

	Ore	Bullion Gold	Bullion Silver	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
1909-23...	5,815,309	870,602	3,999,888						
1924-31...	1,699,688	99,661	73,159	138,184	178,643	3,643,851	461,885	29,388,009	456,000
1932-41...	871,326	46,591	45,330	73,462	77,278	1,721,551	219,226	11,722,601	
1942-45...	430,705	20,087	12,004	40,999	38,976	502,954	212,379	8,651,287	4,861,000

ORE TO CONCENTRATING MILLS

	Ore	Concentrates Tons	Concentrates Gold	Concentrates Silver	Concentrates Copper	Concentrates Lead	Concentrates Zinc
1909-23...	780,408	442,915	551,788	13,012,937	11,466,934	96,367,721	17,073,066
1924-31...	201,277	23,515	7,953	1,078,545	849,068	15,406,438	948,000
1932-41...	270,046	16,675	17,465	742,579	732,089	2,920,556	53,000
1942-45...	250,618	19,870	20,890	454,910	1,188,421	5,784,513	2,915,000

San Miguel County

Lower San Miguel (Placerville, Sawpit, Newmire) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Lead (pounds)	Total Value
1932		7			21	21		4	4		$ 432
1933		8			61	61		18	18		1,261
1934		19			50	50		16	16		1,749
1935	2	12	6	3	25	28	32	11	43	200	1,037
1936	2	9	36	9	10	19	439	5	444	1,890	1,124
1937	1	6	6	3	10	13	37	3	40	1,800	578
1938		5			6	6		3	3		219
1939		11			10	10		9	9		356
1940		6			5	5					175
1941		1			7	7		3	3		247

The Sawpit mineralization is found along an 8-foot bed of limestone. Chief values are silver and lead with gold. The ore is highly oxidized so that the original character of the mineralization is obscured, but the deposits are unlike those that characterize the Telluride district to the west.

Placer operations along the San Miguel River are small sluicing operations which yield relatively little gold. The gold content of the gravels is low, and the gold is fine but the gold is widely distributed.

Telluride Quad., 1:62,500, contours 100 ft., ed. 1904.

Uncompaghre National Forest Map.

Purington, C. W., Preliminary report on the mining industries of the Telluride quadrangle, Colo.: U. S. Geol. Survey 18th Ann. Rept., pt. 3, pp. 745-848, map, 1898.

Mount Wilson

T. 42 N., R. 10 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 12,000 to 13,000 feet.

Mount Wilson (alt. 14,250 ft.) and Wilson Peak (alt. 14,026 ft.) are two prominent peaks on the divide between San Miguel and Dolores Counties about 15 miles southwest of Telluride. The more important mines and prospects are on the west slope of Wilson Peak at the head of Big Bear Creek that joins the San Miguel River about 8 miles to the north of Newmire. Newmire on State 108 is 8 miles west of Telluride. The altitude at Newmire is 7,800 feet, making the rise to the mineralized area 4,200 to 5,200 feet. Needless to say, access is difficult and the high altitude makes for high mining costs.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to page 428.

Telluride Quad., 1:62,500, contours 100 ft., ed. 1904.

Montezuma National Forest Map.

Uncompaghre National Forest Map.

Ophir (Iron Springs, Ames)

Tps. 41 and 42 N., R. 9 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 9,000 to 11,000 feet.

Ophir is on Howard Fork, a tributary of the San Miguel River. The district extends from Ames (on State 145 and 9 miles southwest of Telluride) east for 6 miles to Iron Springs. The slopes to the north and south of the Howard Fork valley rise 2,000 to 3,000 feet in a horizontal distance of 1 to 2 miles. The road along the valley is usually fairly good, but the adjoining slopes are very steep and difficult for either prospecting or mining.

San Miguel County

Mount Wilson District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Total Value
1932	3		12	25		25	11		11			$ 521
1933	1		5	17		17	3		3			348
1934	1	1	1	3	3	6	5	1	6			230
1935	2		13	53		53	139		139		350	1,967
1936	2		22	74		74	222		222		840	2,808
1937	3		45	115		115	198		198	200	300	4,206
1938	4		29	99		99	153		153	200	300	3,598
1939	3		15	103		103	286		286	200	900	3,862
1940	2		5	21		21	17		17			747
1941	2		1	7		7	7		7			250

San Miguel County

Ophir (Iron Springs, Ames) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932..	7	2	708	285	3	288	170		170				$ 6,003
1933..	8		400	219		219	548		548	300	4,300	1,000	4,930
1934..	11		136	115		115	4,269		4,269	2,550	43,800	1,000	9,679
1935..	7		157	114		114	8,889		8,889	3,950	18,750		11,440
1936..	8		3,986	297		297	38,470		38,470	13,500	294,700		54,988
1937..	3		8,965	542		542	43,108		43,108	15,100	104,700	10,000	60,975
1938..	7	1	16,322	1,126	11	1,137	145,360	5	145,365	62,800	468,800		161,473
1939..	4	1	23,161	1,247	2	1,249	174,567		174,567	88,800	550,700	12,000	197,951
1940..	6		12,199	1,076		1,076	82,731		82,731	34,100	333,600	14,000	117,906
1941..	9	1	178	101	1	102	2,662		2,662	2,000	17,400		6,691
1942..	2		19	5		5	917		917		3,900		1,088
1945..	1		3	1		1							35

San Miguel County

Upper San Miguel (Telluride) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	15	1	1,075	2,971	11	2,982	4,553	7	4,560	1,000	21,000		$ 63,617
1933	13	3	23,208	3,361	29	3,390	22,969	22	22,991	27,700	244,000	16,000	89,590
1934	24	10	66,399	5,991	81	6,072	62,594	53	62,647	109,650	349,200	32,000	275,792
1935	17	11	81,408	11,557	22	11,579	163,854	7	163,861	101,050	840,900		565,075
1936	11	7	85,766	11,786	54	11,840	128,053	22	128,075	37,500	836,570		555,547
1937	11	5	78,841	10,934	11	10,945	161,032	5	161,037	155,000	1,020,200		586,577
1938	13	7	108,568	15,846	47	15,893	326,151	17	326,168	75,000	1,770,900		855,908
1939	11	6	179,435	28,541	52	28,593	402,049	31	402,080	119,300	2,977,400		1,426,027
1940	7		223,305	26,241		26,241	386,266		386,266	69,900	2,555,400		1,328,782
1941	10		234,651	23,981		23,981	447,843		447,843	76,500	2,816,600		1,327,374
1942	7		178,984	23,446		23,446	314,903		314,903	78,800	3,432,800	780,000	1,356,614
1943	4		162,556	20,204		20,204	210,763		210,763	142,000	4,149,000	2,426,000	1,448,659
1944	5		154,784	18,542		18,542	169,650		169,650	138,000	2,883,000	1,655,000	1,207,550
1945	6	2	184,996	17,760	19	17,779	274,552	7	274,559	1,042,000	3,971,000	2,915,000	1,634,908

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 425-27.

Telluride Quad., 1:62,500, contours 100 ft., ed. 1904.

Montezuma National Forest Map.

San Juan National Forest Map.

Uncompaghre National Forest Map.

Upper San Miguel (Telluride)

T. 42 N., Rs. 8 and 9 W., New Mexico Principal Meridian. (See pl. 4.)

Altitude 10,000 to 12,000 feet.

Telluride is at the end of State 108 in the valley of the San Miguel River, and 36 miles by State 62 and 108 southwest of Montrose. The mines are 2 to 6 miles to the east and southeast and 1,000 to 3,000 feet above the valley. Access to the mines is difficult but the higher costs were more than offset by the rich ore.

The Sneffels district to the northeast near Ouray is only a few miles in a straight line, but the intervening high divide separates the two areas. The Treasury tunnel with its portal 10 miles south of Ouray has crosscut under the Black Bear mine in the southern part of the area.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 421-25.

Telluride Quad., 1:62,500, contours 100 ft., ed. 1904.

San Juan National Forest Map.

Uncompaghre National Forest Map.

Summit County

Breckenridge (Bevan, Union, Minnesota, Blue River, Swan River, Illinois Gulch, French Gulch, etc.)

Tps. 6 and 7 S., R. 77 W. (See pl. 4.)

Altitude 9,500 to 11,000 feet.

The area is about 5 miles square east and northeast of Breckenridge, the county seat and supply center for the district. Breckenridge is 38 miles by State 91 and 9 northeast of Leadville. The road to the district is good; but as is common in most mountainous areas in Colorado, many slopes adjoining accessible valleys are difficult to reach. The short distance to the Leadville smelter is a favorable feature.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 421-24.

Breckenridge Special Quad., 1:24,000, contours 50 ft., ed. 1910.

Arapahoe National Forest Map.

Pike National Forest Map.

White River National Forest Map.

Summit County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly: Lode	Mines Producing Yearly: Placer	Gold (fine ounces): Lode	Gold (fine ounces): Placer	Gold (fine ounces): Total	Silver (fine ounces): Lode	Silver (fine ounces): Placer	Silver (fine ounces): Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1859-08				217,486	388,968	606,454			11,701,433	767,041	118,015,871	17,945,297	$28,665,847
1909-23	627,924			31,603	287,100	318,703	1,795,071	76,966	1,872,037	298,085	35,689,794	119,200,263	20,355,711
1924-31	182,113	5–23	5–21	4,476	34,906	39,382	306,740	8,832	315,572	113,623	12,217,773	21,045,600	3,382,008
1932-41	34,246	7–40	49–97	6,307	26,578	32,885	306,105	6,844	312,949	62,000	1,977,600	2,007,000	1,534,947
1942-45	110,766	17–22	2–11	4.473	1,500	5,973	249,106	390	249,496	71,800	5,019,200	14,307,400	2,373,110
CRUDE ORE SHIPPED TO SMELTERS													
[illegible]	115,098					16,801			1,029,150	221,779	7,843,621	14,079,354	
[illegible]	11,460					1,347			176,419	113,300	1,509,285	111,200	
[illegible]	12,159					4,806			211,078	28,040	1,163,584	121,974	
[illegible]	1,256					416			18,567	3,342	292,206	357,900	
[illegible] TO GOLD AND SILVER MILLS													
		Bullion: Gold	Bullion: Silver		Concentrates: Tons	Concentrates: Gold			Concentrates: Silver	Concentrates: Copper	Concentrates: Lead	Concentrates: Zinc	
[illegible]	17,783	9,035	4,313										
[illegible]	17,853	771	3,586		175	232			9,250	13,233	82,859		
[illegible]	9,278	575	752		170	98			393		4,060		
[illegible]	36,008	371	2,496		5,505	1,440			47,830	31,912	1,336,884	3,275,120	
[illegible] TO CONCENTRATING MILLS													
[illegible]	495,043				200,275	5,767			761,608	76,306	27,846,173	105,120,909	
[illegible]	447,147				151,014	3,301			366,868	92,090	24,821,357	84,841,400	
[illegible]	12,809				3,666	828			93,882	33,960	809,956	1,885,026	
[illegible]	73,502				15,659	2,246			180,213	36,546	3,390,110	10,674,380	

...luction for 1926 includes Summit and Eagle Counties.

...luction from 1924 through 1929 includes Summit and Eagle Counties.

Summit County

Breckenridge (Bevan, Union, Minnesota, Blue River, Swan River, Illinois Gulch, French Gulch, etc.) District
Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short tons)	Gold (fine ounces)			Silver (fine ounces)			Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode	Placer		Lode	Placer	Total	Lode	Placer	Total				
1932	6	48	5,517	242	1,329	1,571	1,131	340	1,471	700	1,000		$ 32,974
1933	7	54	540	382	3,034	3,416	1,395	780	2,175		26,300		72,347
1934	7	91	269	214	7,639	7,853	1,850	1,924	3,774	700	38,000		278,345
1935	15	77	557	357	4,788	5,145	8,448	1.240	9,688	7,050	79,850		190,800
1936	14	64	867	520	2,449	2,969	13,286	633	13,919	6,100	60,900	96,000	122,840
1937	13	57	5,137	1,041	2,562	3,603	51,585	635	52,220	10,800	198,000	377,000	203,998
1938	8	61	1,020	427	1,415	1,842	27,166	362	27,528	850	43,700	21,000	85,367
1939	16	92	1,748	632	1,260	1,892	10,224	329	10,553	2,500	71,000	98,000	82,076
1940	19	67	3,842	307	1,061	1,368	12,472	322	12,794	400	60,800	23,000	61,512
1941	13	52	1,260	325	894	1,219	11,901	256	12,157	300	35,600	39,000	56,299
1942	5	11	82	66	1,210	1,276	235	315	550	100	400		45,090
1943	6	2	11,469	355	74	429	4,244	21	4,265	16,200	472,200	461,000	105,357
1944	4	2	1,912	276	151	427	9,824	37	9,861	6,600	97,600	635,000	103.046
1945	4		6,910	354	65	419	8,633	17	8,650	14,800	297,100	1,445,000	214,540

Frisco

T. 5 S., R. 78 W. (Not shown on pl. 4.)

Altitude 9,100 to 10,000 feet.

Frisco, a small community on State 91, is 28 miles northeast of Leadville and 4 miles southwest of Dillon. A mile or two west of Frisco, Tenmile Creek emerges from a narrow canyon where the mineralization occurs.

The canyon of Tenmile Creek is in pre-Cambrian schist and gneiss. The canyon walls are steep and the rock is well-exposed over a large part of the surface; consequently fractures and veins are easily recognized. A few scattered veins have been prospected but the known veins have proved too narrow. Gold is said to be the principal value but dumps show considerable sphalerite and galena. Pyrite and quartz constitute the chief gangue minerals although locally dark brown iron carbonate (siderite) is present. Production has been small.

Dillon Quad., 1:62,500, contours 50 ft., ed. 1934.

Arapahoe National Forest Map.

Pike National Forest Map.

White River National Forest Map.

Green Mountain (Wilkinson)

T. 2 S., R. 80 W. (Not shown on pl. 4.)

Altitude 7,500 to 8,500 feet.

Green Mountain is a low mountain in the valley of the Blue River about 12 miles south of Kremmling (U. S. 40). Green Mountain dam recently completed in the Blue River is immediately to the west. Except for the power installation at the dam, Kremmling is the nearest town. State 9 along the valley is fair except during a rainy season.

Mineralization has been found in a small area on the west slope of Green Mountain a few hundred feet above the water level of the reservoir. The producing mine is on a vein at the contact of an irregular quartz monzonite sill with Mancos shale and possibly Dakota sandstone. The igneous contact crosses the east-dipping beds at nearly right angles. The ore is found at the porphyry contact and the harder beds, and several feet away from the contact along favorable beds. The ore consists of galena and sphalerite with silver and a little gold. The stopes are small in cross section and several hundred feet long. The deposit was discovered about 10 years ago and an almost continuous though small production has been maintained since.

Mt. Powell Quad., 1:62,500, contours 50 ft., ed. 1940.

Arapahoe National Forest Map.

White River National Forest Map.

Summit County

Green Mountain (Wilkinson) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1936		2			4	4		1	1				$ 132
1937	2	3	58	13	6	19	2,044		2,044		3,400		2,464
1938	3		209	73		73	11,815		11,815		15,500		10,906
1939	1		363	33		33	16,930		16,930	1,700	15,000	100,000	18,729
1940	4		933	61		61	30,790		30,790	3,900	47,900	487,000	57,547
1941	4		791	25		25	21,496		21,496	2,200	60,800	458,000	54,237
1942	1		387	6		6	2,392		2,392	1,600	7,600	322,000	32,500
1943	2		512	13		13	5,116		5,116	1,000	5,800	207,000	27,014
1944	3		631	18		18	1,855		1,855	600	11,700	207,500	26,621
1945	1		169	1		1	696		696		1,500	51,200	6,547

Summit County

Montezuma (Snake River, Peru) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing	Ore Sold or Treated (short tons)	Gold (fine ounces)	Silver (fine ounces)		Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
	Lode		Lode	Lode	Total				
1933	2	12	2	938	938		5,000		$ 548
1934	4	73	11	1,123	1,123		7,700		1,378
1935	5	95	58	1,760	1,760	950	21,650		4,236
1936	4	475	10	11,778	11,778	6,400	171,000	10,000	18,424
1937	5	194	2	4,839	4,839	1,900	72,600	10,800	9,018
1938	7	2,124	4	16,284	16,284	2,550	259,000	10,000	23,311
1939	7	252	5	5,071	5,071	1,500	73,700		7,237
1940	8	915	11	12,524	12,524	4,700	123,800		16,012
1941	7	1,641	14	13,808	13,808	5,300	178,900	45,000	24,506
1942	9	1,127	20	7,768	7,768	1,800	195,600	96,600	28,531
1943	6	1,360	13	5,985	5,985	2,100	118,000	126,500	27,496
1944	10	2,118	19	11,413	11,413	3,800	232,400	223,500	53,365
1945	8	2,542	11	18,083	18,083	5,000	299,900	54,000	45,920

Montezuma (Snake River, Peru)

Tps. 5 and 6 S., R. 76 W.; T. 5 S., R. 75 W. (See pl. 4.)

Altitude 10,000 to 12,500 feet.

Montezuma is about 40 miles by road northeast of Leadville. Of this distance 33 miles is on State 91, and the last 7 miles is on a good dirt road (State 294).

The mineralized area extends 2 to 5 miles from Montezuma easterly to the Continental Divide and county line between Summit and Clear Creek to east and northeast, and between Summit and Park County to southeast. Montezuma is readily accessible but a relatively large part of the mineralized area is difficult to reach. The winters are long and severe.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 300-02.

Montezuma Quad., 1:62,500, contours 50 ft., ed. 1926.

Arapahoe National Forest Map.

Pike National Forest Map.

Tenmile (Robinson, Kokomo)

T. 7 S., Rs. 78 and 79 W. (See pl. 4.)

Altitude, 10,500 to 12,500 ft.

Kokomo, on State 91, is 19 miles northeast of Leadville. The principal mines are west of Kokomo but mineralization is found along the valley of Tenmile Creek for 2 to 3 miles northeast of Kokomo and to Robinson about 5 miles to the southwest. The divides and peaks on either side of Tenmile valley rise to 12,000 and 13,000 feet so that a considerable part of the area is accessible with difficulty.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 370-78.

Tenmile Mining District Colorado (north and south halves) U. S. Geol. Survey, 1:12,000, contours 25 ft., ed. 1942.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Arapahoe National Forest Map.

Pike National Forest Map.

White River National Forest Map.

Upper Blue River

Tps. 7 and 8 S., Rs. 77 and 78 W. (See pl. 4.)

Altitude 10,000 to 12,000 feet.

This area includes the upper reaches of the Blue River and its tributaries, beginning a few miles south of Breckenridge. It is about 4 by 5 miles centered roughly at the common corner of the four townships listed. State 9 along the valley makes the lower areas easily accessible. Prospects only a mile or two from the highway may be difficult to reach.

Summit County

Tenmile (Robinson, Kokomo) District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing Lode	Mines Producing Placer	Ore Sold or Treated (short tons)	Gold (fine ounces) Lode	Gold Placer	Gold Total	Silver (fine ounces) Lode	Silver Placer	Silver Total	Copper (pounds)	Lead (pounds)	Zinc (pounds)	Total Value
1932	1	1	5	3	27	30	4	4	8				$ 613
1933	5	1	159	90	2	92	307		307		8,000		2,298
1934	7	6	494	174	27	201	1,598	5	1,603		46,600		9,784
1935	8	11	343	212	61	273	1,213	8	1,221		4,000		10,601
1936	5		719	220		220	927		927		1,600		8,491
1937	5	3	902	445	17	462	2,574	4	2,578	1,300	25,000	91,200	25,703
1938	3	1	138	165	1	166	458		458		23,800		7,229
1939	5	1	1,239	61	3	64	2,755	1	2,756		79,300		7,838
1940	9		440	124		124	1,838		1,838		18,500		6,572
1941	6		915	46		46	3,773		3,773	200	99,700	141,000	20,575
1942	2		8,693	200		200	30,091		30,091	8,300	985,600	1,286,800	215,109
1943	7		16,264	402		402	28,163		28,163	7,700	451,000	1,941,500	278,605
1944	5		22,387	1,544		1,544	47,385		47,385	2,000	482,300	2,966,000	464,714
1945	6	6	34,203	1,175		1,175	67,223		67,223	200	1,360,500	4,283,800	698,595

The area generally has not been listed as a district. At Hoosier Pass and North Star Mountain to the south it joins the Montgomery district in Park County. North along the Mosquito Range on the east side of the valley scattered veins continue as far as Breckenridge and even the Frisco district.

No production is reported for recent years but according to unverified reports early production may have been as much as a million dollars.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 343-46.

Mt. Lincoln Quad., 1:62,500, contours 50 ft., ed. 1945.

Pike National Forest Map.

Teller County

Cripple Creek

T. 15 S., Rs. 69 and 70 W. (See pl. 4.)

Altitude 7,500 to 10,500 feet.

Cripple Creek is 42 miles over U. S. 24 and State 67 southwest of Colorado Springs. The most direct route (State 122) is not as far, but this road has not been kept open through the winters; moreover the road is narrow and better suited as a scenic route for tourist travel than for hauling ore. U. S. 24 and State 67 are excellent well-maintained roads summer and winter.

For a summary of the general geology and ore deposits of this district, with selected bibliography, refer to pages 387-95.

Pikes Peak Quad., 1:125,000, contours 100 ft., ed. 1901.

Cripple Creek Special Map, 1:25,000, contours 50 ft., ed. 1895.

Pike National Forest Map.

East Beaver

T. 16 S., R. 68 W. (Not shown on pl. 4.)

Altitude 9,500 to 11,000 feet.

This area is described as 8 miles south of Rosemont. Rosemont is about 10 miles on State 122 southwest of Colorado Springs, but the maps show no road south from Rosemont.

Information is limited to the statement in the U. S. Geol. Survey Bull 507 that copper, gold, and silver are present in veins in pre-Cambrian granite cut by basic dikes.

Colorado Springs Quad., 1:125,000, contours 100 ft., ed. 1909.

Teller County

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Ore Sold or Treated (short tons)	Mines Producing Yearly Lode	Mines Producing Yearly Placer	Gold (fine ounces) Lode	Gold (fine ounces) Placer	Gold (fine ounces) Total	Silver (fine ounces) Lode	Silver (fine ounces) Placer	Silver (fine ounces) Total	Copper (pounds)	Lead (pounds)	Total Value
1891-08......				9,221,827		9,221,827			924,385			$190,627,763
1909-23......	11,145,978			6,445,848		6,445,848	826,154			451	612	134,370,206
1924-31......	3,223,594	36–63	2	1,350,184	13	1,350,197	153,688					28,002,476
1932-41......	4,791,519	80–125	3–13	1,299,446	362	1,299,808	158,417	30	158,447			42,452,024
1942-45......	848,238	19–42		208,970		208,970	28,811		28,811			7,334,438
CRUDE ORE SHIPPED TO SMELTERS												
1909-23......	293,953					662,791			240,546	451	612	
1924-31......												
1932-41......	36					94			36			
1942-45......												
ORE TO GOLD AND SILVER MILLS		Bullion			Concentrates							
		Gold	Silver		Tons	Gold			Silver			
1909-23......	10,798,777	5,626,688	533,449									
1924-31......	3,223,594	1,350,184	153,688									
1932-41......	4,698,165	1,283,706	149,489		13	19			23			
1942-45......	832,729	207,272	27,679									
ORE TO CONCENTRATING MILLS												
1909-23......	53,248				67,740	156,369			52,159			
1924-31......												
[1]1932-41......	93,318				4,014	15,627			8,869			
1942-45......	15,509				1,702	1,698			1,132			

[1]Production for years 1938-1941.

Teller County

Cripple Creek District

Mine Production of Gold, Silver, Copper, Lead, and Zinc in Terms of Recovered Metals

Year	Mines Producing		Ore Sold or Treated (short (tons)	Gold (fine ounces)			Silver (fine ounces)			Total Value
	Lode	Placer		Lode	Placer	Tptal	Lode	Placer	Total	
1932	80	3	312,882	109,347	20	109,367	7,656	7	7,663	$2,262,967
1933	104	7	349,470	109,815	53	109,869	7,700	5	7,705	2,273,878
1934	125	10	425,242	127,901	49	127,950	12,555	1	12,556	4,479,966
1935	122	8	460,448	124,288	36	124,324	13,287	2	13,289	4,360,891
1936	122	13	607,690	141,539	69	141,608	16,541	4	16,545	4,969,101
1937	105	10	498,097	145,002	69	145,071	16,053	5	16,058	5,089,899
1938	106	11	498,357	145,186	30	145,215	15,492	3	15,495	5,092,556
1939	104	6	538,138	133,967	36	134,003	17,705	3	17,708	4,702,125
1940	99		572,554	128,932		128,932	29,828		29,828	4,533,831
1941	99		528,641	133,470		133,470	21,600		21,600	4,686,810
1942	42		377,995	104,455		104,455	15,660		15,660	3,667,061
1943	22		226,908	45,105		45,105	7,543		7,543	1,584,039
1944	20		113,565	30,886		30,886	4,611		4,611	1,084,289

MISCELLANEOUS METALS

Iron and Titanium

Iron deposits in Colorado were thoroughly investigated at an early date. The only commercial production has been limonite ore from the Orient mine briefly described below.

Magnetite (Fe_3O_4) with or without titanium is the most usual form of iron occurrence in the State. Combinations of manganese and iron are found in several places. (See Manganese Deposits.) Irregular bodies of magnetite are found:

1. High on the slopes of Taylor Peak about 20 miles south of Aspen and near the Gunnison-Pitkin County line. The magnetite is a product of contact metamorphism of limestone.

2. Near White Pine in the Tomichi mining district in Gunnison County. Limonite bog iron is present but the larger deposits are magnetite resulting from contact metamorphic replacement usually of limestone near a granite contact.

3. In the Russell mining district in Costilla County. The magnetite is contact metamorphic in origin.

4. On Caribou Hill, Boulder County. The magnetite with titanite is found as segregations in basic intrusions. The titanium dioxide content probably as ilmenite varies from a few to over 30 per cent.

5. At Iron Mountan in the Grape Creek district (see pl. 4.) southwest of Canon City in Fremont County. Ilmenite (titanium) is intimately intergrown with magnetite in veins 10 to 50 feet wide.

6. On Cebolla Creek in Gunnison County. The magnetite is titaniferous and occurs with specular hematite.

The contact metamorphic magnetite deposits are usually too low in iron content and too high in sulfur and silica content to meet the rigid requirement of the iron and steel making. The ore bodies are too small to warrant special metallurgical treatment and in addition they are located in mountainous areas so that transportation and mining costs are prohibitive.

The titanium-iron ore might some day receive further consideration should the demand for titanium increase greatly as some believe it will.

The only production of limonite as an iron ore in Colorado has come from a deposit in limestone in Saguache County. Production came from the Orient mine at an altitude of about 9,000 feet in T. 46 N., R. 10 E. Orient is at the foot of the Sangre de Cristo Mountains east of the San Luis Valley, and the area is shown on the maps of the San Isabel and Rio Grande National Forests.

Geologically the ore deposits are very interesting. Although production beginning in 1881 was continuous for over 50 years, the total production has been only about 2,000,000 gross tons. Production of limonite ore was stopped several years ago in favor of hematite ore from Wyoming.

Workable bodies of limonite ore are confined to the lower part of the Leadville (Mississippian) limestone. The limestone strikes north and dips 40° to 50° east with variations due to local minor folds. The ore bodies are irregular lenses or pipes with their long axes either parallel to or at large angles with the dip of the bedding. Ore has developed over a vertical range of 1,000 feet, and some bodies have a horizontal section of 80 by 200 feet. It is believed that the iron was introduced by ascending solutions. The particular carbonate responsible for the iron has not been definitely identified although ankerite is present.

Leith, C. K., Iron ores of the western United States and British Columbia: U. S. Geol. Survey Bull. 285, pp. 194-200, 1906.

Woolsey, L. H., Lake Fork extension of the Silverton mining area, Colo.: U. S. Geol. Survey Bull. 315, pp. 26-30, 1907.

Harder, E. C., The Taylor Peak and White Pine iron-ore deposits, Colo.: U. S. Geol. Survey Bull. 380, pp. 188-198, 1909.

Jennings, E. P., Titaniferous iron-ore deposits in Boulder County, Colo.: Am. Inst. Min. Eng. Bull. 70, pp. 1045-1056, 1912; Trans. 44, pp. 14-25, 1913.

Singewald, J. T., The iron ore deposits of the Cebolla district, Gunnison County, Colo.: Econ. Geology, vol. 7, pp. 560-573, 1912.

Argall, P. B., Siderite and sulphides in Leadville (Colorado) ore deposits: Min. Sci. Press, vol. 109, pp. 50-54, 128-134, 148, 1914.

Umpleby, J. B., Manganiferous iron ore occurrences at Red Cliff, Colo.: Eng. Min. Jour. 104, pp. 1140-1141, 1917.

Henderson, C. W., Geology of the northern magnetic deposit, Caribou, Boulder County, Colo.: U. S. Bureau Mines Tech. Paper 439, pp. 4-7, 1929.

Stone, J. B., Limonite deposits at the Orient mine, Colorado: Econ. Geology, vol. 29, no. 4, pp. 317-329, 1934.

Vanderwilt, J. W., Geology and mineral deposits of the Snowmass Mountain area, Gunnison County, Colo.: U. S. Geol. Survey Bull. 884, p. 70, 1937.

Manganese

Manganese ores have been thoroughly investigated in Colorado. The known deposits are too small to be of national importance as a source of manganese in the steel industry. Not only are the known deposits small but they are too low-grade except for particular and unusual demands that develop from time to time. The only outlet for manganese ore in Colorado has been the iron plant of the Colorado Fuel and Iron Company at Pueblo.

The manganese deposits in Colorado are in veins and brecciated zones, as replacement bodies, and original bedded deposits enriched by subsequent oxidation; examples of the latter are reported in western San Miguel County. (See also Denver Basin deposits, page 490.)

The veins and brecciated zones are the most numerous. The manganese may occur alone or in association with silver and gold or other sulfides, as in the Cripple Creek, Ouray, and Rico mining districts. Manganese without other metals occurs in veins 10 miles north of Salida. The vein type of occurrence has proved of little importance.

Replacement deposits occur at Red Cliff in the oxidized parts of zinc-pyrite zones and at Leadville in oxidized lead-silver deposits. In each locality the manganese ore was derived from oxidization of manganiferous siderite in limestone of Carboniferous age. Considerable manganese has been shipped from the Leadville district and several million tons of low-grade ore are believed to remain, which constitutes a potential mineral resource for future mining when economic conditions become favorable.

Manganese oxide is found in narrow veins and stringers in the volcanic rocks near Rabbit Ears a few miles north of Rabbit Ears Pass. This occurrence though interesting mineralogically has no reported production of manganese ore.

Bulletin 15 of the Colorado Geological Survey is devoted to manganese deposits in the State. A dozen or more localities are listed and briefly described. None of these deposits under ordinary conditions is commercial either as to grade or size except those in the Leadville district already referred to.

Muilenburg, G. A., Manganese deposits of Colorado: Colorado Geol. Survey Bull. 15, 76 pp., 1919.

Jones, E. L., Some deposits of manganese ores in Colorado: U. S. Geol. Survey Bull. 715, pp. 61-72, 1921.

Crawford, R. D., and Gibson, Russell, Geology and ore deposits of the Red Cliff district, Colorado: Colorado Geol. Survey Bull. 30, p. 50, 1925.

Hedges, J. H., Mineral industries survey of the United States; Colorado, Lake County; Possibilities of manganese production at Leadville, Colo.: U. S. Bureau Mines Inf. Circ. 7125, 23 pp., July 1940.

Mercury

Cinnabar (HgS), the ore mineral of mercury, has been reported in various places in Colorado, but the quantity is so small it would be difficult to verify most of the occurrences. The most recent discovery is in T. 47 N., R. 2 E. (see pl. 4), Saguache County, on Cochetopa Creek about 20 miles south on State 114 from its junction with U. S. 50 east of Gunnison.

The cinnabar is associated with vein quartz and pyrite apparently in a breccia. The breccia is quartzite or a silicified porphyry. Occasional boulders of relatively high-grade ore have been found, but the character of the mineralized rock in place remains to be determined. A heavy surface cover has made exploration difficult. Development is by trenches, cuts, and a shaft 72 feet deep. Cinnabar in place is said to have been cut in the shaft at 60 feet. Further development is planned.

No topographic map of the area is available, but the area is within the boundary of the Gunnison National Forest Map.

Molybdenum

Molybdenite, the ore mineral of molybdenum, is found in many places in the State. In Bulletin 14 of the Colorado Geological Survey occurrences are listed and briefly described in each of 25 counties. The most common occurrence is conspicuous plates of molybdenite scattered through pegmatite characteristic of the pre-Cambrian granite and gneiss. Molybdenite is also common in small quantities in quartz veins in pre-Cambrian rocks and later porphyry dikes, sills, and stocks.

An interesting observation regarding quartz veins that carry conspicuous amounts of molybdenite is that they seldom contain commercial quantities of gold. Copper (chalcopyrite) is the most common associating mineral found with molybdenite, and hubnerite is probably second to chalcopyrite. Small quantities of galena with silver may occur in molybdenite veins. Pyrite and quartz are the most common gangue minerals associated with molybdenite. These mineral associations apply not only for molybdenite occurrences in Colorado but they hold for most areas in the United States.

Of all the molybdenite deposits in Colorado only the Climax mine in Lake County and the one at Urad mine in Clear Creek County have produced important quantities of molybdenite. During the first World War the Urad mine was the first to produce substantial quantities of molybdenite concentrate, but only Climax became and remained outstanding. It is doubtful that any of the other known occurrences of molybdenite in the State could compete with established production.

The intent of this report is to stress mineral resources that may be of interest for future development; developed mines are not in this category. However, the molybdenite mines are of such interest that an account of the mineral resources of the State would be incomplete without a brief summary of the molybdenite at both Climax and at Urad.

CLIMAX

Climax, strictly speaking, is a post office and a store, but the name has come to mean the Climax mining camp and mine, which is wholly owned and operated by the Climax Molybdenum Company.

Climax is on Fremont Pass on the Continental Divide in northeastern Lake County and 13 miles north and 7 miles southeast from the Leadville and Kokomo mining districts, respectively. A large cave resulting from the extraction of a little over 40,000,000 tons of ore marks the position of the deposit on the southwestern slope of Bartlett Mountain about 1 mile east of Fremont Pass. The cave is 100 to 300 feet deep, 600 to 800 feet wide, and the outside rim is about 9,000 feet long.

Bartlett Mountain is a high round-topped mountain on the north side of Tenmile Amphitheater, a prominent glacial cirque in the west side of the Mosquito Range. This cirque is bounded by Ceresco Ridge on the south and high peaks on the east that form the Continental Divide easterly from Fremont Pass. The elevations vary from 11,320 feet at the Pass to over 14,000 at the crest of the Mosquito Range.

The molybdenite deposit is in an area of pre-Cambrian granite and schist intruded by dikes of quartz monzonite porphyry. A stock of the same type of rock played an important role in the localization of the molybdenite mineralization. The pre-Cambrian rocks are bounded to the west by the northwest-trending Mosquito Fault. West of the fault are folded and crushed Pennsylvanian "Weber" shales with arkosic sandstone and an occasional bed of limestone. The portal of the Phillipson tunnel is about 1,800 feet west of the Mosquito Fault, and the entire camp including the mill is in the area of sedimentary rocks.

An area about a mile in diameter in Tenmile Amphitheater shows a conspicuous surface iron stain which marks the outside limits of mineralization. The iron stain and highly altered character of the rock is evident throughout the extent of the cave referred to above. The ore body and thus the cave also is centrally located in the mineralized area.

Mining has been confined to the upper part of the ore body where it is cone-shaped and enlarged downward. On the Phillipson level the outside diameter of the cone is 2,500 to 3,000 feet, but a central area 1,500 to 1,800 feet across is not ore. The boundaries between ore and waste are gradational. Thus the ore zone in plan is a circular band or zone 300 to 500 feet wide. It dips away from the center at 45° to 80° from the surface down to about the Phillipson level below which the dips steepen and in places reverses. Below and in part inside the ore zone described, a second ore body occurring largely in the porphyry stock has been explored by means of diamond drilling and drifting on the 500 level 500 feet below the Phillipson level. The area of mineralization has been explored with mine workings to a depth of about 1,300 feet below the highest surface outcrops (altitude 12,200 feet). Much diamond drilling has been done in this interval and several holes have been drilled a thousand feet deeper.

Mineralization is characterized by fine-grained quartz replacement on a large scale of the granite, schist, and porphyry stock. In the central core of waste referred to above, this fine-grained quartz replacement has obliterated all but indistinct remnants of the original rock. The highest molybdenite concentrations surround the quartz area. The molybdenite is fine-grained and occurs in countless criss-crossing quartz veinlets that give the rock the appearance in places of a breccia. In the ore zone considerable secondary orthoclase occurs in addition to fine-grained quartz replacement, but as a rule the original rock can be identified. Farther outward in a broad marginal zone the number of molybdenite-quartz veinlets and the quartz replacement decrease and mineralization gradually dies out.

At depth the central quartz area gives way to porphyry, and a second silicified zone is found at a lower level. A change in the general character of the mineralization has not been found with depth, but changes have been encountered in the relative positions of the areas of complete quartz replacement and areas of greatest molybdenite cencentrations.

The source of the molybdenite is from hydrothermal solutions believed to have come from the same source as the porphyry stock.

Approximately 100,000,000 tons, nearly half of which has already been mined, was developed above the Phillipson level. A new level, 300 feet below the Phillipson level, should make an equal amount available.

A modified block caving system is used at Climax, and the mine and mill capacity is around 15,000 to 18,000 tons daily. During the war 20,000 tons per day were mined and milled for short periods. Climax has been the largest producer of molybdenum in the world and for a number of years accounted for over 80 percent of the total world production. In recent years this percentage has been decreased; molybdenite has become an important by-product of copper mines in the southwestern states. The production of molybdenum from the Climax mine has been as follows:

1924......	156,935	1932......	1,913,375	1939......	21,796,116
1925......	821,757	1933......	5,028,695	1940......	22,782,608
1926......	1,057,367	1934......	8,378,683	1941......	27,751,273
1927......	1,858,228	1935......	10,168,635	1942......	41,852,136
1928......	2,957,845	1936......	15,216,806	1943......	46,133,715
1929......	3,529,295	1937......	22,750,368	1944......	23,608,421
1930......	3,083,511	1938......	28,242,085	1945......	18,525,041
1931......	2,644,399				

URAD

The Urad mine is owned and operated by the Molybdenum Corporation of America. Production of molybdenum began at Urad during the first World War. After the war, however, the Urad mine remained closed until 1942-43 when the present operators acquired the property. A 200-ton flotation mill was erected and production began early in 1944. Early production was probably several hundred thousand pounds of molybdenum. Production figures from the new operation have not been made public.

Urad is in Clear Creek County 9 and 18 miles west of Empire and Idaho Springs, respectively, and only 2 miles from U. S. 40. During the interim the mine was closed, Urad was only a name on old maps. It is now the location of a mine and mill; the workmen commute from nearby towns.

The molybdenite deposit is on the southwest slope of Red Mountain, a high peak with prominent iron-stained outcrops. A quartz monzonite stock about a mile in diameter intruded into pre-Cambrian granite and schist forms the core of the mountain. The granite and schist surrounding the porphyry stock are highly altered, bleached, and probably crushed. This alteration does not seem to be associated with molybdenite mineralization as molybdenite is found only in the area of the mine.

The molybdenite is associated with an east-west trending vein system that dips 45°-50° N. The feldspar in the granite and schist are completely replaced by sericite. Numerous branching veins and cross veins are present and molybdenite tends to be segregated at vein intersections. Pyrite is plentiful everywhere, but quartz is associated with the molybdenite only in the larger veins. Galena and sphalerite occur locally in the main vein and in associated branching veins, some of which also contain rhodochrosite.

The porphyry contact dips nearly vertical so that the vein system intersects it with depth, and this zone of intersection may have controlled localization of the molybdenite.

During early production the objective seems to have been for a small tonnage of relatively high-grade ore, and consequently mining was confined largely close to the main vein or veins. Recent development includes an exploration of the vein walls for larger tonnages of lower-grade ore. Present indications are that in places 50 to 100 feet on each side of the main vein may constitute minable ore.

Worcester, P. G., Molybdenum deposits of Colorado with general notes on the molybdenum industry: Colorado Geol. Survey Bull. 14, 1919.
Butler, B. S., and Vanderwilt, J. W., The Climax molybdenum deposit, with a section on history, production, metallurgy, and development by C. W. Henderson: U. S. Geol. Survey Bull. 846c, 1933.
Vanderwilt, J. W., and King, R. U., Geology of the Climax ore body: Mining and Metallurgy, vol. 27, no. 474, pp. 299-302, June 1946. (This entire issue is devoted to the "Climax Molybdenum Enterprise.")
Vanderwilt, J. W, Private unpublished report (Urad).

Nickel

Nickel as a mineral curiosity is found in a few places in Colorado.• The metal is associated very locally with small copper deposits, believed to be of pre-Cambrian age, found in the eastern slopes of the Colorado Front Range. Considerable prospecting has yielded only minor quantities of nickel ore and only few authenticated occurrences of nickel minerals.

The best known nickel deposit is the Copper King mine near Gold Hill, Boulder County, where nickel was discovered in 1930. A somewhat similar deposit has been opened many years ago in the Gem mine near Canon City in Fremont County.

The nickel deposit of the Copper King mine is a lenticular layer of amphibolite in biotite schist of the Idaho Springs formation of pre-Cambrian age. It is about half a mile from a small batholith of granite. A dikelike body of hornblende-quartz gabbro, related to the granite, is exposed in the lower part of the mine. Many irregular pegmatite dikes cut the schist, amphibolite, and gabbro.

Disseminated intergrowths of pyrite, pyrrhotite, chalcopyrite, and several nickel minerals have replaced the silicate minerals. Samples yield 0.48 to 6 percent nickel, 0 to 0.60 percent cobalt, and a little copper. Oxidized ores average as high as 1.32 to 13.02 percent nickel, 0.27 to 6.22 percent cobalt, and 0.05 to 3.6 percent copper. About 25,000 tons of ore have been blocked by the mine workings and diamond drilling that contain between 2 and 3 percent nickel. The complex geologic relations prevent projections of ore far beyond mine openings and diamond drill holes.

No production is reported.

Goddard, E. N., and Lovering, T. S., Nickel deposit near Gold Hill, Boulder County, Colorado: U. S. Geol. Survey Bull. 931, pp. 349-362, 1942.

Tantalum

The ore minerals of tantalum are tantalite and microlite. Both are pegmatite minerals. For a summary of the general geology and ore deposits of pegmatite minerals refer to page 469.

The chief ore mineral of tantalum until a few years ago was tantalite ($FeTa_2O_6$) as a rule with varying amounts of chemically combined columbite ($FeCb_2O_6$). Chemical analyses are required to determine the percentage of titanium oxide (Ta_2O_5) which determines its market price. Pure columbite and pure tantalite are similar in appearance but the former has a relatively low value compared with market prices of $2-$3 per pound paid for high-grade tantalite.

Tantalite has been produced intermittently and in small quantities in Colorado for many years. It is a heavy shiny black mineral that is easy to recognize. As a rule the mineral has come as a by-product in mining feldspar, but occasionally pockets of ore are discovered in mining feldspar that are large and rich enough to be mined on their own account. The tantalite minerals are scattered irregularly through the pegmatite, and there are no satisfactory guides for prospecting. In all probability, tantalite production in the future as in the past will depend on feldspar mining.

Microlite is not as well-known as tantalite. It is a heavy gray to flesh pink mineral and easily overlooked. The first known attempt made to mine microlite has been from the Brown Derby group of claims in the Quartz Creek district in Gunnison County. In this locality microlite is closely associated with lepidolite. Development was initiated in 1943 and according to Chapman the operation is not expected to exceed 100 to 200 tons of lepidolite concentrates per month. The quantity of microlite expected from this rate of production has not been made public.

The ore is crushed to –20 mesh and actual separation is made in a Humphrey spiral concentrator.

Chapman, E. P., Jr., Address delivered before the annual meeting of the Colorado Mining Association, at Denver, Colorado, on January 26, 1946.

Titanium (See Iron)

Tungsten

For a summary of the general geology and ore deposits of tungsten, with selected bibliography, refer to pages 328-36.

Vanadium

For a summary of the general geology and ore deposits of vanadium, with selected bibliography, refer to pages 451-56.

Uranium

Information concerning uranium is still considered confidential in Government reports. It is common knowledge that in southwestern Colorado uranium is closely associated with vanadium and that the general geology of the two are almost identical. A separate chapter (pages 451-56) describes these vanadium deposits, but carefully avoids mention of uranium in accordance with the above-mentioned regulations.

The uranium-vanadium deposits occur over a large area. (See pl. 4). They first attracted attention for the radium contained, and a considerable quantity of radium was produced prior to 1920 when production from the Belgian Congo lowered prices and the radium industry in Colorado came to an abrupt end. During this period the uranium was not saved and vanadium was a by-product.

The early mining for radium centered around uranium with which the radium is intimately associated. Vanadium was without much value. Rich uranium ore in the form of carnotite was found replacing or filling the core of carbonized logs and disseminated through sandstone. Stopes were seldom large, and frequently the walls of openings left after removal of carnotite ore contained sufficient vanadium content to constitute ore some 20 years later when vanadium was in demand.

Although individual ore bodies are relatively small, the area in which they are found is so extensive that reserves will tend to be limited only by the market value of the metal, and Government restrictions as to sale of uranium ores will probably dictate value. No other area in Colorado is known to have potentially commercial uranium deposits.

The large vanadium deposit a few miles northeast of Rifle in Garfield County and the small mines and prospects found in central Colorado also occur in sandstone somewhat similar to those in southwestern Colorado. However, these vanadium deposits are known to contain subordinate quantities of uranium.

Pitchblende (U_3O_8), the chief source of uranium from Canada and the Belgian Congo, occurs in small quantities in Gilpin County and in the Jamestown area in Boulder County. Production of pitchblende from these areas has not been reported in recent years; even hand specimens are scarce.

Coffin, R. C., Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, 1921.

Vanderwilt, J. W., The occurence of uranium: The Engineers' Bulletin, vol. 29, nos. 10, 11, and 12, October, November, and December 1945.

NONMETALS

EXPLANATORY STATEMENT

The nonmetallic mineral resources are not developed in a manner that compares with metals like gold, silver, copper, lead, and zinc. Metals have stipulated prices, and the accumulation of stocks tends to regulate development and production. The nonmetallic minerals, on the other hand, are often not favored with quoted value for a raw material; supplies of raw materials are usually large, not only in Colorado but also in other states; and manufacturers as a rule own and operate their own deposits.

The cost of a finished product of some nonmetallic materials is made up of relatively high processing charges and a correspondingly low cost usually prevails for the raw material. Furthermore, the accumulation of stocks of raw materials of nonmetallic minerals is not practical beyond a moderate reserve for current needs. Under these conditions the individual prospector is less interested to prospect for new deposits. Producers are more interested in processing and marketing than the source of their raw material. As a result, the fund of overall information as to occurrence, distribution, and reserves of nonmetallic materials is more limited than for metals.

The occurrence in Colorado of more than adequate reserves of a variety of materials is indicated, but in a number of instances development will be held back by a limited demand for the product. Companies or individuals with initiative and ability to develop markets for products using industrial materials or nonmetallic minerals can well afford to consider the occurrences described in the following paragraphs.

Construction material and nonmetallic minerals overlap, and the distinction is more one of convenience than necessity. These subdivisions with the localities of mineral deposits shown on the accompanying index maps (pls. 5 and 6) were taken from parts 2 and 4 (separate maps) of the U. S. Geological Survey's Missouri Basin Studies No. 1. The descriptions, however, include a few commodities and minerals not shown on the index maps.

The localities for the industrial materials and nonmetallic minerals shown on the index maps are those that are considered the most important and those that have been developed to some extent. Thus the index maps do not show the full extent of the areas where further prospecting would be justified should additional or new supplies be desired.

CONSTRUCTION MATERIALS*

Abrasives

Quartz sand and garnet suitable for grinding; volcanic ash and pumicite suitable for polishing and burnishing are found in Colorado. The latter is described under volcanic extrusive rocks. Quartz sand is found everywhere.

Red, brown, and pale green garnet are common minerals. The brown-red varieties are plentiful in places in the pre-Cambrian gneiss and schist. The red-brown and the green garnet is common in contact metamorphic zones related to igneous intrusions of Tertiary age. Massive beds of green garnet 10-40 feet thick are found in the Snowmass Mountain area on the western slope, but the known occurrences are in rugged mountain areas that are not favorable for cheap mining.

The known occurrences of corundum are too limited to be of commercial importance.

Development of these mineral resources would seem to be dependent largely on market, processing and freight costs; the cost of the raw materials are relatively small as compared with the finished product.

Vanderwilt, J. W., Geology and mineral deposits of the Snowmass Mountain area, Gunnison County, Colorado: U. S. Geol. Survey Bull. 884, p. 78, 1938.

Bentonite

Bentonite is a clay composed largely of the mineral montmorillonite. One type of bentonite has the property of absorbing water with an accompanying swelling to several times the original volume. Another type absorbs as much water without an accompanying increase in volume, like ordinary plastic clay. Between these two types there are many gradational products. The swelling type of bentonite has many uses that take advantage of the increase in volume as well as the property of remaining in suspension even in dilute dispersion in water; an important use is a sealing medium against water flow and seepage through porous materials of various kinds. The second or nonswelling type of bentonite has been used in quantity somewhat like fuller's earth for bleaching and clarifying oil.

Small quantities of bentonite of the nonswelling type have been produced almost yearly in Colorado since an early date; however, commercial quantities of the swelling type are not known.

Near Creede in Mineral County a deposit of volcanic ash has been altered to montmorillonite, making it resemble bentonite but which is more like fuller's earth. Some of this material has been worked in recent years for clarifying oil. Other large deposits of a similar nature are reported in Lost Canyon ten miles north of Gunnison in Gunnison County and in the area west of Rosita Hills in Custer County. (See fig. 5.)

Bentonite is an alteration product of volcanic ash and therefore the Tertiary volcanic areas are more or less favorable for its occurrence. The Tertiary Oligocene formations in northern Weld

*Map in colors published recently shows, Construction materials and nonmetallic minerals of Colorado: U. S. Geological Survey, Missouri Basin Studies No. 10, 1947.

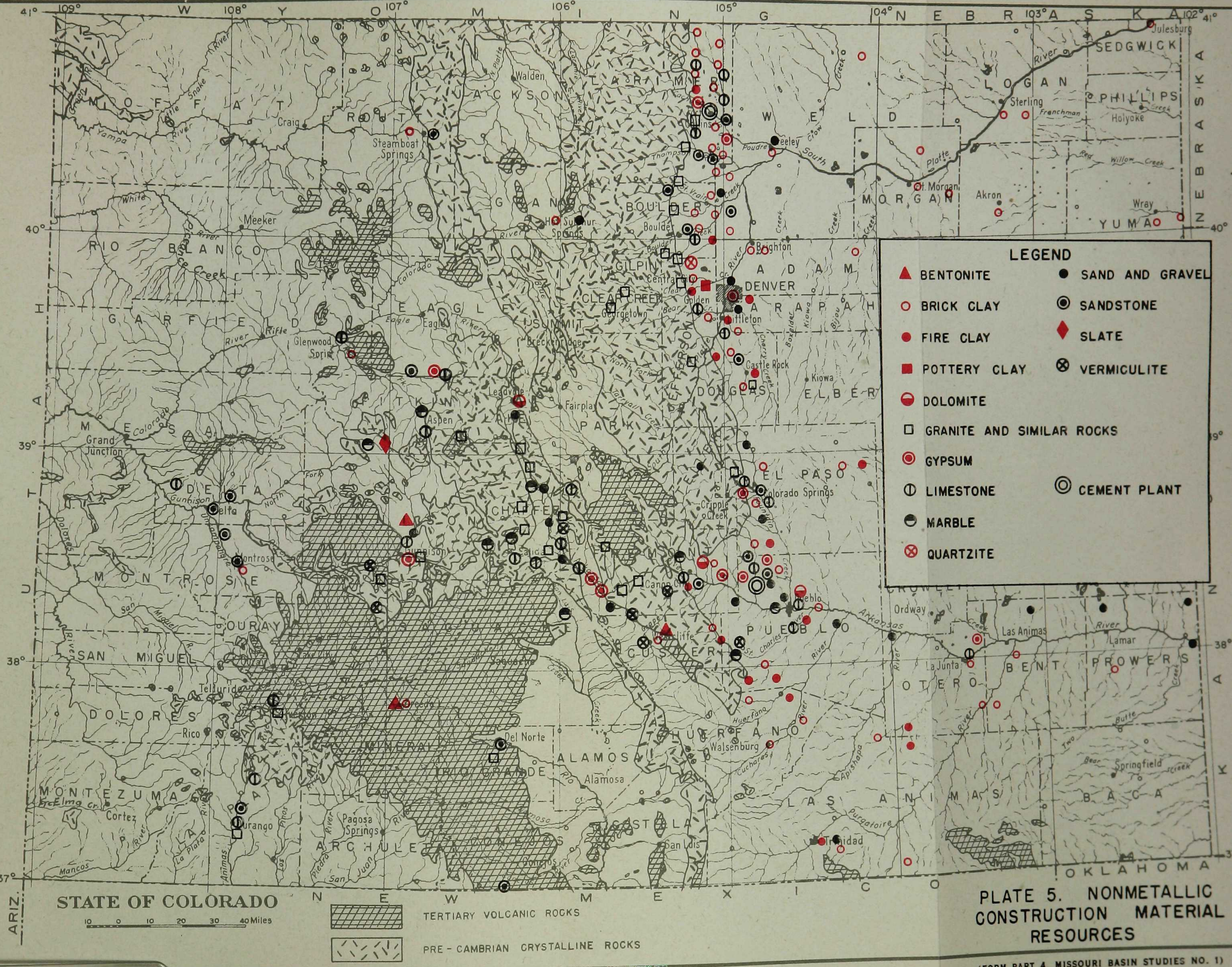

PLATE 5. NONMETALLIC CONSTRUCTION MATERIAL RESOURCES

(FORM PART 4, MISSOURI BASIN STUDIES NO. 1)

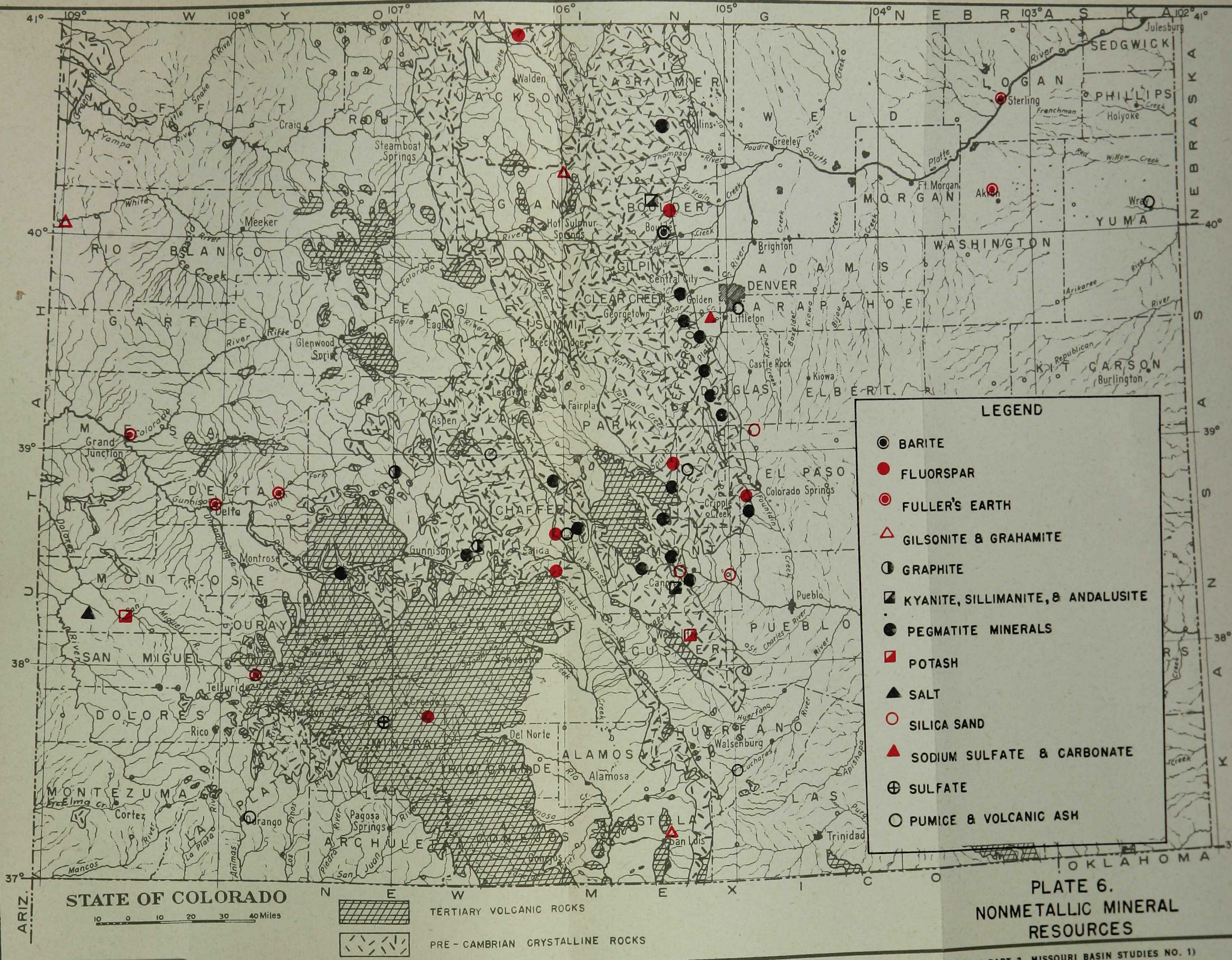

PLATE 6.
NONMETALLIC MINERAL RESOURCES

(FORM PART 2, MISSOURI BASIN STUDIES NO. 1)

and northwestern Logan Counties contain considerable material of volcanic origin, and this area also is favorable for bentonite. The particular area or areas most favorable for bentonite can be determined only through detailed geologic studies. Bentonite products usually require considerable processing. The raw material as it comes from the deposit does not command a high price per ton and therefore a location favorable for cheap mining and low transportation cost is essential.

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Cement Materials

Limestone and shale are the constituents used in the manufacture of Portland cement. In general, cement materials should contain about 75 percent calcium carbonate ($CaCO_3$), 10 percent silica (SiO_2), and 10 percent alumina (Al_2O_3) and iron oxide (Fe_2O_3), allowing about 5 percent of magnesia alkalies and other impurities. These compounds are usually obtained readily by combinations of limestone or marl and shale. Throughout the country cement manufacturers have attempted to find natural mixtures of limestone and shale. If the available limestone is too poor, shale or clay is added. In recent years there has been a tendency in the cement industry to select rock of known composition for mixing to the desired proportions. Cleaning of limestone by means of flotation or washing also is being practiced in places.

In Colorado two large cement plants (see pl. 5), owned by the Ideal Cement Company, have been in operation for a number of years. One plant is at Portland, 40 miles west of Pueblo, and the other is about 6 miles northwest of Ft. Collins. It is understood that present productive capacity of these two mills is approximately 2,000,000 barrels annually, and that the Portland, Colorado, plant is being re-built and enlarged. When this program is finished, the combined productive capacity of the two plants will be 2,800,000 barrels a year.

Each of the cement plants referred to uses Niobrara (Upper Cretaceous) limestone. This limestone is thin-bedded with sufficient shale that is easily available to give the desired proportions of the two rocks. Niobrara limestone is 25 to 50 feet thick and crops out in an almost continuous zone immediately east of the Front Range in Colorado. Where the limestone has an appreciable dip the volume available for cheap quarrying is relatively small. In the vicinity of Colorado Springs the Niobrara limestone is relatively flat and covers large areas. In the western part of the State it is relatively thin and therefore less favorable for cement manufacture. Other limestones, particularly in the Mississippian formation, suitable for cement manufacture are present in the Colorado Springs area and various parts of central Colorado and in the San Juan region. Reserves of limestone and shale suitable for cement manufacture are inexhaustible, and utilization is limited by location and demand for cement. Cement materials are without value until made into cement, and each plant quarries its own raw materials.

Figures as to production of cement in Colorado are not available. However, the indicated consumption in Colorado together with average U. S. price can be used as a basis for estimating production and value, as cement is seldom shipped far. These figures taken from the U. S. Bureau of Mines reports are as follows:

Year	Indicated Consumption In Colorado	Av. mill value per barrel in bulk in U. S.	(Total Value)
1935	596,772	$1.51	$ 901,125.72
1936	1,141,399	1.51	1,723,512.49
1937	1,056,286	1.48	1,563,303.28
1938	856,634	1.45	1,242,119.30
1939	1,170,566	1.47	1,720,717.32
1940	1,028,753	1.46	1,501,979.38
1941	1,520,646	1.47	2,235,349.62
1942	2,204,461	1.53	3,372,825.53
1943	951,031	1.57	1,493,118.67
1944	694,058	1.59	1,103,552.22

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Clay

Much of the clay that covers large areas of Colorado is not usable. To be useful for the manufacture of brick, pottery, and other products, the clay must possess plasticity when wet in order to permit molding; when heated in a furnace the clay must harden without undue shrinkage or change in form; and it must be readily accessible, because the prices paid for raw clays are low.

The most direct source of ordinary clay is shale, which is indurated clay. Clay shale has not undergone much hardening and therefore reverts to usable clay very readily. Ordinary shale requires considerable weathering to revert it to usable plastic clay. In evaluating a deposit of clay, it is important to understand the degree and depth of weathering that has taken place as these factors cause variations in the quality of the clay at shallow depths. The quality of a clay can be determined only from actual furnace tests.

The reserves of various types of clay in Colorado are inexhaustible, and developed deposits are more than adequate to supply anticipated demands. Expansion in the utilization of clay is limited by the demand for finshed products.

Clays are so widespread in their occurrence that producers of cheaper types used for building brick, drain tile, and the like, usually mine the raw clays from their own deposits. Only better types of refractory clay and china clay can profitably be shipped to distant markets. In European countries clays are washed, graded, and processed, and the resulting products command correspondingly higher prices; a considerable tonnage is imported yearly into the United States. Similar practices of clay benefication have been adopted in certain localities in the United States. but thus far not in Colorado. The possibility of processing high-grade clay in Colorado for shipment to markets outside the State merits further study.

Brick Clay

Brick clay is widely distributed in Colorado (see pl. 5) and brick-making is one of Colorado's oldest industries. The brick produced is roughly divisable into two classes with numerous intermediate gradations; building brick that is hard, dense, and requires relatively high furnace temperatures, and what is usually referred to as common brick that is soft, porous, and requires only moderate furnace temperatures. The latter type of brick can be made with inferior types of clay that are available nearly everywhere. Brick clays are found in abundance many places in the State. In addition to brick such clay is suitable for the manufacture of structural tile, some types of terra cotta, and other similar products. The following counties contain brick clays:

Adams	Douglas	Huerfano	Mineral	Routt
Arapahoe	El Paso	La Plata	Montrose	Sedgwick
Bent	Fremont	Larimer	Morgan	Washington
Boulder	Garfield	Las Animas	Otero	Weld
Custer	Grand	Logan	Prowers	Yuma
Delta	Gunnison	Mesa	Pueblo	

In western Colorado, shale in a Mancos formation weathers to clays that make good brick and earthenware. Light-colored beds near the base of the formation are suitable for pink and red press brick. Thin beds of clay shale are associated with the coal beds of the Mesaverde formation. At Durango in La Plata County ordinary red brick has been made from strata about 100 feet below the lowest coal seams in the Mesaverde. The development of the clay industry has been retarded in western Colorado because of distance to larger markets. Enormous bodies of usable clays remain practically untouched.

In eastern Colorado brick clays have been developed in Boulder, El Paso, Fremont, Huerfano, Jefferson, Morgan, and Pueblo Counties. In the Golden area red burning brick, sewer pipe, and tile are manufactured from clays that are mined locally from the Benton, Fox Hills, and Laramie formations. Brick plants are present in or near each of the larger towns.

Miscellaneous Clay Sold by Producers
(all clays except fire clay)
Colorado Year Book, 1943-1944

Year	Short Tons	Av. Value per Ton	Value
1935	23,342	$0.85	$19,867
1936	53,881	0.88	47,643
1937	65,190	0.92	59,916
1938	54,115	0.91	49,249
1939	76,081	1.03	78,150
1940	62,803	1.03	64,842
1941	79,458	1.05	83,246

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Fire Clay

GENERAL DESCRIPTION.—As can be seen on plate 5, fire clay is less widely distributed in Colorado than brick clay but the known and indicated reserves are none the less large.

The most widely known deposits of clay in Colorado are the fire clays found in the Dakota formation. Among the products made from these clays are refractory bricks for boilers and furnaces, laboratory ware for chemical and metallurgical uses, and insulators for electrical construction. Crucible ware is near to fire brick in the quality of the clay used, and Colorado products have supplanted English ware in the United States. In 1941, the last peacetime year, Colorado producers reported total sales of 85,000 short tons of fire clay valued at $143,400.

In western Colorado fire clay occurs in at least three geologic formations. Fire clay in the Dakota formation generally is found near the middle of the formation in a shale zone that is easily recognizable in many localities. Shale beds tend to be lenticular. In Garfield County near Glenwood Springs the fire clay in the Dakota is a less heat-resistant type, but refractory bricks for coke ovens at Cardiff have been made by mixing the clay with crushed quartz. Low-grade fire clay from the top of the Mancos formation is suitable for semi-refractory brick. The Mesaverde formation locally contains fire clay of different grades interbedded with sandstone, shales, and coal. These clays are often found in lenticular beds underneath the coal and sometimes are mined with the coal. At Durango in La Plata County semi-refractory bricks suitable for boiler lining have been produced from beds of clay that lie immediately under the lowest coal bed of the Mesaverde formation. In general the Mesaverde fire clays are not as heat-resistant as those found in the Dakota formation. Further prospecting undoubtedly would show the presence of adequate reserves of fire clay in both the Dakota and Mesaverde formations in western Colorado.

In eastern Colorado fire clay is confined to beds of Upper Cretaceous Age. High-grade fire clay is found in a black shale zone near the middle of the Dakota sandstone at Golden in Jefferson County, in the vicinity of Colorado Springs, El Paso County, Canon City, Fremont County, and in adjoining areas to the south and southeast where the Dakota formation is exposed at the surface. A fire clay of intermediate grade is found locally with the lower coal beds of the Laramie formation in the Golden area and elsewhere. Fire clay from the Dakota formation has been mined from surface pits and underground at Golden and at Stone City near Pueblo since an early date. The following counties contain undeveloped deposits of clay which according to furnace tests are of good refractory quality:

Arapahoe	Douglas	Larimer
Bent	El Paso	Las Animas
Boulder	Fremont	Otero
Custer	Huerfano	Pueblo

Fire Clay Sold by Producers
(Colorado Year Book, 1943-1944)

Year	Short Tons	Av. Value per Ton	Value
1935	33,227	$1.49	$49,628
1936	54,433	1.44	78,567
1937	59,828	1.56	93,587
1938	48,702	1.35	65,678
1939	52,310	1.39	72,644
1940	52,695	1.69	89,206
1941	84,986	1.68	143,398

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FIRE CLAYS OF EASTERN FREMONT, WESTERN PUEBLO AND ADJACENT COUNTIES*

By K. W. Waage†

Introduction—Plastic and flint fire clays have been mined in eastern Fremont and western Pueblo counties since about 1900. In eastern Fremont County the principal activity has been in the vicinity of Canon City. In Pueblo County most of the flint clay has come from the Turkey Creek district in the northwest corner of the county, and in recent years some flint clay has been mined on Rock Creek, about 14 miles southwest of Pueblo. A fourth area situated just south of the Pueblo County line at Capers Spur in Huerfano County has supplied plastic clay.

Three companies, the Standard Fire Brick Co. and the Pueblo Clay Products Co. of Pueblo, and the Diamond Fire Brick Co. of Canon City, operate all the active fire clay mines in the area, with the exception of one mine in the Turkey Creek district owned and operated by Mr. A. J. Wands of Stone City. The Standard and the Diamond Fire Brick companies manufacture refractory products of various types and grades, and the Pueblo Clay Products Co. markets both raw and calcined clay. The clay from the Wands mine is sold to the Denver Fire Clay Co.

Most of the flint clay produced since 1942 has come from the Turkey Creek district and Rock Creek area of Pueblo County. As the flint clay is mined together with associated plastic clays it is not possible to state the output of flint clay alone. In 1943 the total output of clay for the mines supplying both flint and plastic clay amounted to about 60,000 short tons, of which it is estimated between 25,000 and 30,000 tons was of flint clay.

Geology of Fire Clays.—The known deposits of fire clay in the area occur in the Purgatoire formation and the overlying Dakota sandstone. The Purgatoire, as subdivided by Finlay,[1] consists of a lower unit, the Lytle sandstone member, and an upper unit, the Glencairn shale member. These members are persistent throughout the area.

The Dakota sandstone generally consists of massive cross-laminated sandstones, but locally in the middle part is a mappable unit of sandy clays, fire clays, and even-bedded sandstones.

The Purgatoire-Dakota sequence is exposed in hogbacks along the south end of the Colorado Front Range and the east side of the Wet Mountain or San Isabel Range. It also crops out over large areas in the southwest and south-central parts of Pueblo County, where it is essentially horizontal. The flint fire clays are restricted to the clay-bearing unit of the Dakota sandstone. Plastic fire clays are present in the Glencairn shale member of the Purgatoire and are also associated with the flint clays of the Dakota.

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†Geologist, United States Geological Survey.

[1]Finlay, G. I., U. S. Geol. Survey Colorado Springs Folio, no. 203, 1916.

FIRE CLAY OF THE GLENCAIRN SHALE MEMBER *(Purgatoire Formation)*.—A bluish-black to light blue-gray, tough plastic clay with a rough, blocky fracture forms tabular lenses near the top of the Glencairn shale member of the Purgatoire formation. The clay is fairly uniform in chemical composition, with a silica-alumina ratio of about 3:1 and fusible impurities amounting to about 5 percent. It is a low-grade refractory to semi-refractory clay which is mixed with the higher-grade flint clay of the Dakota sandstone for the manufacture of refractory products or is used alone in lower-grade refractories.

The fire clay of the Glencairn has been mined from the Grape Creek and Skyline hogbacks of the Canon City district and from the hogback between Oil and Sixmile Creeks northeast of Canon City. In the first two areas the clay has been mined out, in the last area mines are being operated by the Diamond Fire Brick Co. in SE¼, sec. 18, T. 18 S., R. 69 W., and the Standard Fire Brick Co. in NW¼, sec. 20, T. 18 S., R. 69 W.

At Capers Spur in sec. 6, T. 25 S., R. 65 W., south-central Pueblo County, the Standard Fire Brick Co. operates the Vulcan mine, in what appears to be the largest single clay body of the Glencairn in the area.

CLAY-BEARING UNIT OF DAKOTA SANDSTONE.—The clay-bearing unit of the Dakota sandstone is found in isolated bodies of various size within the massive sandstones of the formation. It is believed to have been a single continuous deposit, much of which was removed by erosion prior to the deposition of the upper part of the Dakota sandstone. Exposures of the unit are present along Wilson Creek in the Canon City district, in the Turkey Creek district, and in the Rock Creek area. The clay seam is locally thinned or cut out by channels filled with sandstones of the overlying part of the Dakota sandstone.

The clay seam consists of an upper zone of plastic and semi-plastic clays and a lower zone of flint clay. The plastic clay is light gray to blue-gray and has a massive to blocky structure. It is compact and tough and breaks with a splintery to rough blocky fracture. The semi-plastic clay is black, fairly hard, and dense, and has a splintery to poorly-developed conchoidal fracture. It occurs locally between the plastic and flint clay and is the least common of the three types.

The plastic and semi-plastic clays of the clay-bearing unit in the Dakota sandstone are of better grade than those of the Glencairn shale member of the Purgatoire formation, being white-burning semi-refractory to refractory clays. They are uniform in composition and fusion point, but the semi-plastic clay is the less desirable because of its higher content of carbonaceous matter. The good non-sandy plastic clay contains less than 5 percent of fusible impurities and has an average alumina (Al_2O_3) content of 29 or 30 percent. Its average fusion point is about cone 29 and samples fusing up to cone 31 are not uncommon.

The flint clay of the Dakota sandstone is a hard light gray to light blue-gray fine-grained clay with a well developed conchoidal fracture. The principal visible impurity is sand. In most places the flint clay grades downward through sandy clay and argillaceous sandstone into quartzose sandstone. The clay contains isolated grains of sand throughout and in places also contains blebs and small lenses of sand.

The minable flint clay of the Dakota sandstone is a white-burning, highly refractory fire clay fusing between cones 31 and 36. It is fairly uniform in chemical composition, the only major variation being in the content of silica, which appears to be related directly to the amount of quartz sand present. The fusible impurities average less than 5 percent of the total in both the sandy and non-sandy flint clay. The alumina (Al_2O_3) content of the non-sandy clay averages 35 percent.

Range of Silica and Alumina Contents of Non-sandy Flint Clays
(Based on 51 analyses of flint clay)

	Average	Minimum	Maximum
Silica (SiO_2)	48.73	44.25	51.00
Alumina (Al_2O_3)	35.69	33.51	39.40

Range in content of fluxible impurities and TiO_2

	Average	Minimum	Maximum	No. of Analyses
Ferric Oxide (Fe_2O_3)	1.02	.16	2.87	62
Titania (TiO_2)	1.00	.50	1.39	33
Lime (CaO)	.23	None	.72	37
Magnesia (MgO)	.20	None	.73	39

Development.—The largest known deposits of the clays in the Dakota sandstone are in the Turkey Creek district of Pueblo County, where the Purgatoire-Dakota sequence is exposed in the nose of the southeast-plunging Red Creek anticline, between Red and Turkey Creeks in T. 18 S., Rs. 67 and 68 W. Clay has been mined since 1906 along the southwest limb of this anticline in the vicinity of Stone City, but the remainder of the district is undeveloped. Three mines are being operated in the Stone City area, two by the Pueblo Clay Products Co., and one by Arthur Wands of Stone City. The clay seam averages about seven feet in thickness; the flint portion is about four feet thick except in local areas where plastic clay predominates.

In the Canon City district of Fremont County, the Diamond Fire Brick Co. has mined clays of the Dakota sandstone along Wilson Creek in parts of sections 3 and 4, T. 18 S., R. 70 W. High-grade flint clay has been produced only from the Diamond Flint Mine in SW¼, sec. 4,T. 18 S., R. 70 W.

In the Rock Creek area of Pueblo County, the Standard Fire Brick Co. is working clays of the Dakota sandstone from several entries in the N½, sec. 35, and SW¼, sec. 26, T. 22 S., R. 67 W. Here the clay seam averages about 6 feet in thickness with the flint clay rarely exceeding 2 feet of the total.

Reserves.—The principal known reserves of fire clays in the Dakota sandstone are in the Turkey Creek district. The Canon City area is apparently too near the marginal phase of the member to expect more than spotty development of the flint fire clays, even where the whole thickness of the member is present. The Rock Creek area may contain considerable reserves of plastic clay, but the expectable percentage of flint clay is small.

Only in the Turkey Creek district are outcrops sufficiently numerous to permit inferences as to reserves. The total indicated and inferred tonnage of flint and plastic clay in the Turkey Creek district, based upon detailed areal geologic mapping and examination of active and abandoned mines, is estimated to be between two and four million tons, of which about two-thirds is flint clay.

Pottery Clay

The chief requirements for good pottery clay are high plasticity necessary for producing desired forms; a low iron content to avoid undesirable coloration; and high alumina with a low silica content to insure a high firing temperature. As a rule fire clay contains too much iron oxide or possesses insufficient plasticity to meet the above requirements. In addition to suitable clays, the final pottery mixture contains other ingredients, such as pure silica, pure feldspar, and kyanite. High-grade pottery clays, plus feldspar, tin oxide, and other ingredients are used in the glazes.

Among the pottery products made in Colorado are earthenware, decorative ceramics, chinaware, and chemical porcelain ware. The latter product is considered to be of higher quality than the best peacetime German scientific ware, and it has the reputation of being stocked in every chemical laboratory in North America. Present markets are world wide.

No pottery has been made from clays of western Colorado to date. However, good pottery clays are found in the Dakota formation, as has been mentioned previously; and high refractory plastic clays are reported at Glenwood Springs, Aspen, and Grand Junction. The latter are alluvial and river terrace deposits. They are being used for semi-refractory brick; one deposit 2 miles south of Grand Junction is said to be suitable for pottery. These alluvial plastic clays are often sandy, but if worked far enough back from the river, less sand can be expected and it should also be possible to improve the clay by washing.

The best pottery clays in Colorado, and equal to those found anywhere, are found in the foothills belt along the eastern flank of the Front Range. The pottery clays of the Golden area in Jefferson County are found chiefly in the Dakota and very locally at the base of the Benton formation (Upper Cretaceous). These clays produce high-grade, white-burning porcelain and pottery.

Another important source of Colorado pottery clay is near Calhan (east of Colorado Springs) in El Paso County. In Huerfano County, fine pottery clay occurs at an outcrop about 6 miles northeast of Cuchara Junction and at another about 9 miles east of the mouth of Apache Creek. The bed of clay at both places is from 3 to 6 feet thick and is capped with Dakota sandstone. In Pueblo County, excellent pottery clay occurs at two known localities; one is 6 mile east of Graneros, and the other is northeast of Beulah at Galbreth Creek. As with the other clays the available supplies of pottery clay are far in excess of anticipated requirements.

The production and value of pottery clay are not known. On a tonnage basis the production is low but average values per ton are 3 to 5 times higher than fire clay.

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Butler, G. M., The clays of eastern Colorado: Colorado Geol. Survey Bull. 8, pp. 153-313, 1915.

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U. S. Geol. Survey Missouri Basin studies No. 1, Mineral resources of the Missouri Valley region (map) pt. 4, Construction materials: compiled by D. M. Larrabee, S. E. Clabaugh, and D. H. Dow, scale 1:2,500,000, 1945.

Van Tuyl, F. M., et al, Guide to the geology of the Golden area: Colorado School of Mines Quart., vol. 33, no. 3, p. 29, July 1938.

Dolomite

Dolomite beds several hundred feet thick are present in the Ordovician, Devonian, and Leadville formations in Colorado. These formations are present over large areas in western, central, and eastern parts of the State. They are particularly prominent in Lake and Park Counties; in Glenwood Canyon on the Colorado River in Garfield County; along the Eagle River in Eagle County; in the canyon near Manitou in El Paso County; along Trout Creek in Douglas and Teller Counties; and near Pueblo in the Canon City area of Fremont County. Any of these areas could produce unlimited quantities of dolomite.

Dolomite is a calcium magnesia carbonate ($CaMg(CO_3)_2$). In outcrops it resembles limestone ($CaCO_3$). Chemical analyses are expensive, but the two rocks can be distinguished easily by applying dilute hydrochloric acid. The dilute acid on limestone will effervesce briskly, but dolomite will not react unless powdered and even then it will effervesce slowly. Dolomite has been suggested as a source for metallic magnesium; however, according to latest reports the cost of magnesium produced from dolomite does not compare favorably with the cost of the metal produced by other processes. Dolomite has been used to a limited extent in furnace bottoms and for patching. Dolomite has not been produced in Colorado.

U. S. Geol. Survey Missouri Basin studies No. 1, Mineral resources of the Missouri Valley region (map) pt. 4, Construction materials: compiled by D. M. Larrabee, S. E. Clabaugh, and D. H. Dow, scale 1:2,500,000, 1945.

Various geologic reports on the general geology of mining districts, particularly in the Leadville and San Juan areas.

Granite

Granite is an igneous rock composed chiefly of orthoclase, quartz, and mica. In industrial use the term usually signifies the medium-grained crystalline silicate rocks irrespective of mineral composition. Because of the large mountainous areas where igneous rocks are exposed, it is not surprising that Colorado contains an abundance of granite, but fracturing and jointing limit the places where dimension stone required for building purposes and even small dimension stone suitable for monuments is to be found. Localities well-known for granite are near the towns of Gunnison in Gunnison County, Silver Plume in Clear Creek County, and Salida and Cotopaxi in Fremont County. The use of granite in construction of buildings requiring dimension stone has decreased virtually to the vanishing point; however, the possibilities are good for continued production of granite suitable for monuments. Monument granite has been quarried in a number of localities and particularly near Salida. Other localities undoubtedly could be developed.

Any part of the pre-Cambrian crystalline areas (see pl. 5) are possible sources of granite, but commercial development will depend largely on transportation facilities and quarry conditions. Only the more important localities are shown on plate 5.

Monument granite, both finished and unfinished, is imported to Colorado from distant points. The potential reserves of suitable granite in Colorado are sufficient not only for local demands, but also for export to other states. The following table shows the production in Colorado:

Rough Monumental Granite Produced

Year	Cubic Feet	Value
1938	2,300	$4,534
1939	1,680	2,417
1940	a	a
1941	2,380	5,672
1942	a	a
1943	2,100	4,630
1944	2,030	4,914

a—Figures not available.

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Gypsum and Alabaster

Gypsum ($CaSO_4.2H_2O$) is a white to gray granular rock that is used in large quantities in the cement and plaster industry. Selenite is gypsum in coarse, often colorless to clear, crystal forms that may be prized by mineral collectors but otherwise has no special value. Alabaster is a very fine-grained dense variety of gypsum, and attractive colored varieties have been mined for carving ornaments from an area in Larimer County about 18 miles northwest of Ft. Collins, and near La Junta in Otero County.

Soils in arid regions commonly contain valueless quantities of gypsum. Relatively pure deposits are required for the manufacture of plaster, and these are widespread in the United States, including Colorado. The value of a deposit depends on the purity of the gypsum, on favorable quarrying conditions, and on transportation costs. Manufacturers of plaster using gypsum usually own and operate their own quarries.

Much of the gypsum in Colorado is too far from transportation to be of commercial value, but adequate reserves are located favorably.

For the purposes of discussion the gypsum deposits of Colorado are divided into three areas: eastern Uinta Basin, southwestern Colorado (or the Paradox and Uncompahgre region), and eastern Colorado along the Front Range. Most of the gypsum in Colorado is Carboniferous in age; however, the Morrison (Jurassic) formation contains deposits in eastern Colorado, notably at Glen Eyrie near Colorado Springs, and near Stone City in Pueblo County. Gypsum deposits are being worked about 16 miles north of Portland in Fremont County and at Loveland in Larimer County.

In the extreme eastern part of the Uinta Basin along the valleys of the White, Colorado, and Eagle Rivers, and many of their tributaries, undeveloped gypsum beds of Pennsylvanian age overlie the dark limestone and shale of the Weber formation. As a rule the gypsum is interbedded with shale, and weathering has produced extensive accumulations of soil (gypsite) that is composed largely of gypsum, but which is without value as a source of gypsum. Individual beds of gypsum of seeming high purity vary in thickness from a few feet to over 100 feet. In some places the gypsum is 90 feet thick in a stratigraphic section 140 feet thick. North of the town of Gypsum in Eagle County, gypsum crops out in large masses for about four miles across the valley of the Eagle River.

In southwestern Colorado on the flanks of the Uncompahgre Plateau, beds of gypsum are exposed along the valley of the Gunnison River in Delta and Montrose Counties. The beds average 110 feet in thickness for 20 miles from Smith's Fork to Red Rock Canyon. Attempts to develop the gypsum northeast of Montrose have not been successful probably because of the great distance to the larger markets.

In the Paradox Basin area gypsum associated with limestone and shale of Carboniferous age extends over about 85 square miles in east Paradox Valley and about 7 square miles in Sinbad Valley. A thick bed of gypsum (Pennsylvanian) crops out along the north side of Big Gypsum Valley. The same bed crops out in Little Gypsum Valley, especially on the north side. The total area of gypsum in these last two valleys is about 25 square miles. The gypsum beds are 5 to 10 feet thick and occur throughout a series of strata 250 feet thick. Locally there is evidence of gypsum plugs probably analogous to the salt plugs or domes found in the Gulf States, and thickening due to squeezing resulting from folding also may have occurred. In the Rico district, Dolores County, a bed of gypsum 30 feet thick is present in the lower part of the Hermosa formation (Pennsylvanian) at Newman Hill. Gypsum deposits are reported also in San Miguel County.

In eastern Colorado gypsum is being mined west of Loveland in Larimer County from the Morrison (Jurassic) formation. Northward continuations of this horizon and of gypsum in the Lykins formation are known at Owl Canyon and Table Mountain in Larimer County. Gypsum is found in the Lykins formation (Permian) at Deer Creek in Jefferson County, but not in commercial amounts. Other gypsum deposits of unknown size occur in the Lykins formation at Glen Eyrie and along Fountain Creek in El Paso County; from Ute Creek to Beaver Creek in Fremont County; and at Perry Park (also Morrison formation) in Douglas County. Large deposits of gypsum of Permian age have been worked at Coaldale in Fremont County and north of Stone City in Pueblo County. Undeveloped deposits are reported in Custer, Huerfano, and Otero Counties.

Gypsum is reported in South Park, but the quantity does not seem to be large. Impure gypsum (Jurassic?) occurs in Park County, and gypsum of unknown quality and quantity is present in Chaffee County.

Alabaster, the compact variety of gypsum, is found near Livermore in Larimer County and near La Junta in Otero County. As the stone can be shaped and polished on lathes, it is manufactured into vases and ornaments. Plants for manufacturing alabaster ornaments are operated near the Livermore deposit. A recently developed deposit about 20 miles southwest of La Junta produces an attractive alabaster.

Production of gypsum for cement and plaster in Colorado is confined to Larimer and Fremont Counties.

Production of Gypsum (Crude)
U. S. Bureau of Mines

Year	Quantity (short tons)	Value
1935	17,610	(a)
1936	27,424	(a)
1937	28,586	$50,034
1938	21,591	41,080
1939	24,013	40,694
1940	24,641	36,787

[a] Figures not available.

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Limestone

Limestone is calcium carbonate ($CaCO_3$). It closely resembles dolomite both in occurrence and appearance but can be readily distinguished from dolomite with the use of cold dilute hydrochloric acid. Limestone will effervesce vigorously in contact with cold acid, but dolomite will not react unless the rock is first powdered or hot acid is used. Limestone is seldom pure but commonly contains varying percentages of magnesium, sand, shale, chert, as well as small amounts of iron oxide and other impurities. The terms sandy, shaley, and cherty limestones refer to limestones that contain appreciable quantities of either interbedded or scattered sand, shale, or chert.

The chief use of limestone is for the manufacture of cement, as has been explained in a previous section under Cement Materials. The other important uses are for lime and agricultural purposes. Market prices of these products do not permit shipment to distant markets, and thus the use of limestone is limited to local demands. In Colorado the use of limestone for agricultural purposes has been small.

Beds of limestone occur in each of the major sedimentary basin. (See pl. 9, page 278.) The limestone that has been quarried was used almost entirely for its lime content and rarely as a building stone.

In the Green River Basin, because of the overlapping Tertiary beds, limestone crops out only at the western end in the Yampa Canyon on the Uinta Mountains uplift. This limestone has not been developed commercially, as far as is known. Transportation from the canyon and the distance to markets prevent development in this area.

In the eastern Uinta Basin of Colorado nearly all of the Carboniferous formations contain limestone beds of commercial grade that crop out in numerous places. These limestones have a low magnesium content and are suitable for the manufacture of lime. Shale necessary for cement manufacture, as previously mentioned, is available from the Mancos and other formations which are present close to the limestone deposits. In Pitkin County kilns operated at Thomasville and Meredith formerly produced a good grade of lime. The Mississippian (Leadville) limestone has been quarried northwest of Glenwood Springs in Garfield County and cliffs of limestone nearly 200 feet high crop out immediately east of the town. Limestone, probably of Mississippian and Pennsylvanian age, has been quarried near Dominguez in Delta County, where it has been used locally for building purposes. In the extreme southeast end of the Uinta Basin northeast of Gunnison on Cement Creek in Gunnison County, limestone beds (Mississippian) 150 to 200 feet thick are present.

In the southeastern end of Paradox Basin in Ouray County, inexhaustible quantities of limestone can be obtained from the Ouray and Hermosa formations. In San Juan County a small amount of limestone from a quarry south of Silverton on the Animas River was used as a flux in smelting ore.

An excellent grade of limestone has been quarried in La Plata County at Rockwood, north of Durango, and burned for lime and shipped for flux.

In eastern Colorado limestone quarries have been developed along the Arkansas River between Pueblo and Salida in Fremont and Pueblo Counties, in the vicinity of Colorado Springs in El Paso County, and in the foothills west of Ft. Collins in Larimer County. Mississippian (Leadville) limestone west of Salida at Monarch in Chaffee County has been used extensively as a flux for the manufacture of iron at Pueblo and also as a flux for smelting lead ores in the smelter at Leadville. Other large limestone areas of central and eastern Colorado that have not been developed but which hold possibilities are: along the Sangre de Cristo Mountains in Costilla, Huerfano, Custer, and Fremont Counties; along the Wet Mountains at Beulah in Pueblo County and at Canon City in Fremont County; and south of La Junta on the Purgatoire River in Otero and Las Animas Counties.

In the literature that describes the geologic formations in Colorado and particularly the Leadville area, the Leadville (Mississippian) formation generally is referred to as a limestone even though its composition is dolomite. True limestone in the Mississippian beds are confined in eastern Colorado to the

Colorado Springs area and to the south; in central Colorado in the Salida area and to the south; and in western Colorado to the westerly flanks of the Sawatch Range and White River Plateau. True limestone of Mississippian age is also present in the San Juan area in the southwestern part of the State.

Production of Lime (Limestone)
U. S. Bureau of Mines

Year	Quantity (short tons)	Value
1937	7,163	$ 72,831
1938	9,564	95,207
1939	10,699	103,097
1940	7,944	82,486

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Marble

Marble is recrystallized limestone. Recrystallization is a metamorphic process brought about by heat, pressure, and circulating solutions that accompanies mountain building forces and igneous intrusion. Where limestones have been changed to marble it is common to find shale metamorphosed to slate and sandstone to quartzite. Verde antique, a serpentine marble, has not been found in commercial quantities in Colorado.

Onyx marble, also called Mexican onyx and cave onyx, is characterized by a banding in various colors. Onyx is a chemical precipitate of calcium carbonate from cold-water springs. Travertine, a chemical precipitate of calcium carbonate from hot-water springs, is called limestone or marble, depending on its texture, coloration, and other factors essential for building stone or decorative use. The travertine quarried south of Salida is known as travertine marble.

In Colorado the most extensively developed deposit is the Yule marble, a recrystallized Leadville (Mississippian) limestone on Yule Creek in northern Gunnison County and about 4 miles southeast of the town of Marble. The marble bed crops out for a distance of 4,000 feet along Yule Creek and the adjoining slopes of Treasury Mountain. The marble is about 240 feet thick, but a number of chert bands one to four feet thick limit the productive horizon to 40 feet in thickness in the lower half of the formation. The marble is predominantly a white medium-grained rock with a gray to yellow banding. Marble with yellow banding or veining is commonly referred to as "golden vein" marble. The following are a few of the more than 60 public buildings in the country containing Colorado Yule marble: the Post Office, Customhouse, City and County Building, Federal Reserve Bank, and State Capitol Annex in Denver; the Lincoln Memorial in Washington, D. C.; the Tomb of the Unknown Soldier in Arlington Cemetery, Virginia; the municipal buildings in both San Francisco and New York City; and the Field Building in Chicago.

The wide use of Yule marble is a testimonial of its worth. Large reserves are available, and except for the somewhat unfavorable quarrying conditions and transportation costs, this marble would probably be used even more extensively than it has been. Other deposits of marble in western Colorado on which there is little information are reported in Pitkin and Saguache Counties.

Onyx is so named because of its banded color variation similar to that of true onyx, a chalcedony or silica rock. A deposit of onyx marble suitable for ornamental use and said to be large is located on the south side of the Yampa River southwest of Steamboat Springs in Routt County.

In the central and eastern part of Colorado a marble deposit is reported at Cotopaxi in Fremont County. At Twin Mountain about 5 miles north of Canon City a quarry has been opened in marble with delicate shades of lavender mingled with yellow. The quantity of this marble seems to be large but relatively little stone has been quarried.

In addition to marble, travertine is of great importance in Colorado. The largest and best-known travertine marble quarries are about 6 miles southeast of Salida in Chaffee County. The stone is a motley of tan and light brown colors that has been popular for decorative uses. It has been used for the interior of the City and County Building of Denver, Colorado; at the Sunnyside Mausoleum at Long Beach, California; in the Department of Commerce Building in Washington, D. C.; and in other important buildings throughout the country. The travertine deposits at Salida are favorably located for quarrying. A second quarry of Colorado travertine is at Beulah near Canon City in Fremont County. The reserves of travertine at Salida and Beulah are not known, but indications are that they are ample for anticipated demands.

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Mineral Wool Materials

Mineral wool is a glass fiber obtained through various processes by melting suitable mixtures of clay, shale, impure limestone, or waste materials. The wool is used widely as an insulating material. The manufacturing process is comparatively simple, and plants costing $50,000 to $60,000 have been sufficient for producing 1,000 pounds of wool per hour. In 1944 mineral wool production in the United States reached 568,296 short tons valued at $54,482,796. No production is recorded for Colorado.

It was formerly believed by many that a certain type of natural rock or iron blast-furnace slag was required, which confined production to a few localities. It has been subsequently shown, however, that a variety of raw materials is suitable for manufacturing mineral wool so that it is possible to decentralize production. An inducement to local production is the relatively high cost of shipping due to the fact that only about 12 tons of mineral wool can be packed in a freight car.

Some of the materials used in the manufacture of mineral wool include one or more of the following combinations:

1. Common shale.
2. Clay.
3. Combinations of calcareous and siliceous rocks. (The so-called "wool rock" of Indiana is a calcareous (lime) shale or argillaceous (clay) limestone.)
4. Waste materials including glass and china have been utilized to obtain suitable furnace mixtures. Certain types of iron, copper, and lead blast-furnace slags also have been used.

Although the chemical composition of the raw materials used varies among different manufacturers, the required rocks or waste materials can be obtained in Colorado. This should be an incentive for the development of local manufacturing plants.

A prospective new producer should not allow himself to be misled by the apparent ease with which rock wool can be made. Market specifications are becoming increasingly specific and rigid; but if these are understood and the technology with suitable controls is worked out, there is an opportunity for the manufacturer of mineral or rock wool in Colorado, as adequate supplies of raw materials should be relatively easy to develop.

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Sand and Gravel

Sand and gravel are found in every part of Colorado. In the mountain valleys extensive deposits of glacial outwash consist of sand, gravel, and coarser material. These deposits contain materials varying in size from large boulders to sand. Where the mountain streams flow onto the adjoining plains the coarse gravels are transported for several miles away from the mountains, and sand-filled channels extend everywhere to the boundaries of the State.

Production of Sand and Gravel
U. S. Bureau of Mines

Year	Quantity (short tons)	Value
1935	1,266,073	$ 528,030
1936	3,400,051	1,653,426
1937	4,287,491	1,986,015
1938	3,841,759	1,432,975
1939	627,306	361,747
1940	1,853,359	508,403
1941	809,270	528,116
1942	4,631,942	3,220,706
1943	1,575,949	915,664
1944	2,369,521	1,518,718

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Sandstone and Quartzite

Sandstone as a source of silica sand for making glass is discussed under the heading Silica Sand.

Sandstones are found over large areas on both sides of the mountain ranges in Colorado. The principal use for sandstone has been for building, although very little sandstone has been used for this purpose in recent years. Numerous public buildings and homes throughout the State were built at an early date with native sandstone, and during that time the building stone industry was important in Colorado. Important quarries were located at Lyons in Boulder County, Colorado Springs in El Paso County, Stone City in Pueblo County, and near Glenwood Springs in Garfield County.

Dakota sandstone, locally quartzite, was a popular building stone not only because of its strength and color, but also because of favorable bedding that made it easy to obtain dimensions suitable for building. Except for such favorable conditions the cost of quarrying quartzite would be prohibitive.

In recent years quarrying has been confined almost entirely to the Lyons sandstone. This sandstone is a pink to red thin-bedded formation that is over 300 feet thick at Lyons in Boulder County. The sandstone splits easily along the bedding in large slabs that have been used extensively for buildings and, in the early days, for sidewalks. Sheets of sandstone 4 to 5 feet across and only 2 to 3 inches thick are common. The Lyons sandstone taken from a quarry northwest of Boulder is used by the University of Colorado at Boulder in the construction of its buildings.

In Gunnison County, Dakota sandstone near the town of Gunnison is suitable for grindstones. Sandstone crops out along the river bank for about half a mile and is near a railroad. The workable bed is 21 feet thick but production has been small.

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Slate

Slate has been found in Gunnison and Ouray Counties. The large deposit of slate near the town of Gunnison has been worked commercially and is said to be of good quality, but as the operation was discontinued it must be concluded that the venture was not a success. The reason for the failure is not known, but distance from markets probably was a contributing factor.

The slates of Ouray County are exposed in Uncompahgre Canyon near the mouth of Bear Creek. They are badly shattered and seem to be of little commercial value, although further development may disclose better material.

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Vermiculite

Vermiculite is a group name used for a number of hydrated silicate minerals that vary in color from light yellow to brown with a bronze-like luster. They are products of alteration of biotite, phlogopite, and related micas, which retain a platy mica structure. Whether hydration is hydrothermal alteration or the work of surface water is not known. Many vermiculite deposits either seem to pinch out or their quality decreases at shallow depths.

The vermiculite minerals have an indefinite chemical composition that varies with the original mineral and the degree of alteration. They do not rank as distinct species and identity is difficult. Jeffersite is believed to be the predominating vermiculite mineral in Colorado.

When heated, vermiculite loses hydroscopic water with accompanying exfoliation and expansion in volume. Small slivers will exfoliate in an alcohol flame, and this is a convenient identification test. Larger grains require more heat. The relatively dull luster and the pliable inelastic character of the micaceous plates also help to identify vermiculite. Unaltered mica plates have a high luster, and they are resilient and elastic.

Exfoliated vermiculite has been used for insulation against sound and heat. It also has been used in refractory products and for lightweight cement. Vermiculite plasters have fire retardent qualities. The value of vermiculite as a substitute for peat moss and other agricultural uses has been investigated, but the final results are not known.

Good grades of 4-mesh granular vermiculite sold on the market (1946) weigh 24 pounds for 4½ cubic feet, and assuming 30 per cent intragranular pore space, the ungranulated vermiculite weighs 8 pounds per cubic foot.

The amount of expansion resulting from heating is a criterion for establishing market value of vermiculite, and is dependent on the character of the raw material. However, the expansion is influenced by the heating temperature and the rapidity with which the heat is applied.

The first deposit of vermiculite in the United States was discovered in 1913 in the Turret mining district near Hecla in Chaffee County, Colorado. The bulk of production in Colorado in recent years has come from deposits south of Iola in Gunnison County and near Westcliffe in Custer County. Some material can be shipped as mined, but cleaning is necessary where excessive alteration has produced talc, clay, quartz, or other impurities. Cleaning may be done before or after exfoliation, depending on the character of the vermiculite deposit. The extent of the reserves is not known but they may be large, and the discovery of other deposits also is a possibility.

Production of Vermiculite

Year	Quantity (short tons)	Value
1942	2,574	$25,996
1943	356	2,529
1944	1,189	11,890

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Volcanic Extrusive Rocks

General Statement

Volcanic extrusive rocks have been used in a variety of ways depending on their physical and chemical properties, which vary from hard, dense, medium and fine-grained types, to porous and fragmental material. The dense, medium-grained types originated as molten flows that formed in layers or beds of large extent. Porous and fragmental volcanic materials were blown with explosive force from a volcanic vent and accumulated on adjoining slopes in massive irregular or rudely stratified deposits called volcanic ash. The finer materials commonly are transported by wind currents or water to form stratified deposits that resemble sedimentary formations except for their mineral and chemical composition.

Chemical compositions of volcanic rocks vary from those with a relatively high iron and low silica content (basic rocks) to the reverse relationship (acid rocks).

Basic Rocks

Basic lava forms dense dark-colored rock called basalt or trap rock. Capping rock of North and South Table Mountains near Golden in Jefferson County is dense basalt that has been quarried for road metal and for rip-rapping streams for flood control. Basalt is also used for ballast by railroads, and it is suitable for any other use for which hard, relatively heavy rock is desired. Some varieties of basalt will take a high polish, but it has not been popular for monuments or as building stone because iron stain commonly develops after several seasons of exposure.

Fragmental material or volcanic ash of basic extrusions have not been used extensively although a variety called scoria obtained from a quarry in Routt County has been used for track ballast by the Denver & Rio Grande Western Railroad in Routt and Moffat Counties.

Basalt flows cover extensive areas of Grand Mesa east of Grand Junction and large areas in the Flat Tops on the northern side of the White River Plateau north of Glenwood Springs. Basalt covers extensive areas southeast of Glenwood Springs. Raton Mesa southeast of Trinidad is capped by basalt, and Mesa de Maya farther east also has an abundance of basalt. These areas are shown on the State Geologic map. Additional areas of basalt are included in those areas on the State map that are shown under undifferentiated volcanic rocks.

Acidic Rocks

The acidic lava rocks are subdivided on the basis of potash, sodium, calcium, and silica content, and they are known as rhyolite, phonolite, latite, and andesite when they occur as uniformly dense and fine-grained rocks. The term porphyry is added when relatively large crystals are present throughout the rock. Rocks of this type are plentiful in Colorado, particularly in southeastern Las Animas County; in the San Luis Valley north of Saguache; in parts of the San Juan area associated with tuff and other igneous rocks; in the vicinity of Glenwood Springs; in the area west of Cripple Creek; and in the southern half of North Park. Commercial quarries for building stone were operated at an early date near Del Norte in Rio Grande County and at Volcano in Routt County. Near Castle Rock in Douglas County an attractive rhyolite was quarried for buildings in Denver and Colorado Springs.

PERLITE, PITCHSTONE, AND OBSIDIAN

Another type of volcanic rock that has become of interest rather recently is volcanic glass, particularly perlite. Some varieties of perlite when heated produce excessively cellular glass, very similar to pumice, that promises to be useful as an insulating material. Very little has been made public as to the technic necessary to produce the cellular structure, but presumably the process is related to expanding steam bubbles analogous to the formation of natural pumice. Although perlite has been considered of greatest interest, the subject is new and with improved technics other types of rock glass may be usable.

The principal types of volcanic glass related to lava flows are obsidian, pitchstone, and perlite. Intermediate rocks composed of mixtures of glass and crystals are not considered at this time. Obsidian is a homogeneous black to red glass with a relatively low water content. Pitchstone is similar to obsidian except that it is usually more resinous, red to green in color rather than black, and the water content is much higher. Perlite is a gray to black glass characterized by numerous concentric cracks that formed through contraction in cooling. The water content of perlite is intermediate to that of typical obsidian and pitchstone.

Volcanic glass is a lava that chilled too quickly to permit crystallization; and therefore it is commonly found at the top and bottom of lava flows and along the margins of dikes, but it also occurs as independent sheets and dikes. Volcanic glass is widely distributed and individual localities have not been mapped. Obsidian has been reported in various places in the San Juan region, and pitchstone is described near Silver Cliff in Custer County. Gray perlite with scattered round pellets of black glass crops out at the north end of Ruby Mountain on the east side of the Arkansas Valley opposite Nathrop in Fremont County. Should the use of volcanic glass for conversion to cellular material for insulation or other uses reach worth while proportions, the prospects are excellent for finding the raw materials in Colorado.

Rhyolite, latite, and related acidic lavas ejected by explosive volcanic eruptions form white to gray volcanic ash. Small sizes are usually carried some distance by wind and water to form fine-grained deposits. When deposited on alluvial plains or in lakes by streams, the resulting deposits are stratified so as to resemble ordinary sedimentary rocks. Volcanic ash is usually composed of fine-grained crystalline material or glass, and as a rule the feldspathic minerals show moderate to intense alteration.

PUMICE AND PUMICITE

Pumice is a cellular glass found in fragments ranging in size from two or three feet to a powdery ash. Pumicite is a name used in industrial circles for powdery pumice ash, a substantial part of which is minus 200 mesh found in large quantities in Kansas and Nebraska. Coarser sandy varieties of cellular glass common in the Rocky Mountain and Pacific Coast States are called pumice.

Pumice has been used extensively as an abrasive and in more recent years as a light-weight aggregate in cement. Granular pumice is used in stucco plaster for acoustic properties. In general the uses for pumice and pumicite are highly specialized industrial applications, and a given raw material must be thoroughly tested for a particular prospective use. Prices for raw pumice or pumicite are relatively low so that shipment to distant markets is not feasible.

Pumicite related to the deposits of Kansas and Nebraska are reported in Logan and Weld Counties of eastern Colorado. These deposits are undeveloped and very little is known about them. Little is known about pumice in Colorado, but it could be expected in those areas in the San Juan region and the Rosita Hills area where the volcanic glasses previously described are found. Volcanic ash, having been transported by wind and running water, usually extends over large areas some distance from the volcanoes from which it came. This relationship is important in prospecting for various types of volcanic ash as the finer varieties will be found at some distance from the coarser varieties closer to volcanic centers.

Volcanic ash occurs in large quantities in the San Juan area, particularly in Mineral County. In La Plata County near Durango ash deposits suitable for abrasive purposes are reported. These deposits consist of three isolated beds probably of Pleistocene age. One bed is located at the east end of the valley north of Animas City Mountain on the shoulder of the southward facing spur. A second bed is opposite the west end of the same valley, and a third lies easterly of Durango on the east slope of Florida Mesa. These beds are lens-shaped and were deposited in irregular depressions in the former bedrock surface. One deposit is over 150 feet long and 50 feet thick, and another is 100 feet long and about 40 feet thick. A small amount of this material has been used locally. In Grand County a small deposit of light brown volcanic ash crops out on the south side of the Colorado River about 1½ miles southeast of Kremmling. The ash is uniformly sized and composed of thin white angular flakes. A gray volcanic ash near Troublesome five miles east of Kremmling has been used in the manufacture of hand soap and scouring powder.

Miscellaneous areas of volcanic ash in Colorado are located near the Cripple Creek area in Teller County, near Walsenburg in Huerfano County, and near Wray in Yuma County.

The volcanic regions in Colorado have not been studied in relation to the occurrences or distribution of potential commercial deposits of volcanic materials. Without doubt a variety of materials suitable for industrial uses could be found when and if demand develops.

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NONMETALLIC MINERALS*

Asbestos

Ultrabasic rocks with which asbestos is commonly associated are not plentiful in Colorado. Although the occurrence of asbestos is reported from time to time, deposits of commercial grade and size are not known.

Barite

Barite is a common gangue mineral in the ores of many metal mining districts of Colorado, but its low value has not permitted profitable recovery. Barite has been reported in the following counties: Boulder, Custer, Grand, Gunnison, Mesa, Ouray, Park, Pitkin, San Miguel.

In western Colorado barite has been found on the Vasquez River, a branch of the Fraser River in Grand County, but no known development of the deposit has been made. In Gunnison County the mineral exists in the ores of several mines, although no commercial quantities are present. Low-grade barite has been found near Grand Junction in Mesa County. In Ouray County baritic siliceous ores are found as flat masses associated with vertical fissures, and as a gangue mineral in silver veins. In

*Map in colors published recently shows, Construction materials and nonmetallic minerals of Colorado: U. S. Geological Survey, Missouri Basin Studies No. 10, 1947.

San Miguel County north of Placerville, barite is found in veins from 2 to 7 feet wide. In Park County about 2 miles southwest of Hartsel, a small barite deposit is located in the Maroon formation (Permian). In Pitkin County the ores of several mines at Aspen contain barite as a common gangue mineral; in the Smuggler mine of this area native silver was found enclosed in pink and gray barite. A little barite was produced from veins in the granite in the Wet Mountains near Ilse in Custer County.

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Corundum

Finlay describes corundum in a quartz-feldspar pegmatite dike on Grape Creek 7 miles southwest of Canon City in Fremont County. The corundum is not of gem quality although it occurs in clear blue glassy crystals about one-half inch across. The corundum content is not given. In Chaffee County at the Calumet iron mines considerable corundum is reported by Pratt in a band of rock 2 to 6 inches thick that is continuous for 500 feet at the contact of mica schist and dikes of diorite.

Several miles east of Georgetown in Clear Creek County residual boulders of schist have been found containing 30 to 50 percent corundum. Corundum is present in colorless barrel-shaped crystals one-fourth to one-half inch across, but the source of the boulders has not been determined.

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Fluorite (Fluorspar)

For a summary of the general geology and ore deposits of fluorite, with selected bibliography, refer to pages 457-65.

Fuller's Earth

Fuller's earth is a clay that will absorb coloring matter from oil. The coloring is removed by filtering the oil through granular material or by agitating a mixture of powdered clay and oil. For the latter process bentonitic clay is commonly used. The refining action is dependent on close contact between oil and clay.

Fuller's earth is found in a number of localities in Colorado. Deposits are known at Delta and to the east on the Gunnison River in Delta County, at Grand Junction in Mesa County, near Telluride in San Miguel County, at Sterling in Logan County, and north of Akron in Washington County.

Some of the fuller's earths and bentonite have a number of properties in common, and in addition they are related somewhat as to origin. Therefore, the bentonite localities given on page 230 are also favorable for occurrences of fuller's earth.

The quantity of fuller's earth produced in Colorado in recent years has not been made public; however, the average value per ton is relatively low, and therefore individual prospectors have little interest in the material. Particularly favorable locations and mining conditions are essential for successful exploitation of deposits of fuller's earth. Without doubt substantial quantities could be developed in Colorado.

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Gem Stones

Interest in gem stones in recent years has been limited to mineral specimens. Gem stones are a very specialized field, and satisfactory summaries cannot be included in the limited space that is available.

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Gilsonite, Grahamite, and Asphalt Sands

Bitumens include solid and semi-solid hydrocarbons formed in nature by evaporation of petroleum. Gradational types, both in physical and chemical constitution, are common in one area.

Gilsonite and grahamite are solid hydrocarbon minerals with fusion temperatures of 230° to 350° F. and 350° to 600° F. respectively. They are characterized by a black color with a bright luster and a conchoidal fracture. Wurtzilite is a non-fusible variety that occurs locally in small quantities and commands a higher price than gilsonite or grahamite.

Industrial uses of the solid hydrocarbons vary somewhat with temperature of fusion, the most important properties are resistance to grease, acids, and water. In recent years production of gilsonite in Utah greatly exceeds all other varieties. Gilsonite is used as an electrical insulating material; in rubber compounding; in roofing cement and paper; acid resisting paint; acid containers and many other special uses. The use of gilsonite as a fuel has not been developed as a potential value, probably because prices commanded for other uses are greater. However, with a British thermal unit of around 20,000 and virtually no ash, it should make a suitable fuel.

These solid hydrocarbons seem to be confined to the Uinta Basin in Western Colorado and eastern Utah; however, one deposit is reported to be near the town of San Luis in the San Luis Valley of Costilla County. Many of the asphaltic veins near the Colorado-Utah line occur in nearly vertical fissures in the Green River formation and in the overlying Bridger formation. It is believed by some that the fissures were filled, after opening, with material derived from adjacent oil shale strata, which are commonly known to possess high kerogen or bitumen

*Turquoise is being mined at the King turquoise mine about 11 miles east-southeast of Manassa in Conejos County on the east side of San Luis Valley. The turquoise is in nodules and veins in altered and much weathered andesite porphyry.

content. The variation in the ultimate material is perhaps the result of processes in nature, similar to fractional distillation, brought about by pressure and other factors.

A vein of gilsonite in Rio Blanco County just east of the Utah line is a part of a system of veins that extend northwest into Utah, where individual veins are 10 to 14 feet wide and continuous for several miles. Veins of gilsonite at Bonanza, Utah, have been explored to depths of several hundred feet. The outcrop of the vein in Rio Blanco County is on the crest and eastern slope of the ridge dividing Evacuation Creek from the adjoining almost parallel stream to the northeast. The vein has an average width of 30 inches, and is continuous for about 2 miles. In places it has been prospected to a depth of at least 100 feet. A sizeable vein of gilsonite is found on Piceance Creek southwest of Meeker, also in Rio Blanco County. Gilsonite, or some related hydrocarbon, occurs in the Dakota sandstones about five miles north of Rabbit Ears in the Green River basin, and a similar material has been mined at the head of Parachute Creek in Garfield County.

An isolated deposit, either gilsonite or grahamite, is located on the east side of Sherman Creek near the northern edge of Middle Park. The veins are fissures in clay, sandstone, and conglomerate of the Middle Park formation (Tertiary). The veins range in thickness from a few inches to 6 feet, and are traceable for 3,000 feet. Considerable work has been done on the deposit, the products having been hauled to nearby Granby for shipment by railroad.

In addition to the above bitumens a number of tar or asphalt sands are reported in several western counties that justify further study as a possible road material.

Details including size of the deposits of bitumens in Colorado are not known and no production is reported in recent years. The average price of Utah gilsonite has varied from $22 to $28 per ton.

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Graphite

Graphite has been found in Chaffee, Gunnison, Las Animas, and San Juan Counties, but no production is recorded in recent years. The mineral occurs both in veins of igneous origin and in beds which are the result of extreme metamorphism of coal seams. The quality of amorphous graphite varies with the intensity of metamorphism, which is usually caused by folding, faulting, or intrusion of igneous rock.

In Gunnison County the graphite deposits occur in Cretaceous rocks near the head of Cement Creek. The beds are nearly vertical and contain three graphite veins about 50 feet apart. The largest vein is 4 to 6 feet thick and has been developed commercially by means of a number of open cuts near the summit of Italian Mountain.

A second deposit of graphite in Gunnison County is found in a large vein traceable for more than 10 miles from the White Pine district, through the Quartz Creek district, and to the Tin Cup district. The vein ranges in thickness from a few inches to several feet. Some graphite was shipped from the Quartz Creek district.

In San Juan County near the common corner of Dolores, San Miguel, and San Juan Counties, a large deposit of low-grade graphite is present. This locality is near the divide between Cascade Creek and the south fork of Mineral Creek. In Chaffee County graphite occurs south of Buena Vista on the Arkansas River.

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Kyanite, Sillimanite, and Andalusite

Schist and gneiss, often relatively close to granite areas, containing several per cent of sillimanite are common in the Idaho Springs formation in the Front Range. Similar occurrences have been noted by the writer in the Mosquito Range in Park County. The sillimanite is fine-grained and intimately intergrown with other silicate minerals. Commercial concentrations have not been found. Flotation of sillimanite in the schist and granite might be possible, but it is doubtful that the costs would compare favorably with high-grade sillimanite found in other states.

Andalusite and kyanite are less common than sillimanite in Colorado.

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Ocher

Ocher, sienna, umber, and other forms of iron oxide are used in considerable quantities as pigments in house and barn paints, in linoleum, and as mortar colors. Iron oxide is used also in chicken feed, and glass polishing.

Iron oxides are common, but the right quality and low-cost availability are seldom found. Synthetic iron oxide is replacing a number of the products. The red oxide is still obtained from natural material.

Ocher and the related oxides have not been produced in Colorado, and promising deposits are not known.

Pegmatite Minerals

For a summary of the general geology of pegmatite minerals, together with selected bibliography, refer to pages 466-70.

The pegmatite minerals produced in Colorado are tantalum minerals, beryl, mica, and feldspar; the latter being the most important. Tantalum production is described on page 469.

Some production of beryl occurred from 1939 through 1942, but the amount is not reported. Production amounted to 68 and 35 tons valued at $8,348 and $5,125, respectively, in 1943 and 1944.

Mica is a conspicuous mineral in many pegmatites; however, material suitable for sheet mica has not been found in commercial quantities. The utilization of scrap mica offers more promise but thus far production has been limited largely to war demands as follows:

Year	Quantity (short tons)	Value
1935-1937	*	*
1938	870	$ 9,842
1939-1941	*	*
1942	3,923	30,641
1943	3,477	29,801
1944	7,640	40,846

*Figures not available.

Feldspar is the most abundant mineral in pegmatite, but only where it is relatively free of intergrown quartz and mica can it be used commercially. Production of feldspar in Colorado increased from a relatively few tons ten to fifteen years ago to around 20,000 tons annually in recent years. This growth is an excellent example of individual enterprise and courage that is required to develop a mineral resource. Large reserves of feldspar ore are indicated. Near Parkdale in Fremont County construction was started in 1946 of a feldspar flotation mill with a reported daily capacity for treating several hundred tons of pegmatite rock. Production has been as follows:

	Crude Feldspar		Ground Feldspar	
Year	Quantity (Long Tons)	Value	Quantity (Short Tons)	Value
1933	(1)		10,300	$ 79,310
1934	(1)		12,417	95,858
1935	22,275	$ 64,151	22,320	166,071
1936	25,806	101,950	28,034	206,550
1937	42,221	178,148	43,618	307,412
1938	27,452	104,673	33,529	219,699
1939	29,995	107,536	41,176	264,153
1940	34,105	123,514	44,260	282,178
1941	42,326	147,640	61,141	387,338
1942	23,610	135,569	51,684	349,065
1943	20,659	88,691	39,854	271,854
1944	15,787	81,967	45,365	318,696
1945	26,279	105,021	41,433	307,619

(1)—Figures not available.

Potash

The possibilities of commercial production of potash in Colorado seem to be limited. The mineral alunite ($K_2O.3Al_2O_3.4SO_3.6H_2O$) has been used in the production of alum, and in recent years attempts have been made to recover both potash and aluminum from deposits at Marysvale, Utah. Alunite is a characteristic mineral in altered volcanic rocks. In Colorado alunite is found in Costilla County; east of Silver Cliff in Custer County; in Delta County; near Rico in Dolores County; near the main up-stream fork of the San Miguel River in Montrose County; and at Red Mountain in San Juan County.

The alunite deposits in Colorado have not been of commercial importance; potash is produced at a low cost from potash salt mines in New Mexico.

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Salt

Natural sodium chloride has been encountered in drilling deep tests for oil in the Paradox basin in Montezuma, Dolores, San Miguel, and Montrose Counties.

Salt from salt springs in Paradox Valley has been used locally in the salt-roast process for the recovery of vanadium. High freight costs are unfavorable for development of salt deposits in this area.

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Silica Sand

The possibility of a glass-making industry in Colorado is discussed from time to time, and conflicting statements are common as to the availability of suitable silica sand. In spite of the apparent interest little information is published on the subject. For this reason a full summary is given of a private report on "Some High Silica Sandstones of Douglas and Jefferson Counties." These sandstones are not necessarily the largest nor the best in Colorado, but they are better known than most others, and they have been developed by local quarries. In addition, these deposits of sandstone are believed to be fairly representative as to quality and quantity, and their location is probably as favorable as any other deposit in Colorado. In the report referred to, three beds are described about three miles southeast of Waterton in Douglas County and another bed about three-quarters of a mile north of the town in Jefferson County. Waterton (on State 124) is in the mouth of Platte Canyon and about 14 miles southwest of Denver.

The sandstone beds strike northwesterly parallel to the Front Range, dip easterly at 50° to 15° and locally form prominent hogbacks. The so-called first hogback is Dakota (Upper Cretaceous) sand and the second hogback is the Lykins (Permian) sandstone.

Molding Sand Quarry. NE ¼, Sec. 11, T. 7 S., R. 69 W.

The Dakota sandstone bed is 10 feet wide and unsuitable for the manufacture of glass. The height from the floor of the quarry to surface is only 40 feet.

Analysis:	SiO_2	98.70	percent
	Fe_2O_3	0.25	"
	Al_2O_3	0.95	"
	CaO	0.04	"
	Na_2O	0.74	"

Helmer Quarry. SW ¼, Sec. 12, T. 7 S., R. 69 W.

This quarry is in the east side of the Dakota or first hogback. The sandstone has an overall width of 50 feet. It is a white fine-grained soft rock that is easy to quarry. Iron-stained streaks were eliminated by hand sorting.

Analysis:	SiO_2	98.7 to 98.2	percent
	FeO_3	0.09 to 0.16	"
	Al_2O_3	0.98 to 0.55	"
	CaO	0.05 to 0.035	"
	Na_2O	0.80 to 0.75	"

The analyses do not quite reach the requirements for plate glass but they are suitable for window glass.

Kassler Quarry. NE ¼, Sec. 34, T. 6 S., R. 69 W.

This quarry is in the Lykins sandstone or second hogback. The sandstone is fine-grained, white, and soft. Only a small tonnage is indicated.

Analysis:	SiO_3	95.4	percent
	Fe_2O_3	.18	"
	Al_2O_3	4.09	"
	CaO	0.04	"
	Na_2O	1.08	"

The analysis is below the specifications required for window glass, although washing probably would eliminate the alumina.

Little Quarry. SW ¼, Sec. 27, T. 6 S., R. 69 W.

This quarry is about ¾ of a mile north of Waterton and on the same bed as the Kassler quarry. Sand was obtained from this quarry for a bottle factory that operated in Denver 30 to 40 years ago. About 116,000 tons above the quarry floor are indicated.

Analysis:	SiO_2	96.7	percent
	Fe_2O_3	.13	"
	Al_2O_3	.09	"
	CaO	.055	"
	Na_2O	.86	"

The alumina is too high for making glass but washing would undoubtedly improve the composition.

Roxborough Park Deposit. SE ¼, Sec. 11, T. 7 S., R. 69 W.

Two carloads of white sandstone were obtained from the Lykins (2nd Hogback). A sample from the quarry analyzed 0.32 percent Fe_2O_3, 2.44 Al_2O_3 and is probably unsuitable for good quality window glass without washing. A possible reserve of 600,000 tons is indicated.

The limits of iron oxide and alumina followed by some glass manufacturers are:

	Fe_2O_3		Al_2O_3	
	Desirable	Maximum	Desirable	Maximum
Plate glass	0.05 percent	0.15 percent	0.10 percent	0.50 percent
Window glass	0.10 "	0.25 "	0.50 "	1.00 "

The sandstones described are not as good quality as the glass sands in Pennsylvania, West Virginia, Missouri, and Illinois that generally run over 99 percent silica. However, these latter sandstones are not everywhere good enough for better grades of glass and consequently washing is a general practice. The washing of the glass sands found in Douglas and Jefferson County has not been attempted and this possibility should be studied.

The Dakota and Lykins sandstone formations are extensive in the foothills along the Front Range, and other localities similar to those described are to be expected. Local variations in the sandstone beds are unfavorable for finding a single large deposit capable of supplying a large glass factory for many years; large tonnages probably would have to come from several different places.

References

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Sodium Sulfate and Carbonate

Sodium salts do not seem to exist in large quantities in Colorado; however, at least three deposits are known. The first of these is near Morrison and the Soda Lakes in Jefferson County.

The second deposit is of natural sodium carbonate, or trona, located in the alkali lakes about 14 miles west of the town of Hooper in Alamosa and Saguache Counties. The visible deposits are probably too small for economical development for outside markets. Old buried lake beds of the arid San Luis Valley may contain commercial quantities of sodium salts, if they can be located.

Natural sodium bicarbonate (nahcolite) occurs as fracture fillings in the oil shales of the Uinta basin. Small quantities of this natural baking soda have been found during the mining of shales in Garfield County for the Bureau of Mines oil shale plant at Rifle.

References

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U. S. Geol. Survey Missouri Basin studies No. 1, Mineral resources of the Missouri Valley region (map), pt. 2, Nonmetallic mineral resources: compiled by D. M. Larrabee, S. E. Clabaugh, and D. H. Dow, scale 1:2,500,000, 1945.

Sulfur

Sulfur deposits of limited size have been reported in several places. In Delta County sulfur is reported near the mouth of the Black Canyon of the Gunnison River, but details as to the extent of this deposit are lacking. In Gunnison County some sulfur has been mined from the oxidized zone of a gold-bearing pyrite chimney in the Vulcan mine, 12 miles southeast of Iola; the sulfur grades downward into pyrite. In Mesa County sulfur is reported near Grand Junction. In Mineral County south of Creede, one of the larger deposits of sulfur banded with chalcedonic silica is found in volcanic rocks of Miocene age. This deposit, estimated to contain 30,000 tons of ore averaging 50 percent sulfur, has been partially worked. In Montezuma County low-grade sulfur is present about 20 miles east of Dolores; very little work has been done on the site but a deposit of considerable size is indicated.

Large quantities of pyrite occur in the Kokomo district (p. 377) and in the Gilman district (pp. 384, 385) from which sulfur can be obtained but not at a profit under present economic conditions.

Production of Sulfur Ore
U. S. Bureau of Mines

Year	Quantity (long tons)	Value
1936	13	*
1937	11	*
1938	No production	
1939	36	$ 400
1940	89	1,000
1941	49	550
1942	90	1,000
1943	*	*
1944	89	1,200

*Figures not available.

FUELS

COAL

Reserves, Production, and Quality

Colorado, according to estimates of the U. S. Geological Survey, has 15.1 per cent of the total bituminous coal reserves of the nation. Reserves of bituminous coal at the end of 1936 were sufficient to supply the United States for 500 years on the basis of consumption and exports for that year. Colorado ranks second in subbituminous coal reserves and fourth in anthracite coal.

The area of Colorado underlain by all kinds of coal probably exceeds 25,000 square miles, or nearly one-fourth that of the State, and workable coal beds are from 2 to 60 feet thick. The estimated gross reserve of 500 billion tons includes coal beds to a maximum depth of 6,000 feet. The more significant estimate to the coal industry, however, is that nearly 200 billion tons of coal are minable. Minable coal underlies at least 25 counties (see tables 4 and 5, pages 267 and 268), and no part of the State is far from a source of coal, a fact that is important to industrial development.

The average price per ton and dollar value of coal in Colorado since 1864 is shown in figure 2. In recent years the value of coal produced has exceeded any other product of the mining industry in the State, except in 1939 when it was exceeded by molybdenum. The present annual production of 7½ million tons of coal in Colorado is from 230 mines. The quantity of coal produced each year varies, however, because of the varying demand for coal. During the war, shortages of labor affected production unfavorably. During the 82 years since the first coal production was reported in 1864, the greatest output for a single year was 12½ million tons; namely, in 1918, during World War I, when large quantities of coal were shipped to the East.

TABLE 4

COLORADO COAL PRODUCTION BY COUNTIES AND BY YEARS
(in tons)

COUNTY	1940	1941	1942	1943	1944	1945
Green River Region						
Moffat	49,667	51,858	68,518	89,927	138,800	129,166
Routt	913,942	871,367	1,190,354	1,193,546	1,189,483	1,097,304
Uinta Region						
Rio Blanco	9,883	12,709	13,593	8,809	11,434	11,374
Garfield	36,468	40,098	56,345	58,382	56,865	58,810
Mesa	73,081	111,245	122,775	101,150	107,764	109,557
Pitkin	998	1,302	428	......	24	......
Delta	66,703	74,407	96,682	117,312	120,291	132,736
Gunnison	621,479	712,717	775,300	754,947	751,745	778,568
San Juan Region						
San Miguel	1,430	1,049	1,132	753	217	320
Montezuma	4,741	5,723	5,656	2,463	1,398	1,896
La Plata	35,702	40,289	47,018	61,802	71,680	72,574
Archuleta	3,050	1,146	917	874	428	186
North Park Field						
Jackson	15,803	13,183	11,503	12,549	16,276	10,896
Denver Region						
Larimer	2,302	2,394	1,038	228	157	64
Weld	1,215,363	1,272,437	1,564,338	1,530,267	1,483,777	1,507,328
Boulder	623,780	647,921	713,823	602,897	606,949	478,874
Jefferson	147,725	130,035	147,462	155,314	140,310	139,785
Elbert	5,601	6,475	5,107	3,331	2,428	1,832
El Paso	251,644	240,133	249,082	249,454	232,253	215,243
Trinidad Region						
Huerfano	755,607	815,268	988,780	1,085,772	1,004,990	881,516
Las Animas	1,275,817	1,377,882	1,476,491	1,718,298	1,590,136	1,438,447
Smaller Miscellaneous Areas						
Canon City Field						
Fremont	521,080	520,506	549,104	578,612	622,166	557,356
Tongue Mesa Field						
Montrose	40,713	46,548	46,338	44,595	44,442	30,147
Ouray	......	......	......	......	500	......
Total	6,672,579	6,996,692	8,131,764	8,371,282	8,194,513	7,653,979

Source: Colorado State Coal Mine Inspector.

TABLE 5

LOW AND HIGH ANALYSES OF COALS FROM MINE SAMPLES

County and Town	Analysis, percent — Proximate: Moisture	Proximate: Volatile	Proximate: Fixed Carbon	Proximate: Ash	Ultimate: Sulfur	Calorific Value, per Pound: Calories	Calorific Value, per Pound: British Thermal Units
Green River Region							
Moffat	10–23	30–48	42–62	2–12	.2–1	6,300	11,400
Routt	4–21	32–47	40–61	3–15	.3–2	6,400	11,600
Anthracite P.O.	7–12	3–35	47–96	6–15	.6	7,300	13,100
Hayden	4–20	6–43	42–93	3–16	.3–2	6,800	12,300
Uinta Region							
Rio Blanco	9–18	30–50	41–61	2–10	.3–1	6,800	12,300
Garfield	4–14	32–48	34–62	2–18	.3–2	6,900	12,500
Mesa	3–14	26–44	34–62	5–36	.5–5	6,600	11,900
Pitkin	1–3	19–38	55–76	3–20	.4–.8	7,800	13,100
Delta	2–22	21–44	41–69	2–18	.3–2	6,300	11,400
Gunnison	2–21	30–46	44–67	3–12	.3–2	7,300	13,200
Crested Butte	2–9	3–40	52–96	3–10	.4–1	7,700	13,000
Camp Genter	2–5	8–10	76–92	4–10	.6–.8	7,900	14,200
San Juan River Region							
Montezuma	2–14	28–49	39–69	4–20	.4–10	7,000	12,700
La Plata	1–12	31–45	40–62	4–24	.5–6	6,800	12,300
Archuleta	9.5	35–38	46–51	10–11	1.2	....	.....
North Park Field							
Jackson	14–26	31–52	34–59	3–15	.1–1	6,200	11,100
Denver Region							
Larimer	29–33	27–47	31–56	6–14	1–6	6,100	10,500
Weld	21–31	26–44	35–62	3–9	.2–.7	5,900	10,700
Boulder	17–24	28–44	40–63	3–12	.2–2	6,300	11,900
Adams	19–35	28–42	44–61	4–11	.3–.6	5,500	9,800
Jefferson	19–29	28–49	35–60	4–10	.3–2	5,800	10,500
Elbert	31–35	26–54	25–52	8–26	.4–2	5,100	9,200
El Paso	19–34	24–49	25–56	4–28	.1–1	5,100	9,200
Trinidad Region							
Huerfano	3–19	6–47	43–91	7–22	.4–2	6,800	12,300
Las Animas	1–6	25–42	46–69	6–28	.4–5	7,600	13,800
Smaller Miscellaneous Areas							
Canon City Field							
Fremont	5–15	30–46	37–63	2–25	.4–4	6,500	11,700
South Park Field							
Park	15.5	32–41	46–58	6–8	.5–.6	6,200	11,200
Tongue Mesa Field							
Montrose	2–6	32–39	51–61	6–12	.8–1	7,400	13,500
Ouray	14–16	34–47	41–55	7–10	.5–1	6,500	11,600

Data compiled from: A. C. Fieldner et al. Analyses of Colorado Coals. U. S. Bureau of Mines Tech. Paper 574, tables pp. 50-131 (1937).

The coal production decreased from 1921 to 1929 probably in part due to the introduction of natural gas into the State from Texas, and from 1929 to 1933 due to the business depression. Increased production since 1933 has been moderate and in response to war demands reached 8,371,282 tons, valued at $27,039,242 in 1943; but 1944 production was lower, even though the average price per ton was higher.

Colorado has the distinction of producing anthracite, bituminous, semi-bituminous, and subbituminous coal. Anthracite is found near Crested Butte in Gunnison County, and at several localities in Routt and Moffat Counties. High-grade bituminous coal is found in Jackson, Routt, Moffat, Rio Blanco, Mesa, Delta, Montezuma, La Plata, Fremont, and Huerfano Counties. The bituminous coals are the high-grade coking coals found in the Trinidad region (see page 274), in the Glenwood Springs area, and in Gunnison County.

The production of coke reflects changes in certain industries, such as steel-making, foundry work, and smelting. The annual production of coke in Colorado increased from 256,110 tons in 1935 to 605,956 tons in 1940, and varied during the war years 1941 to 1944 from 703,003 to 763,656 tons.

In recent years there has been a pronounced increase in the output of the coal by-products including coke, oven gas (used as a fuel gas), tar ammonia gas, and light oil. The economic value of these by-products has assumed a great importance because of the rapid growth of the chemical industry and the discovery of coal as a chemical raw material. Although in the past the chemicals derived from coal were mainly obtained as by-products of coking, recent developments indicate that in the future large amounts of coal may be processed mainly for the direct production of chemicals, with coke as a by-product. Coal tar yields creosote and the basic materials for the production of dyes, explosives, pharmaceuticals, and plastics; and the ammonia gas is used to produce ammonium sulfate, an important fertilizer. According to one estimate, the Colorado coals could supply enough ammonia to last the United States several thousand years. The distilled light oil obtained from coal can be used for the manufacture of gasoline, the Colorado coal reserves being equivalent to about 700 billion gallons.

An act of Congress (May 15, 1936) enabled the Bureau of Mines to investigate the uses of low-rank coals. A field station making the studies and experiments with coals from Colorado, Wyoming, North Dakota, Texas, Washington, Montana, and New Mexico was established at the Colorado School of Mines at Golden in May, 1938. The laboratory is equipped to study the combustion of the low-rank coals and their processing for by-products. Studies are also made of various furnaces and appliances for utilization of these coals as a fuel.

Summary of the Principal Coal Areas, Regions, and Fields

The coal areas in Colorado are shown on plate 7. Columnar sections (pl. 8) showing the principal coal horizons supplement summaries of the six major coal regions and fields. Production and analyses are given in tables 4 and 5, pages 267 and 268, rather than with a summary of each area. General references and references for the columnar sections also are added.

Green River Region

The Green River coal region is in Moffat and Routt Counties, with a small part extending into northeastern Rio Blanco County. The coal underlies approximately 3,100 square miles and contains an estimated reserve of 40 billion tons. The region is a broad synclinal basin trending northwest-southeast, roughly parallel to the Uinta Mountains-Axial Basin arch (see pl. 9, page 278). The southeastern part of the basin is considerably folded and faulted, and igneous activity has helped to develop high-grade coals locally.

The Mesaverde group, composed chiefly of sandstone and shale, overlies the Mancos shale conformably, and, like the Mancos, is of Upper Cretaceous age. The Mesaverde has been subdivided (see pl. 8) into the Iles formation below and the Williams Fork formation above. The lower part of the Iles formation is interbedded sandstones and sandy shales and contains the first, or lower, coal series. The conspicuous "white rock," or Trout Creek sandstone of the region, is the top member of the Iles formation. The Williams Fork formation is much thicker than the Iles, its base being the base of the valuable middle coal series (directly overlying the Trout Creek sandstone). Separating the middle and the upper coal series is the Twenty-Mile sandstone member of the Williams Fork formation that stands out prominently owing to its resistance to erosion. As distinguished from the Iles formation, the Williams Fork formation is characterized by thick zones of brick-red sandstone and baked shale produced by the burning of thick beds of coal.

The Lewis shale (Upper Cretaceous) conformably overlies the Williams Fork formation, and is conformably overlain by the Lance, formerly called the "Laramie," formation (Upper Cretaceous) now considered to be older than the true Laramie beds of eastern Colorado and Wyoming. The Lewis shale is dark gray and closely resembles the Mancos shale. The Lance consists of massive sandstones interbedded with sandy shale, and about 100 feet above the lower massive sandstone is a lenticular, but locally thick, coal bed.

Tertiary formations are the Fort Union ("post-Laramie"), Wasatch, Green River, and Browns Park fresh-water sandstones and shales. These beds overlap older strata throughout a large area in the northwestern part of the region. Coal occurs in the Fort Union ("post-Laramie") and Wasatch but is relatively unimportant.

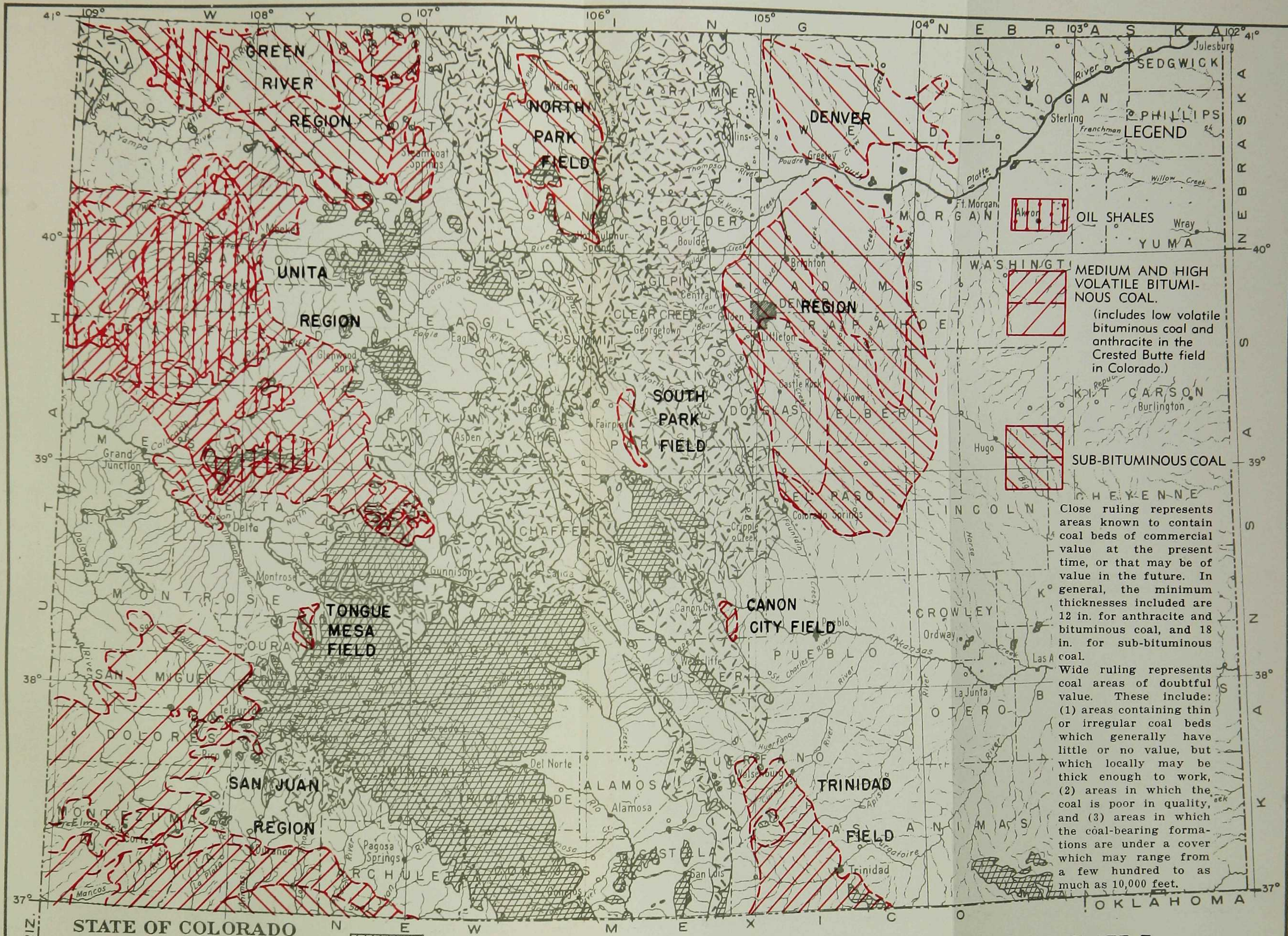

PLATE 7.
COAL AND OIL SHALE

(FORM PART 3, MISSOURI BASIN STUDIES NO. 1)

PLATE 8.

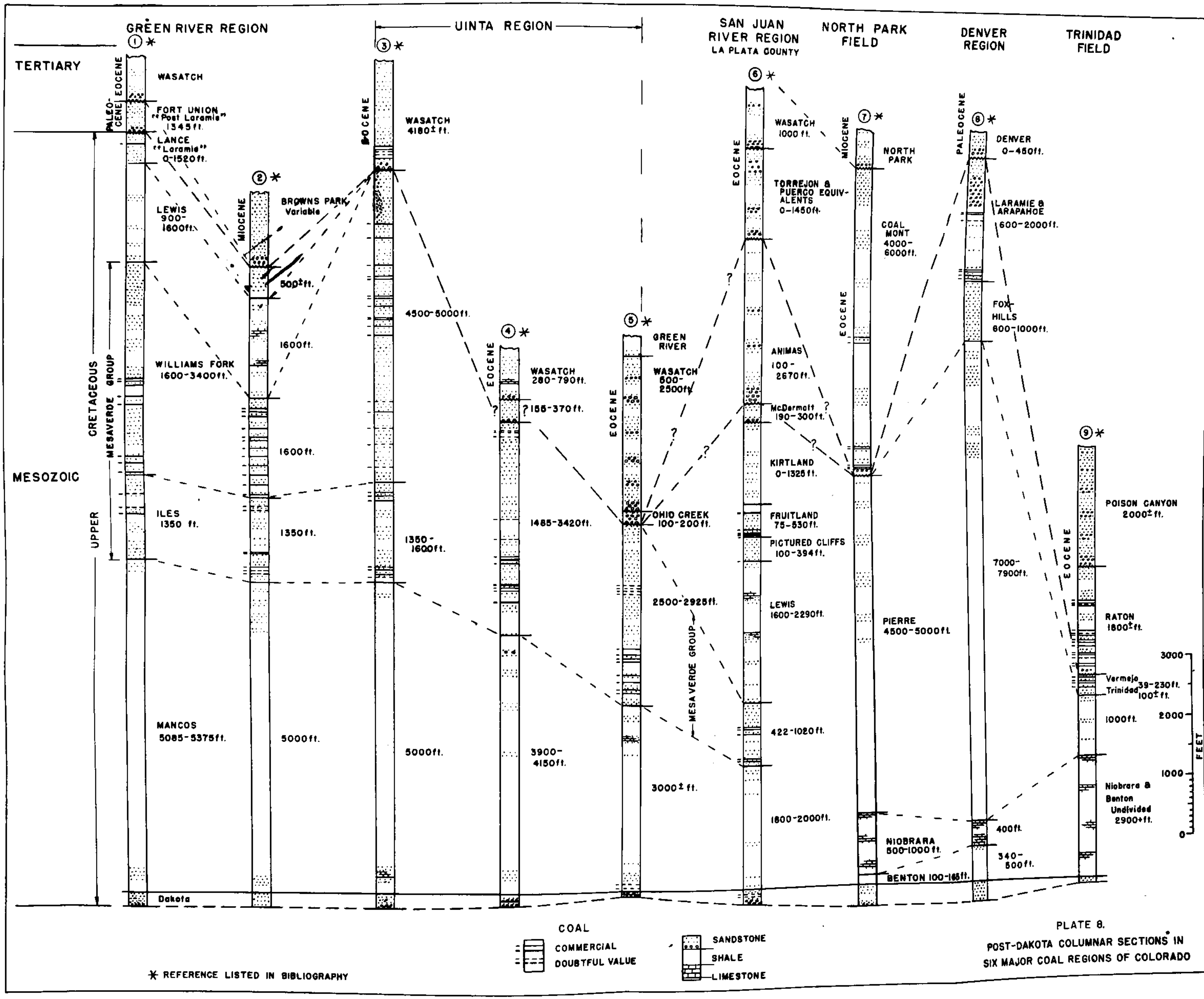

PLATE 8.

The Mesaverde coals range from subbituminous to anthracite, depending largely upon the proximity of late Cretaceous igneous intrusions and possibly to some extent on local folding and faulting. The Lance and Wasatch coals are mostly subbituminous. In the Twenty-Mile Park district the important Mesaverde coals occur in three persistent series—lower, middle, and upper. The coal in the lower series is generally considered the best, and that in the upper series the poorest. The coals of the middle series are the most regular and persistent, and somewhat thicker. The coal of all three series improves near disturbed areas. In the Oak Creek, Milner, and Mount Harris districts the middle series (Wadge bed) and the lower series (Pinnacle bed) have been mined most. These beds are from 5 to 12 feet thick.

Subbituminous Lance coal is mined near Craig from an 8-foot bed. Fort Union coal is mined on Lay and Spring Creeks and west of Cedar Mountain. Wasatch coal is not mined.

Uinta Region

The Uinta region includes parts of Gunnison, Pitkin, Delta, Mesa, Garfield, Rio Blanco, and Moffat Counties. It is about 6,000 square miles in area and contains an estimated 200 billion tons of coal, including about 75 billion tons at depths less than 3,000 feet. This region is a broad synclinal basin extending from the middle of Gunnison County northwestward into Utah. In Colorado it is bounded on the southeast by the Elk Mountains, on the southwest by Grand Mesa, on the east by the Grand Hogback, and on the north by the Book Plateau and Cathedral Bluffs. The Uinta Mountains and Axial basin arch separate the Uinta and Green River regions. At the eastern margins, coal-bearing formations dip steeply to the west and southwest toward the axis of the basin, but they flatten out in the middle of the basin and probably lie at great depth. Igneous activity in the southeastern end of the region has affected the character of the coal.

Coals of the region (see pl. 8) are in two main divisions of the Mesaverde formation (Upper Cretaceous). The lower division is made up of 100 feet of the Rollins sandstone member and 400 feet of the coal-bearing Bowie member. The upper division of the Mesaverde is composed of 400 feet of the coal-bearing Paonia member and 2,000 feet of undifferentiated sandstones and sandy shales. The lower division is marked by heavy ridge-making marine sandstone, and the upper is more largely sandy shale containing a brackish and fresh-water fauna. The coals are in two main series, the Bowie and the Panoia members.

The known coal fields form an almost continuous border around the region. In counter-clockwise order the fields are: Book Cliffs, Grand Mesa, Floresta, Mount Carbon, Crested Butte, Grand Hogback, Danforth Hills, and Lower White River.

The coals of the Book Cliffs field are largely in the lower third of the Mesaverde, with some coal beds in the Paonia member. The beds range from 3 to 21 feet in thickness and from 2 to 5 in number. The lowest bed, known as the "Palisade coal," is very persistent.

The Grand Mesa field extends from Palisade on the Colorado River to the West Elk Mountains. The lowest Bowie coal bed is the only one worked in the west end of the field, but seven beds of this series totaling as much as 40 feet are worked in the east end. Igneous activity has improved the coal locally. The Paonia coal series is not extensively worked because of its grade. Unsuccessful attempts have been made to mine some coal in the Mancos shale (Upper Cretaceous) immediately above the Dakota sandstone north of the Colorado River between Grand Junction and Delta.

The Floresta, Mount Carbon, and Crested Butte fields are characterized by intense folding, faulting, and igneous activity. Complex structures and high-grade coking coals, semi-anthracite, and anthracite coals have resulted. Only one bed, an anthracite of the Paonia series, is worked at Floresta. One Bowie and one Paonia bed are worked in the Mount Carbon field. Four Paonia beds are worked in the Crested Butte field.

The Grand Hogback field lies along the ridge of steeply dipping strata that forms the western flank of the White River Plateau and borders the Uinta region on the east from Meeker to Newcastle to Glenwood Springs.

In the Danforth Hills field, the northwest extension of the Grand Hogback fold, the principal mines are in the Williams Fork formation of the Mesaverde group. From three to ten beds are worked with a total thickness of 20 to 70 feet of coal. The strata dip westward in excess of 30 degrees. This area is closely related to the Green River region previously discussed.

The Lower White River field is along White River and Douglas Creek. This topographical basin is floored by the Williams Fork coal-bearing formation of the Mesaverde group. The strata lie nearly horizontal. Mines have been opened to meet local demand, but the lack of railway facilities has limited production.

San Juan River Region

The San Juan River region, extending from Durango southward into New Mexico, consists of approximately 1,900 square miles in Colorado and has an estimated reserve of 21 billion tons of coal. The region thus defined includes parts of Archuleta, La Plata, Montezuma, Dolores, and San Miguel Counties. The area is part of a great syncline in Colorado and New Mexico that is 125 miles long and nearly 100 miles wide. The northwestern half of the region is bordered by strata dipping steeply toward the center of the basin and ranging in age from Mancos (Upper Cretaceous) to Tertiary. Although there are differences of lithological character between the Cretaceous sediments of the

San Juan, Uinta, and Green River regions, the broad stratigraphic, faunal, and floral features are very similar. Alternations of marine, brackish-water, and fresh-water sedimentation occurred in all parts of the basin but rarely were strictly contemporaneous.

Coal is found in the Dakota, Mesaverde, and Fruitland and its equivalents. In the northwestern part of the region thin lenticular beds of coal in the Dakota occur in Dolores and San Miguel Counties. Dakota coal is usually less than 5 feet thick and lower in grade than that in younger formations. The chief coal-bearing zone of the Mesaverde group is the Menefee formation, which comprises about 400 feet of lenticular sandstones, carbonaceous shales, and groups of coal beds near the top and bottom. In addition to a good grade of bituminous coal, coking coal is abundant. The Fruitland formation (Upper Cretaceous) consists of 75 to 530 feet of gray, sandy shale, soft gray-white cross-bedded sandstone, indurated brown sandstone, carbonaceous shale, and high-grade coal. The Mesaverde and the Fruitland coals are the most abundant and the best.

The Durango field occupies the main part of the San Juan River region in Colorado. In the main producing part of the Durango field the coal comes from the Menefee formation and from the Fruitland formation. (See pl. 8.) Two coal beds 22 and 25 feet thick near the base of the Fruitland yield an excellent grade of bituminous coal and some high-grade coking coal.

North Park Field

The North Park coal field is in Jackson County and embraces about 500 square miles with an estimated reserve of 450 million tons of minable coal. The field is in a syncline between the Medicine Bow Range on the east and the Park Range on the west. The southern limits are the Rabbit Ears Mountains.

The coal beds are in the lower part of the Coalmont formation (see pl. 8) of Eocene age. The Coalmont rests unconformably on the Pierre shale (Upper Cretaceous) and is overlain unconformably by the North Park Miocene fresh-water beds. The Coalmont formation consists of 4,000 to 6,000 feet of dark gray shale and clayey sandstone. The upper part of the Coalmont consists of about 2,000 feet of sandstone barren of coal. Although the formation covers nearly 800 square miles in North Park, the area of workable coal is considerably less than this on account of excessive depths to the coal horizons in the central part of the syncline.

The Sudduth bed at the base of the coal-bearing section is locally more than 50 feet thick and of great extent. The Riach bed is 66 feet thick in the Coalmont district and contains few shale or sandstone breaks. The coals mined in the North Park field are, in general, subbituminous.

Denver Region

The Denver coal region is a depositional basin that extends from the Wyoming line to the middle of El Paso County. The basin covers approximately 7,600 square miles, and contains an estimated reserve of 14 billion tons of coal. The coal beds in the western border of this region are steeply upturned against the Front Range. Continental movements at the close of Cretaceous time caused some metamorphism of the coals, and coal of better quality is found locally where dips are steep in the foothills; however, mining of the steep-dipping coal is more difficult than where flat dips prevail. Furthermore, the steep dips carry the coal strata to increasing depths toward the east and limit the profitable mining to a strip a few miles wide along the foothill. At the margin of the basin in the southern part of the region in Arapahoe, Elbert, and El Paso Counties, the coal beds are thinner and lower grade than farther north.

Most of the coal in the Denver region (see pl. 8) is in the lower 200 feet of the Laramie formation (Upper Cretaceous) above its basal Arapahoe conglomerate member. Some coal east of Denver and near Sedalia is in the Denver-Dawson formation of Paleocene age that directly overlies the Laramie. The coals were formed during long periods, but at no time was the entire region coal-forming as a whole. Rather, it was divided into small basins of accumulation separated by lowlands or submerged areas of shale and sandstone deposition. Coal swamps of one time became areas of sandstone deposition of another. As a result, lenticular coal beds overlap or die out and cannot be correlated over very large areas. The beds range in thickness from a few inches to 16 feet, and two or three workable beds are common in producing areas.

The coal of the Colorado Springs area is of good grade subbituminous type. It occurs in three beds of Laramie age from 3 to 20 feet thick that dip gently to the northeast. The Jefferson County district has coal of good subbituminous type in steeply dipping beds 5 to 8 feet thick, dipping eastward. The Boulder field includes mines in the vicinity of Lafayette, Louisville, Superior, and Broomfield, where mining is in nearly horizontal lenticular beds 4 to 10 feet thick of subbituminous coal of Laramie age. The Weld County district contains coal of slightly lower grade than that of the Boulder field. The mines which are operated through shafts, are working in beds 3 to 12 feet thick; mining conditions are favorable.

Trinidad Field

The Trinidad field, in Las Animas and Huerfano Counties, covers about 1035 square miles and contains an estimated 22 billion tons of coal. The field is made up of the Trinidad and Walsenburg districts on the eastern border; the Stonewall, Tercio, and La Veta districts on the western border; and the Morley and Purgatory districts on the southern border. Structurally, the region is a syncline trending north and south, about 45 miles in length and 25 miles in width. Steep dips prevail on the west limb and gentle dips on the east limb.

The distribution of the principal coal horizons in the Trinidad region is shown in plate 8. Most of the coal is mined from the lower part of the Vermejo formation of Upper Cretaceous age. Coals of somewhat lower grade occur at the base of the Raton formation (Tertiary). The coal of the region is divided into three stratigraphic groups—a lower group in the Vermejo formation and a middle and an upper group in the Raton formation. The beds of the lower group are worked in all districts of the field. There are from one to eight beds in this group, with thicknesses of from 2 to 14 feet of high-grade bituminous coal. The middle group is in a zone about 300 feet above the base of the Raton formation; the beds are thinner (average 4 feet thick), fewer in number, and the coals are not as high grade as those of the lower group. The upper group consists of several thin beds in a 400-foot interval, the base of which is 600 to 1000 feet above the base of the Raton formation. These beds are not so widely distributed in the region as those of the lower group.

In Tertiary time the Spanish Peaks area in the northwestern part of the region was the center of igneous activity. The results may be seen, in addition to the Peaks themselves, in the many sills of igneous rock, found in the coal-bearing strata, and in the numerous dikes that radiate out from the peaks. Near the center of this activity most of the coal was completely destroyed by the heat; farther out it was changed into natural coke; and elsewhere the heat converted subbituminous coal into high-grade bituminous and coking coals.

The coals found in the lower or Vermejo group of the Trinidad district make high-grade hard coke, but from the same horizon in the Walsenburg district the coal is non-coking. The middle group is not well represented, and the upper group seems to be absent at Walsenburg.

The Stonewall district extends from the northwestern margin of the Trinidad region south of the Huerfano-Las Animas County line to the South Fork of the Purgatoire River. The middle and upper groups (Raton) of coal have been prospected to a limited extent and the beds range from a few inches to 8 feet in thickness. The Tercio district, which adjoins Tercio Park on the South Fork of the Purgatoire River, contains two to four beds of the lower group and one of the upper group of coals. The total thickness of the workable coal is 9 to 13 feet, but considerable interbedded shale is present. In the La Veta district at the northwestern margin of the region, the strata have steep dips to the northeast. Only the lower groups of coal (Vermejo) are known to be present in this district, and the beds are from 4 to 8 feet thick.

The Morley district near the New Mexico line contains the lower group of coals exposed along the flanks of an anticline. The coal is high-grade bituminous, and the bed which has been mined is 8 feet thick. Upper-group coal also is present in the district, with at least one workable bed. The Purgatoire district has outcrops of the upper and middle groups of coal along the Purgatoire River. One bed is 7 feet thick, and workable coal of good quality occurs in both groups.

Smaller Miscellaneous Fields

CANON CITY FIELD

The Canon City field south of Canon City in Fremont County covers about 40 square miles and contains an estimated reserve of 900 million tons of coal. The field is a syncline with steep and overturned beds on the west side and gentle dips on the east side.

The coal-bearing formation, like the Trinidad field, is the Vermejo formation. The coal beds, up to sixteen in number and form 1 to 6 feet each in thickness, are found in the lower 600 feet of the formation. Most of the coal is of excellent quality; it is particularly adapted to domestic use, because it is hard, clean, and readily combustible. The upper Vermejo is a heavy ridge-making sandstone overlain unconformably by the Arapahoe conglomerate.

SOUTH AND MIDDLE PARK FIELDS

The South Park field in Park County is in the eastern part of South Park and occupies a faulted synclinal area about 20 miles long and 4 miles wide. The coal reserves of the field are estimated to be about 18 million tons. The coal is in three main beds separated by thick barren strata of Laramie (?) age. Although these coals are rather thick in some places, unexpected lensing makes mining difficult and expensive. Most of the coal is bituminous. To the north in Middle Park field in Grand County thin beds of very low-grade subbituminous coal have been found. Although no workable beds have been developed, possibilities of commercial coal deeply buried are indicated.

TONGUE MESA FIELD

The Tongue Mesa field is in the common corner of Montrose, Ouray, and Gunnison Counties. It covers an area of about 40 square miles with an estimated reserve of 840 million tons of coal. Most of the coal is in the Mesaverde group (Upper Cretaceous) and is subbituminous.

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In 6 Major Coal Regions of Colorado
(The numbers refer to columnar sections)

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PETROLEUM

Distribution and Production

The oil and gas fields, major structural basins, and principal regional structures are shown on plate 9, and the chief stratigraphic relationships in six major basins in Colorado are shown in plate 10.

The production, price, and value of petroleum from the earliest year on record are shown in figure 2. The more important details as to the production of oil and gas fields in Colorado are tabulated on page 279 taken from the references listed below:

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Summary of the Principal Oil and Gas Fields in Colorado

Eastern Colorado

THE DENVER BASIN AND THE CANON CITY EMBAYMENT

The north-south-trending Denver Basin is a broad structural trough, the deepest part of which is at Denver. The basin is bounded on the northwest by the Hartville uplift of southeastern Wyoming, on the northeast by the Chadron arch of northwestern Nebraska, on the south and southeast, respectively, by the Apishapa uplift and the Las Animas arch, Colorado, and on the west by the Front Range uplift.

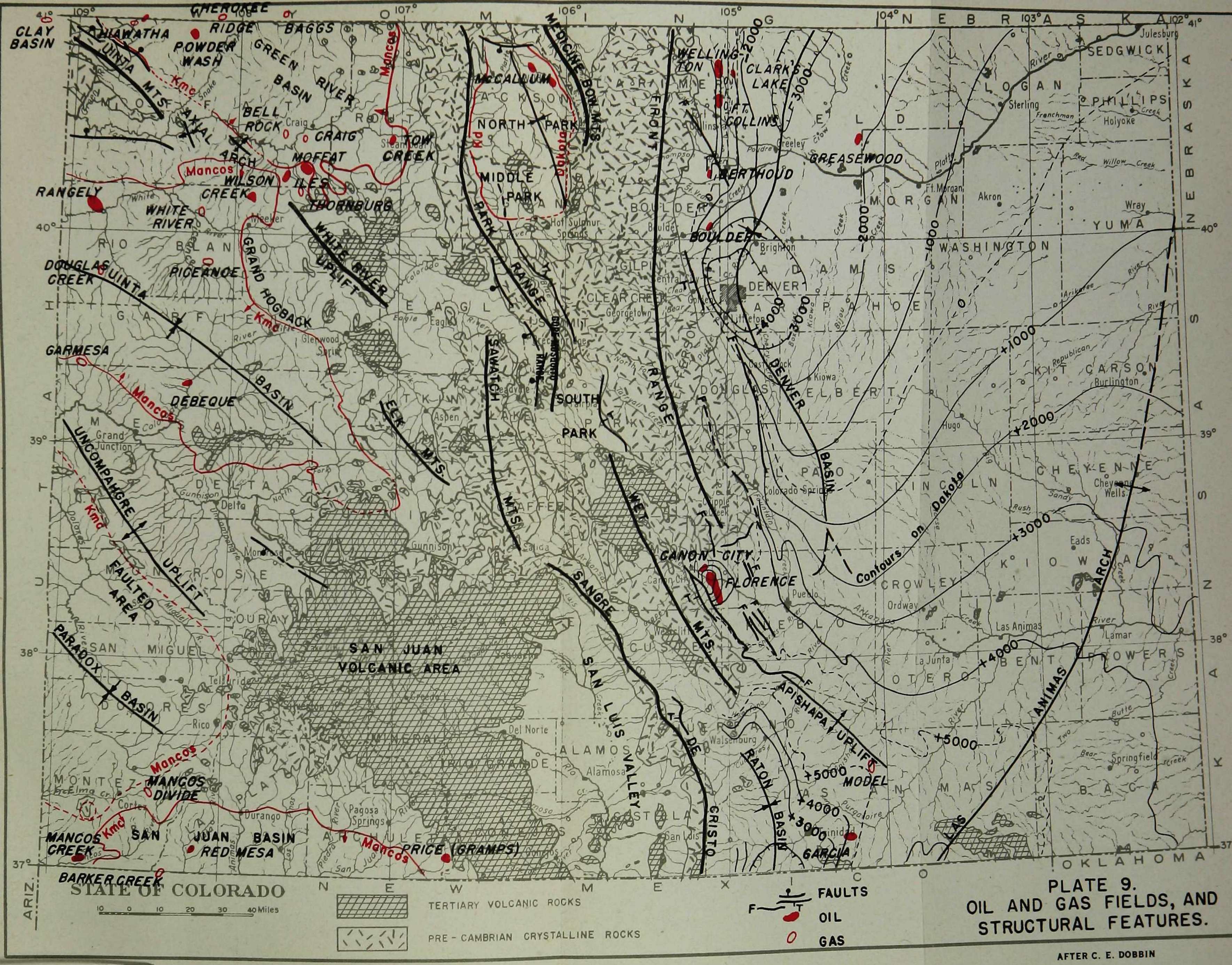

PLATE 9.
OIL AND GAS FIELDS, AND STRUCTURAL FEATURES.

AFTER C. E. DOBBIN

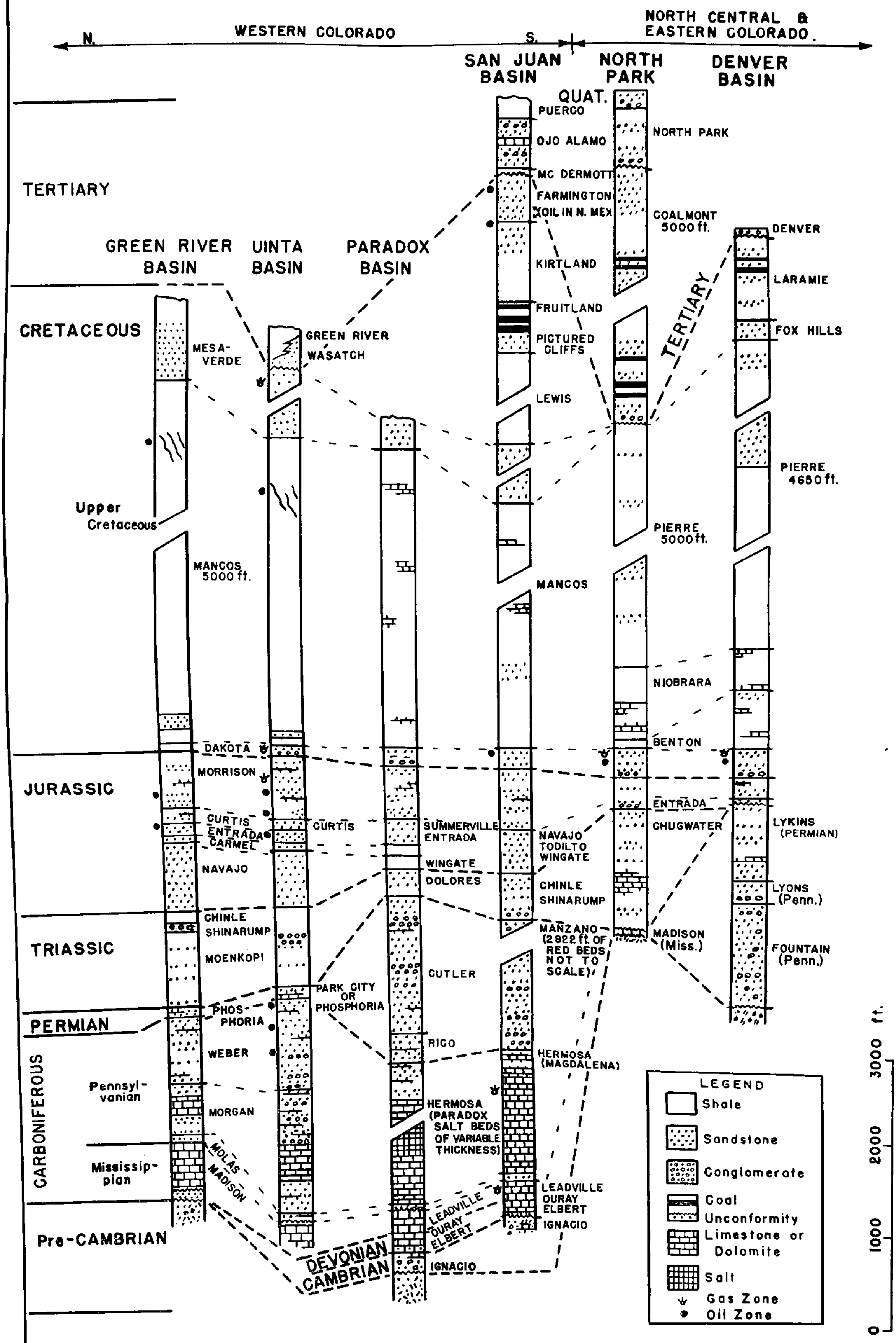

PLATE 10.

COLUMNAR SECTIONS IN SIX MAJOR BASINS IN COLORADO

OIL AND GAS FIELDS IN COLORADO

Pool	Basin	County	Date Opened	Ave. Grav. of Oil	Depth to Sands (feet)	Prod. from	No. Wells Jan. '46	Total Product to Jan. '46
Bell Rock	Green River	Moffat	1930	(gas)	2845	U. Cret.* Iles	2	...
Berthoud	Denver	Larimer	1925	38	3750	Dakota	1 oil	71,000 bbls.
							2 gas	894,682 MCF
Boulder	Denver	Boulder	1901	41	2500	Pierre	2	680,800 bbls.
Clark's Lake	Denver	Larimer	1943	38	6000	Dakota	5	166,390 bbls.
Craig	Green River	Moffat	1932	..	2733	Iles	..	...
				(gas)	3419	Morapos	3	Shut in
Debeque	Uinta	Mesa	1902	38	614	Mesaverde*	..	...
Florence-Canon City	Denver	Fremont	1876	31	1100+	Pierre	76	13,909,000 bbls.
Fort Collins	Denver	Larimer	1924	35	4550	Dakota	8	2,347,000 bbls.
Garcia	Trinidad	Las Animas	1898(?)	..	700—	Pierre	..	...
				(gas)	1700	Apishapa	7	Shut in
Garmesa	Uinta	Garfield	1925	(gas)	2860	Dakota(?)*	..	...
					3320	Morrison	..	...
					3755	Kayenta and Wingate	..	...
Greasewood	Denver	Weld	1930	41	6650	Dakota	2	489,500 bbls.
Hiawatha (East)	Green River	Moffat	1926	(gas)	2400—	Wasatch	6	25,436,250 MCF
			1934	38	2800	Wasatch	9	837,400 bbls.
Hiawatha (West)				(gas only)		Wasatch	3	8,445,744 MCF
Iles	Green River	Moffat	1925	30	3200	Morrison	..	...
				32	3400	Sundance	25	10,984,000 bbls.
Mancos Creek	San Juan	Montezuma	1927	34	300	Mancos*	..	...
Model Dome	Denver	Las Animas	1929	(gas)	1000	Jurassic(?)	6	Shut in
Moffat	Green River	Moffat	1924	40	3800	Dakota	..	...
				38	4400	Morrison	..	...
				..	4500	Sundance	11	6,257,800 bbls.
North McCallum	North Park	Jackson	1926	48	5000	Dakota	10	332,700 bbls.
Piceance	Uinta	Rio Blanco	1930	(gas)	2800	Green River	..	...
						Wasatch	3	Shut in
Powder Wash	Green River	Moffat	1931	(gas)	2150	Wasatch	7	6,226,293 MCF
			1936	38	5000	Wasatch	3	237,700 bbls.
Price (Gramps)	San Juan	Archuleta	1935	32	1300	Dakota(?)	..	...
Rangely	Uinta	Rio Blanco	1902	42	600+	Mancos	27	2,086,600 bbls.
			1933	33	6000±	Weber	33	1,478,000 bbls.
Red Mesa	San Juan	La Plata	1924	(gas)	700	Mesaverde*	..	...
				42	3500	Dakota(?)*	..	...
South McCallum	North Park	Jackson	1928	28	4800	Dakota	1	6,150 bbls. before shut in
Thornburg	Green River	Rio Blanco	1924	(gas)	2000	Dakota(?)	..	...
				(gas)	2550	Sundance	3	1,427,663 MCF
Tow Creek	Green River	Routt	1924	37	2600	Mancos	8	1,915,900 bbls.
Wellington	Denver	Larimer	1923	38	4300	Dakota	11	5,252,373 bbls.
White River	Uinta	Rio Blanco	1890	(gas)	600+	Wasatch	4	Shut in
Wilson Creek	Uinta	Rio Blanco	1938	48	6600	Morrison	..	...
				48	6700	Sundance	22	5,621,900 bbls.
Wray (Arickaree)	Denver	Yuma	1920	(gas)	1600	Carlile	4	Shut in

*Abandoned.

Marine and continental Paleozoic and Mesozoic and continental Tertiary beds are present in the basin. The ancestral Rockies were uplifted during the late Paleozoic time, and there is a resulting change from a westward continental and marine facies to an eastward marine facies in part of the Paleozoic section, a change that is of major importance to oil seekers.

Although Pennsylvanian and older Paleozoic beds are not present on the higher parts of the buried ridges of pre-Cambrian rocks along the Las Animas arch—and possibly the Apishapa uplift—some of them appear with rapid changes in age and thickness on the flanks. The Laramide revolution caused a second uplifting of the Rocky Mountains and brought about the present observable folding and attitude of the beds.

The Denver Basin is a depositional and a structural basin, a large part of which was formed by subsidence during Cretaceous time and before Laramide uplift to the west. It is asymmetric —with high dips on the west flank and dips seldom exceeding 100 feet per mile on the east flank. The thickness of the Cretaceous beds increases from east to west as far as the axis of the basin. (See pl. 9.) The regional dip of the Dakota sandstone on the northeast flank of the basin is the result of subsidence, as indicated by the fact that the dip is at the same rate and in a direction opposite to the thinning of the overlying Cretaceous beds.

The structure changes in the foothills at Boulder. North of Boulder to Wellington there is a series of plunging anticlines lying en echelon, and south of Boulder there is a series of reverse faults, alternating with a foothills monocline, and almost no folding.

The southern end of the axis of the Denver Basin curves rather sharply to the west in the Canon City embayment, and the southeast flank loses its individuality against the Apishapa uplift. East of the Apishapa uplift and intersecting it is the Las Animas arch, northwest of which the dips are steeper than elsewhere in eastern Colorado.

In the Denver Basin and Canon City embayment oil is produced from Upper Cretaceous beds in the Greasewood, Florence, and Canon City fields. Greasewood, a low anticline with one normal fault, owes its oil accumulation to a combination of stratigraphic and structural factors. Well data show that the reservoir sand (Greasewood, or uppermost Dakota) is variable in thickness and porosity, and that it wedges out downdip westward and thins eastward. Recent tests have encountered oil in a second low dome about 2 miles northwest of Greasewood. The Florence field is on the east flank of a complicated syncline, where the lack of a water drive has allowed the oil to settle in joints and fissures in the Pierre shale. In the Canon City field, oil has been found in fissures in the Pierre shale along an anticlinal nose that plunges southward. In addition, small anticlinal folds at Wellington, Fort Collins, Clark's Lake, Berthoud, and Boulder produce oil from Upper Cretaceous beds.

Commercial amounts of pre-Cretaceous oil have not been found in the Denver Basin or elsewhere in eastern Colorado. However, Jurassic (?) beds at Model dome—an asymmetric fold on the Apishapa uplift—yield gas containing 8 percent of helium. Considerable seismographic exploration has been carried on in eastern Colorado, and scattered deep drilling "on structure" found showings of oil in Pennsylvanian beds.

LAS ANIMAS ARCH AND SOUTHEAST FLANK

The Las Animas arch is a northeasterly-plunging anticline, the highest part of which trends from eastern Las Animas County to Kiowa County; in fact, it may extend less prominently northward almost to Wray, Colorado. The present form was developed largely during the Laramide revolution; however, at least two and possibly three periods of deformation have affected sedimentation in southeastern Colorado. During Pennsylvanian time the arch was a positive land mass, as indicated by the fact that wells drilled on top of the arch went from Permian red beds into pre-Cambrian crystalline rock. On the southeastern flank, wells have reached Mississippian and Ordovician beds. Marked rapidity of change in age and thickness of the sediments on the flank has been verified by deep wells. Superimposed upon the top and flanks of the arch are numerous folds, some of which have been tested without finding commercial quantities of oil. These folds seem to be largely the result of minor structural adjustments before the Jurassic and of differential settling in sediments deposited over irregular topographic highs of the pre-Cambrian land mass.

At least 4 wells within a 16 miles radius of Lamar have had showings of oil in Pennsylvanian beds. Difficulties of exploration for stratigraphic traps have retarded development of the Las Animas arch, but marked increase in activity in the area commenced during the Fall of 1945.

THE TRINIDAD OR RATON BASIN

The Trinidad basin is a pronounced structural and depositional basin that trends in a north-south direction in central Huerfano County and extends southward into New Mexico. The western margin is a belt of steep eastward dips similar to the foothills of the Denver Basin, and the eastern flank has much gentler westward dips. The buried southern end of the Wet Mountains enters the northern limits of the basin as a south-plunging anticline. Extreme subsidence during Pennsylvanian and Mesozoic time resulted in the deposition of more than 18,000 feet of sediments. The trough was greatly modified during the Laramide revolution by the uplift of the Sangre de Cristo Mountains to the west, after which the basin received at least 4000 feet of continental Eocene strata. Pronounced igneous activity in the deeper part of the basin occurred later in the Tertiary.

Favorable traps on the eastern flank of the Trinidad basin have been tested without encouraging results. A small production of wet gas is obtained from Cretaceous sand lenses on the southwest flank of a low-plunging anticline at Garcia.

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North Park and Middle Park

North Park and Middle Park lie between the Park Range and the Medicine Bow Mountains in north-central Colorado. About 14,000 feet of strata lie upon the pre-Cambrian basement complex. This thickness includes fresh-water Tertiary beds, Cretaceous marine shale and sandstone, continental Jurassic shale and sandstone, Triassic redbeds, thin marine limestone of Permian or Pennsylvanian age, and possibly older Paleozoic beds at depth. Major unconformities occur at the base of the Miocene, Eocene, Triassic, and Permo-Pennsylvanian. Laramide folding seemingly occurred before the deposition of Eocene beds. Anticlines around the margin are known, and incomplete exposures prove the presence of faulting beneath the Tertiary and Recent overlap. The overlapping beds make prospecting difficult.

Oil seepages from the Dakota (?) sandstone are found on the west side of the area. The McCallum double anticline is producing high gravity oil and carbon dioxide gas from the Dakota (?). These two sharp offsetting anticlines on the east edge of North Park have 1300 and 1500 feet of closure. Production was hampered by freezing when the carbon dioxide expanded to atmospheric pressure; recently this difficulty has been overcome.

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Green River Basin

The Green River Basin extends southward from southwestern Wyoming into northern Moffat County, Colorado, about as far as Craig. Its southern boundary is the Uinta Mountains and the Axial Basin arch. Paleozoic beds crop out on the flanks of the Uinta Mountains and in the Cross Mountain and Juniper Mountain anticlines. Mesozoic rocks occur on the Uinta Mountain-Axial Basin arch, but much of this arch is covered by the overlapping Tertiary Browns Park formation. The stratigraphy of the basin is complicated by overlaps, interfingerings, and variable thicknesses of Mesozoic and Paleozoic formations.

The dominant structural feature of the Colorado part of the Green River Basin is the east end of the Uinta Mountains and the parallel regional fault along its northeast flank. Other faults in the basin in Colorado are isolated and minor. At least one fault has oil saturation on the outcrop, but true oil seepages have not been reported in the basin in Colorado.

Most of the uplifting was at the close of Cretaceous time, after which Eocene beds (Wasatch, Green River, and Bridger) were deposited overlapping the lower slopes of the Uinta Mountains. This well-known Cretaceous-Tertiary unconformity is oil-saturated in numerous outcrops in the Uinta Basin. A second uplift occurred after Eocene time, upturning the edges of the young beds along the arch. On the flanks of the Axial Basin arch the Eocene deposits are parallel to the older Cretaceous beds, proving that this arch did not form until the second or younger uplifting of the Uintas.

At Hiawatha and Powder Wash domes gas and oil are produced from lenticular lower Eocene Wasatch beds. Oil is also produced from Upper Cretaceous Mancos shale at Tow Creek and Iles. The Dakota sandstone is saturated with oil at a few outcrops and yields oil at Moffat (Hamilton) dome. The Jurassic Morrison and Sundance are the best oil-producing zones in the basin, especially at Iles and Moffat domes. A prominent unconformity at the base of the Pennsylvanian, where shale overlies Mississippian limestone, may be a prospective oil horizon, and the Wasatch sandstones may contain oil locally where they overlap older source beds.

The Colorado part of the Green River Basin, beyond the producing fields, has received a relatively few oil tests. Very little folding is visible in exposed Tertiary beds; however, considerable seismic work has been done in the Craig area.

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Uinta Basin

The Uinta Basin is a major structural basin bounded by the Uinta Mountains on the north, the Uncompahgre uplift on the south, the White River uplift and the Elk Mountains on the east, and the faulted Wasatch Mountains of Utah on the west. As much as 20,000 feet of strata may be present in the deeper parts of the basin which lie in Utah. Although contemporaneous with the Paradox Basin of southwestern Colorado, the Uinta Basin was separated from it by the Uncompahgre highland.

The normal stratigraphic section in the Uinta Basin ranges in age from Cambrian to Miocene, the latter being represented by the well-known Green River oil shale of fresh-water origin. (See p. 270, pl. 8.) The deepest well in the area, drilled in the Wilson Creek field in northern Rio Blanco County, started in Upper Cretaceous sandstone and stopped in Mississippian dolomite at a depth of 12,702 feet. Well logs and measured sections in the basin indicate that the Pennsylvanian beds are largely thick continental sandstone (Weber) thinning eastward, red and black shale, marine limestone, and some local evaporites. The Permian (Park City or Phosphoria) is dolomite, which feathers out into shale eastward. Triassic beds are red shale and thin argillaceous conglomerate. Jurassic beds are thick continental wind-blown sandstones (Navajo and Entrada), thin marine glauconitic limestone, blending to black organic shale toward the east (Curtis), and continental sandstone and variegated shale (Morrison). Cretaceous sandstones (Dakota and Frontier) are overlain by marine shale (Mancos), which is overlain by sandstone (Mesaverde group).

The Rangely oil fiield, which is the largest addition to American oil reserves in 1945, is on the north side of the Uinta Basin along White River near the Utah line. Commercial amounts of oil have been produced from shallow fractured zones in the Mancos shale at Rangely since 1902. The discovery of deeper Pennsylvanian oil was made in 1933, but development of the deep oil did not begin until 1944. Scattered oil-saturated red arkosic and white quartz sandstones (Weber) occur through a 600-foot section at a depth of about 6000 feet, but most of the production is coming from the upper third of the section. All the

Pennsylvanian section has not been tested, but it is estimated to be at least 4000 feet thick. The structure is an elliptical, asymmetric dome trending northwestward. Normal faults with northeasterly strikes occur in exposed Upper Cretaceous beds and are associated with fracture systems that yield oil at shallow depths.

Within the Uinta Basin area, in addition to the described Cretaceous and Pennsylvanian oil-bearing formations, there is important oil production from Jurassic sandstones (Morrison and Entrada) at Wilson Creek (Colorado's second largest oil field). Gas occurs in Eocene beds at Piceance and White River domes.

The unconformity between the pre-Cambrian and younger over-lapping beds—especially the Jurassic—is important for possible stratigraphic traps for oil in the Uinta Basin. In the west end of the basin the pre-Cretaceous formations are concealed by flat-lying Tertiary fresh-water sediments. Tertiary formations within the basin were deposited on an erosion surface. The unconformity in many places is marked by tar sands and solid hydrocarbons that are of particular interest to exploration for oil.

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Paradox Basin

The Paradox Basin of southwestern Colorado is the southeast part of the Colorado River salt basin that lies mostly in Utah, and which was named for the great thicknesses of salt beds therein. The basin is elongate with a northwest trend, and lies southwest of and parallel to the Uncompahgre uplift; it is at least 150 miles long and about 80 miles wide.

In the basin rapid changes occur in the character and thickness of as much as 7,000 feet of Paleozoic and Mesozoic strata. Cambrian, Devonian and Mississippian beds, largely limestone, were laid down in an open sea extending over a large part of western Colorado, but these beds were subsequently eroded. In Pennsylvanian time this highland formed a ridge separating two depositional basins. The thick evaporite deposits (Paradox formation) found in the basin southwest of this highland are evidence that this area was a nearly landlocked arm of the sea; a connection probably was to the southeast into the Magdalena sea of New Mexico. In the Uinta Basin to the northeast, the "Weber shales" (black shales, thin limestones, and evaporites) were deposited in a more open Pennsylvanian sea. The Permian beds (Cutler and Rico) are interfingering sandstones and limestones. Beds representing the geologic periods from Triassic through Late Cretaceous are also found in the Paradox Basin; some Triassic beds thin out on the flank of the Uncompahgre arch.

Renewed movement during the Laramide revolution produced a number of parallel synclines and anticlines southwest of the Uncompahgre uplift. Collapsed anticlines resulted in several grabens, and block faulting also is common. Two structures occur in the southern margin of the basin, one prominent anticline at McElmo Canyon and a small gas-producing fold at Mancos Divide. The McElmo anticline may have been formed by the intrusion of igneous rocks.

The Permian Cutler-Rico beds contain sandy zones that have had good showings of oil in the Utah part of the Colorado River salt basin. An unconformity separating Permian and Triassic strata may be favorable for accumulation of oil. The great thickness of salt encountered in a number of deep tests in the Paradox Basin may represent salt domes but further work is required to determine whether structures favorable for oil are present.

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San Juan Basin

The San Juan Basin is almost entirely in New Mexico, and only a small northern part extends into Montezuma, La Plata, and Archuleta Counties, Colorado. The basin is bounded on the north by the San Juan Mountains and Needle Mountains uplifts. The basin is relatively shallow for its breadth, even though the 8,000-10,000 feet of strata in Colorado does not represent the maximum thickness present in New Mexico. The beds range in age from Cambrian to Eocene, Ordovician and Silurian beds probably being absent. Devonian (?), Mississippian, and Pennsylvanian strata are chiefly marine limestone, Permian, Triassic, and Jurassic beds are mostly red sandstones and shales. The Upper Cretaceous is represented by the Dakota sandstone, Mancos shale, Mesaverde group, and younger alternating marine and fresh-water sandstone and shale. (See pl. 10.) Tertiary beds are fresh-water sandstone and shale of Eocene age. As many of the anticlines in the San Juan basin have not been tested below the Dakota sandstone (Upper Cretaceous), relatively little is known about the oil possibilities of its deeper parts. Three Colorado localities have produced small amounts of oil: Mancos Creek, a gentle monocline, produced oil from the Mancos shale; Red Mesa, a narrow elongated dome, produced gas from the Mesaverde and oil from the Dakota (?); and Price (Gramps), a narrow anticline almost surrounded by extrusive rocks, produces oil from the Dakota. Development of the area has been slow because of small closures on surface folds, and because of the lack of knowledge of possibly favorable stratigraphic conditions at depth.

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OIL SHALE

One of the undeveloped natural resources in Colorado is the oil shale in Mesa, Garfield, and Rio Blanco Counties in the northwestern part of the State. (See pl. 7.) According to the United States Geological Survey, 952,200 acres in these counties are oil-shale land. Estimates, based on data from core-drill samples taken by the Bureau of Mines in 1945, indicate, however, that the reserves of oil shale there are larger than previously supposed. According to tests a 490-foot section of oil shale will yield oil per ton as follows:

420 feet of medium-rich shale	15 gal.
70 feet of rich shale	29 gal.

Using these figures, it is estimated that 300,000,000 barrels of oil are recoverable per square mile of shale land.

The lower Carboniferous oil shales of Scotland, which have been commercialized for many years, yield about 25 gallons of oil per ton of shale. Also of commercial importance in Scotland is the ammonia gas used to make ammonium sulfate; about 36 pounds of the sulfate are obtained per ton of oil shale. However, shales that yield the most oil yield the least ammonia gas. In contrast, Colorado shale yields large quantities of oil and ammonia gas from rich shale and small quantities of both from lean shale. The workable Scotland beds are about as thick (70 feet) as the richest Colorado beds. The medium-rich Scotland beds are much thinner than the Colorado beds.

In comparison with oil shales in Germany, France, Spain, and Estonia, the Colorado shale is richer than any, except those of Estonia. One bed of oil shale in Estonia is said to yield 100 gallons of oil per ton of shale, but the bed is only about three feet thick. A few leaner beds are as much as 4 feet thick, but the total thickness of oil shales in Estonia is much less than the Colorado shale. In Germany, 12 gallons of oil per ton of shale are obtained, with a maximum of 15 gallons per ton from the richest beds.

Shale oil is distilled from solid organic matter (kerogen), the composition of which is indefinite; in fact, kerogen may be the material from which some liquid petroleum has been made by heat, pressure, radioactivity, and other forces.

The oil-shale region of Colorado is featured mainly by deeply dissected uplands. The Green River formation, because of its tough oil shale members, resists erosion and forms steep cliffs that rise more than 3,000 feet above the Colorado River north and south of Rifle and De Beque. Other typical cliffs of the Green River formation form the walls of the White River west of Rangely and the Cathedral Bluffs near the Douglas Creek anticline.

The Green River formation, of middle Eocene age, is a series of beds that were deposited in ancient Uinta Lake. Near the central part of the Piceance Creek structural basin the formation has its maximum thickness in Colorado of about 2,800 feet. It is separated into four members, the Parachute Creek member containing most of the rich oil-shale beds. The upper fourth of the formation is practically barren of oil shale; the middle half yields oil; and the remainder is barren. The Green River formation is underlain by shale and soft sandstone of the Wasatch formation of Eocene age, and is overlain by gray sandstones and red clay shales of the Bridger formation of the same age.

The oil shale in the Green River formation is of two main types, with all gradations in between. One type is a hard and tough rock that is the richest in oil content; it forms massive benches, weathers bluish-white, and is dark brown to black on fresh subconchoidal fracture. A second type has pronounced thin bedding, being a typical paper shale, except that the laminations are more flexible. It is light gray or bluish-white on the outcrop and light to dark brown on fresh fracture. Oil has been distilled from both types, but the massive hard type is the richest. Although the oil shale dips as much as 28° just west of the Grand Hogback, it is almost horizontal a few miles farther west and elsewhere.

Visible fossil remains, though not numerous, include leaves, fresh-water shells, insects, and beautifully-preserved fish remains. Fossils of microscopic size are abundant. Well-preserved, delicate plant structures, apparently of fresh-water algae, offer further proof that the shale was laid down in a quiescent lake. There seems to have been very slight disturbance of the original organic material and a lack of the usual metamorphosing agencies since the sediments were indurated to shale.

The destructive distillation of Green River oil shale produces liquids, gases, and solids, the latter being the ash composed of fixed carbon and most of the inorganic material laid down in the original shale. The liquid distillates are oil and water. The gases are of two main groups: (1) combustible gases, which are used as fuel for the distillation process; and (2) non-combustible gases, the most important of which is ammonia gas. The ammonia gas is second in importance to oil as it is used in the manufacture of ammonium sulfate, a fertilizer obtained by passing the gas through a solution of sulfuric acid.

The economic value of the oil shale depends upon the amount of quantity of kerogen in the rock. The character of the oil, which depends on the types of kerogen present, differs from place to place in the formation. Shale oil from Colorado has, in general, a mixed paraffin and asphalt base, and oil from one locality in Utah has an asphaltic base. Most shale oils are reddish-brown and at room temperature range from vaseline-like semi-solids to thin liquids. The oil ranges in gravity from 18° to 36° Baume, but the average is less than 25° Baume. Fractionation of the oil yields a series of products that includes: gasoline, 6 to 12 percent; kerosene, 28.5 to 49 percent; paraffin, 1.6 to 7.7 percent; and sulfur, 0.4 to 1.4 per cent.

Tests on oil shale samples of wide areal and vertical distribution show a variation from a minimum of 0.31 gallon of oil per ton of shale to a maximum of 90 gallons. Ammonium sulfate produced from ammonia gas ranges in amount from a minimum of 0.4 pound to a maximum of 34 pounds per ton of shale. Inflammable gas ranges in quantity from 500 cubic feet per ton of shale to 4500 cubic feet maximum. Steam distillation gives much higher yields of both oil and ammonia gas than does dry distillation.

The Federal government has two oil-shale reserves in Colorado, which were set aside mainly for the future use of the navy. The first of these contains 44,560 acres in Garfield County near Rifle and Grand Valley. The second contains 22,600 acres and adjoins the first. A third reserve is in Utah. The reserves are accessible from the main line of the Denver and Rio Grande Western Railroad, and from roads in the area.

The 78th Congress enacted a law (Public Law No. 290, April 15, 1944) authorizing construction and operation of one or more demonstration plants to make liquid fuels from oil shale. The most important of these plants is expected to be located near Rifle, Colorado. The law provides that the plant is to be of such size as to allow the Bureau of Mines to furnish industry with necessary cost and engineering data for development of a shale oil industry; and at the same time the plant is not to produce commercial quantities of oil. Two new processes of distillation, which were developed in Germany shortly before her surrender in World War II, are to be investigated at the Rifle plant.

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PART II. SUMMARIES OF MINING DISTRICTS AND MINERAL DEPOSITS* ** †

Prepared by the United States Geological Survey,
under the general supervision of
W. S. Burbank

SUMMARY OF WORK UNDER THE COOPERATIVE GEOLOGICAL SURVEY IN COLORADO

By W. S. Burbank and A. H. Koschmann

The cooperative program, covering topographic and geologic mapping, between the U. S. Geological Survey and the State of Colorado began in 1922, when the Colorado State legislature appropriated $25,000 for topographic mapping.[1] Although no long range geologic studies were planned under this cooperative program until 1926, a study of special features of ore deposits was begun in advance of this program. A study of ore at deep levels in the Cripple Creek district, started in 1924 by G. F. Loughlin, was the first geologic project and was carried out under financial cooperation of the Colorado Metal Mining Fund and the U. S. Geological Survey. Field studies of late developments in the Leadville district by Loughlin had been completed before cooperation was started, but the launching of the cooperative program resulted in the publication in 1926 of a preliminary report on Leadville, U. S. Geological Survey Bulletin 779, "Guides to ore in the Leadville district, Colo.", by Loughlin, followed in 1927 by the complete report, Professional Paper 148, "Geology and ore deposits of the Leadville mining district," by Emmons, Irving, and Loughlin. These results formed the basis for continued investigations in the Mosquito Range. Professional Paper 138, "Mining in Colorado, a history of discovery, development, and production", by C. W. Henderson, also published at this time, provided a most valuable background for work throughout the State.

The comprehensive and coordinated program of geologic studies was started in July 1926, under the supervision of B. S. Butler of the U. S. Geological Survey, and it has continued to date, although after 1928 Dr. Butler retired from full-time participation to take a position at the University of Arizona.

*Based on studies by the United States Geological Survey in cooperation with the Colorado Geological Survey Board and the Colorado Metal Mining Fund.

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[1]Henderson, C. W., Colorado points the way to cooperation: Eng. and Mining Jour., vol. 136, no. 8, p. 414 (Colorado number), Aug. 1936.

In 1929, a law was enacted establishing the Colorado Geological Survey under a governing Board, comprising the Governor of the State, as chairman, the President of the University of Colorado, the President of the Colorado School of Mines, the President of the Colorado State College of Agriculture and Mechanic Arts, the President of the Colorado Mining Association, and the State Commissioner of Mines. Biennial appropriations made to this Board have been matched on a 50-50 basis by the U. S. Geological Survey, and from time to time these funds have been supplemented by contributions from the Colorado Metal Mining Fund and other State agencies, and from private industry. In addition, amounts in excess of the 50-50 funds have been expended by the U. S. Geological Survey on certain projects, especially in the processing and publication of the more elaborate reports and maps, such as the regular Survey series of publications, special colored maps, and the State geologic map published in 1935. The Colorado Scientific Society, founded in 1882, also has provided means for publication of many preliminary reports and less elaborate maps.

The general program and lines of study adopted by the U. S. Geological Survey to govern the cooperative geologic work were outlined by Butler before the Colorado Mining Association in 1932,[2] as follows:

"1. The re-study of some districts on which reports had already been made.

2. The detailed study of some districts that had not been previously studied or of which no detailed study had been made.

3. A comprehensive study of the more important mineralized belts or regions to determine the broader factors that control mineralization.

4. A study of special types of deposits, such as the rare metal deposits.

5. A study of special features of ore deposition, such as secondary enrichment and primary change with depth.

6. Finally, the preparation of a revised geological map of the State and a general report on the geology and ore deposits of the State.

"It seemed best so to plan the work that some one or more of the geologists could become thoroughly familiar with the geology of the larger mineralized areas and thus be able to determine the broader geological features that have influenced mineralization in the different areas, and by the combination of these several studies to develop the broader features for the control of mineralization in the State... Such continuous application to the problems has brought results that could not have been attained in any other way."

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[2]Butler, B. S., Report on the cooperative geological survey in Colorado for the year 1932: The Mining Yearbook (Colorado Mining Association and Colorado Chapter American Mining Congress), pp. 3-5, 1933.

Up to and through 1945 the work has progressed fairly well in all of these categories except for the preparation of a general report on the geology and ore deposits of the State. Mainly because the geologists working in the larger mineralized provinces felt the need of devoting their full time to province work, and partly because results of the detailed studies were incomplete, it was decided in 1933 to postpone a review of the entire State until work in the principal mineral provinces was further advanced. Of the larger mineral-province studies planned under item 3 of the program, only that of the Front Range mineral belt is completed, and the review presented later in this volume is condensed from a report now in process of publication by the U. S. Geological Survey. Completion of these general studies does not imply, however, that other detailed local studies are not desirable. The general reviews will provide an excellent basis for work in selected areas. Completion of studies in the Leadville-Kokomo-Gilman belt of mineralization will establish the general controls of mineralization in the Mosquito-Tenmile Ranges. Work in the San Juan region also has progressed to the stage where a regional review is desirable. A condensed review of this province is presented in this volume. More detailed work in parts of the Aspen-Monarch belt of mineralization is desirable before a general review of the Sawatch Range is undertaken. With this possible exception, however, knowledge of the general structural framework in all the larger mineral provinces appears well advanced.

Many smaller districts throughout the State and large areas known to be mineralized to some extent have not as yet received special attention.

Studies of special types of mineral deposits, item 4, are represented by the work done on the molybdenum deposits at Climax and on the vanadium deposits of the western plateau country. Preliminary investigations of vanadium deposits were made as early as 1932, and in 1939 long range studies were started under cooperation. After 1941 these studies were financed entirely by Federal funds provided under the Strategic Minerals Act. Because of present security regulations the full results of this work cannot be reviewed at this time. Under the Strategic Minerals Act, also, special studies were made of tungsten, molybdenum, manganese, nickel and copper deposits in various parts of the State.

Placer deposits were studied in several districts in connection with regular district studies, and one special placer study initiated on Federal funds prior to World War II had to be discontinued. A review of the placer studies in Park County is presented in this volume and the full report will now go forward for publication.

In the nonmetallic field the principal studies under the cooperative program were those of fluorspar, especially in the Jamestown area. Some work has been done also on the lepidolite-bearing pegmatite deposits of the Gunnison area. With Strategic Mineral funds supplied by the U. S. Geological Survey, much additional work has been done during the War on pegmatite, clay, alunite, and fluorspar deposits, of which only the last was cooperative under funds advanced by the Metal Mining fund. Reviews of some of the pegmatite, clay, and fluorspar studies are presented in this volume.

Federally financed studies by the Section of Fuels and by the Section of Stratigraphy and Paleontology have been made in the State from time to time since cooperative work began, and they are continuing. Some of the work in stratigraphy and paleontology has been done especially to aid the various cooperative projects on metals. Such studies are mutually beneficial in all classes of mineral investigations.

A number of scientific papers covering special features of mineralization, such as mineral zoning and rock alteration, have been published outside of official mediums in geologic and mining journals. A list of these papers through 1944 has been published in the Quarterly of the Colorado School of Mines[3], along with lists of the regular publications.

Problems of interest in geophysics, geochemistry, and in rock alteration have been outlined in the course of the work, and a start has been made in some of these special studies. It is hoped that such work can be renewed and increased in the post-war years, as it may aid in uncovering new mineral deposits.

[3]Crain, H. M., Publications on work done by the U. S. Geol. Survey in cooperation with the State of Colorado: Colorado School of Mines Quarterly, vol. 40, no. 4, Oct. 1945.

THE FRONT RANGE MINERAL BELT[1]

By E. N. Goddard

GENERAL FEATURES

Introduction

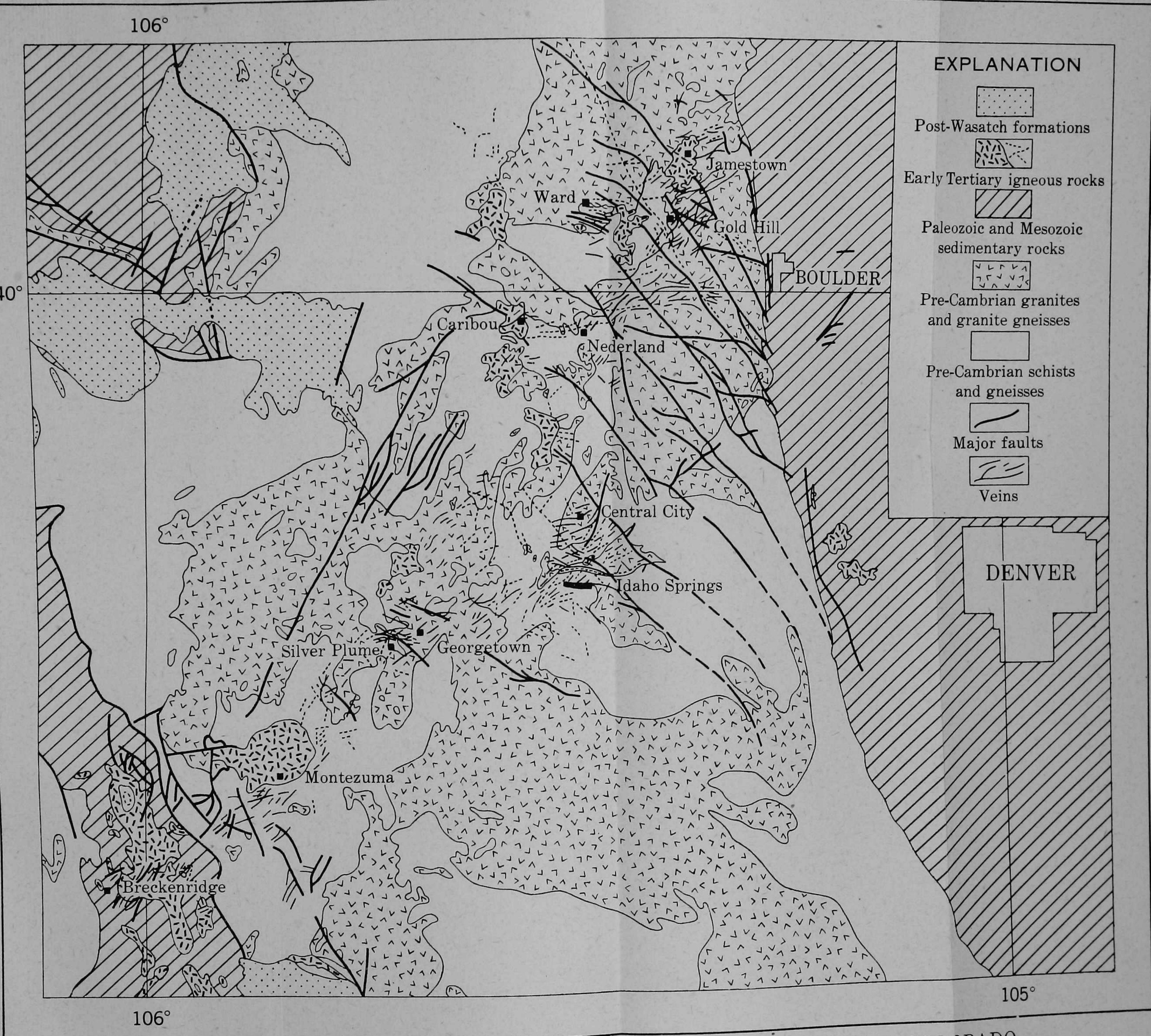
The Colorado Front Range is a northerly-trending mountainous uplift about 30 to 35 miles wide and 175 miles long. It is a complex mass of pre-Cambrian metamorphic and igneous rocks, locally cut by Tertiary intrusives and flanked by uptilted sedimentary rocks of Paleozoic, Mesozoic and Paleocene age. (See pl. 11.) Regional studies indicate that the Laramide folding which uplifted the mountains and deformed the sediments occurred during the transition between Paleocene and early Eocene time.

Geology

The pre-Cambrian rocks include a wide variety of complexly folded schists and gneisses invaded by several different granites. The earliest rocks are quartz-biotite schist and injection gneiss of the Idaho Springs formation, which were probably derived from ancient sediments. In places, the Swandyke hornblende gneiss of probable volcanic origin lies with apparent conformity on the schists and is intercalated with them through a thick transition zone.

[1]Abstracted from references 1, 2 and 3 of the bibliography, Page 298.

PLATE 11.



GEOLOGIC SKETCH MAP OF THE FRONT RANGE MINERAL BELT, COLORADO

0 5 10 MILES

Irregular sheet-like masses of quartz monzonite gneiss represent the earliest intrusive rock in the region. The early schists and gneisses are cut by batholiths, stocks, and dikes of a group of pre-Cambrian granites, including the Boulder Creek granite, the Pikes Peak granite, and the Silver Plume granite, all of pre-Cambrian age.

The pre-Cambrian rocks have been cut by a group of closely related early Tertiary stocks and dikes, commonly known as porphyries. These range in composition from diabase to alaskite, but most of the stocks and many of the dikes are of monzonite or quartz monzonite. These rocks are confined to a narrow belt that trends about N.40°E. across the central part of the Front Range. This belt, called the Front Range mineral belt, includes nearly all the ore deposits of the Front Range, except those of Cripple Creek, which are discussed in another chapter.

Structure

The ore deposits of the mineral belt did not form until after Laramide fracturing had nearly ceased, but their localization was greatly influenced by both pre-Cambrian and early Tertiary structure. Planes of weakness such as schistosity, contacts between dissimilar rocks, or pre-Cambrian shear zones exercised a profound influence on Laramide fracturing. The relations of the granite masses to the mineral belt, as shown in plate 11, suggested that they acted as buttresses between which the incompetent schists and gneisses were fractured.

With the uplift of the Front Range at the beginning of Laramide time, intense folding and faulting occurred along the borders of the range. The western side of the Front Range is marked by great overthrusts. One of the most prominent of these, the Williams Range thrust fault, which is crossed by the mineral belt northeast of Breckenridge, shows a displacement of more than 4½ miles. The eastern side of the Front Range was subjected to much less severe deformation, but was the locus of many echelon northwesterly folds and persistent steep northwesterly faults. These strong northwesterly faults are called breccia reefs because in many places they form prominent silicified outcrops which are colored red by finely divided hematite. They are abundant in the northeastern part of the mineral belt and are found as far southwest as Silver Plume. On most of the breccia reefs along which the direction of movement could be determined, the northeast wall moved northwest and either up or down. The total displacement amounts to several hundred feet. These breccia reefs exerted a strong influence on the distribution of the ore deposits in many districts of the mineral belt, both in the localization of the districts themselves and in the localization of ore bodies within individual veins. It is believed that these strong faults served as trunk channels for the deep circulation of the ore-forming solutions, which worked their way upward and outward and deposited ore in the more open ground prepared by the formation of the vein fissures. In some places, however, the breccia reefs apparently served as dams to the circulating solutions; for example, the Blackhawk fault, which largely terminates the Idaho Springs-Central City district on the northeast, and the Hoosier reef, which terminates the Gold Hill district on the northeast. In addition to the breccia reefs, there are several strong persistent steeply dipping faults of northeasterly trend on the western side of the mineral belt, but these apparently have had little influence on the distribution of ore deposits. The early strong Laramide faulting preceded the intrusions of most of the early Tertiary igneous rocks of the mineral belt.

The period of overthrusting and strong faulting was followed by the formation of the vein fissures in the waning stages of Laramide compression, during and after the intrusion of the igneous rocks. These vein fissures are small and much less persistent than the early faults, but are abundant throughout the mineral belt. Most of them strike northeast and dip steeply southeast, but some trend northwest and some nearly east. Most of those in the Boulder County tungsten belt have an east-northeast trend. Nearly all of these fissures dip steeply. Displacement along the vein fissures has been small, commonly a few feet, and rarely more than 30 feet. Along most of the fissures of northeast strike, the southeast wall has moved down and to the southwest, but along those of west, northeast, and east-northeast trend the north wall has commonly moved west and down at a small angle. These fissures were opened throughout a considerable range during the Laramide revolution and were filled with a variety of ore deposits.

Ore Deposits

The genetic relation of the ore deposits to the early Tertiary porphyries has long been established and later work has served to correlate certain types of ore deposits with certain groups of porphyries. The earliest well-developed veins appear to be strong pyritic gold veins of the Ward district, which are believed to be contemporaneous with the breccia reefs, though they were somewhat enriched at a later period. After the formation of the strong faults valuable lead-silver ores related to a series of diorite, quartz monzonite, and alaskite porphyries were deposited in the Breckenridge, Montezuma, Silver Plume-Georgetown, Central City-Idaho Springs, and Caribou districts. Slightly later lead-silver deposits of minor value are found in the Ward, Gold Hill, and Jamestown districts and seem to be genetically related to a group of alkalic diorite, syenite, and granite prophyries. Related to this series also are the fluorspar deposits at Jamestown, formed in fissures and breccia zones related to local stresses caused by the intrusion of a porphyry stock. Pyritic gold ores were extensively deposited in the Empire, Central City-Idaho Springs, Gold Hill, and Jamestown districts and seem to be related to a series of alkalic syenite and bostonite intrusives. The telluride veins are the latest of the precious-metal deposits and are chiefly confined to the northeastern part of the mineral belt in the Jamestown, Gold Hill, and Magnolia districts, though some telluride veins are found in the Central City-Idaho Springs and Eldora districts. These telluride ores seem genetically related to a biotite monzonite-latite series, the latest members of which occur in places as a matrix in explosion breccia. The tungsten ores of the Boulder County tungsten district are later than the telluride ores and are believed to be the latest ore deposits in the mineral belt.

The localization of ore in the mineral belt seems to have been chiefly controlled by the presence of openings in ground within easy access to the ore-forming solutions. The breccia reefs and other early faults, in addition to serving as trunk channels for the deep circulation of these solutions, also served in places as dams or baffles, and tended to block or retard circulation. Open ground favorable for ore deposition was produced in the vein fissures at their junctions with earlier faults and veins, at junctions of two contemporaneous veins, or at junctions of two or more branches of the same vein. Abrupt changes in strike or dip of the veins also tended to form openings for the localization of ore. In the veins of northeasterly trend, where the southeast wall moved southwest, the more easterly trending parts were the most favorable; in those of east and east-northeasterly trend, where the north wall moved west, the more northeasterly trending parts were favorable; and in the veins of northwesterly trend, where the northeast wall moved northwest, the more westerly-trending parts were the most favorable. In normal faults along which there was a strong vertical component of movement, the steeper parts of the veins were the more open, whereas in reverse faults less steeply dipping parts were more favorable. The localization of ore was also influenced by the character of the wall rock. Granite, porphyry and granite gneiss were favorable host rocks, but chiefly in areas where they were intimately mixed with schist. The schist itself tended to shear easily and form tight gouge-filled fissures unfavorable for ore deposition. Large bodies of solid granite and porphyry tended to resist the compressive forces of late Laramide time and thus avoided any noteworthy amount of fissuracy except near their borders. A combination of the various structural factors mentioned above formed especially favorable ground for ore deposition and many of the larger ore bodies in the mineral belt were formed where such combinations occurred.

The persistence of individual ore shoots in depth is seldom more than a few hundred feet; depths of 1000 feet are unusual. However, there is no evidence that the bottom of mineralization has been reached in any locality, as ore has commonly been found from the tops of the highest hills to the bottom of the valleys. Throughout the mineral belt, in districts that have been studied thoroughly, favorable structural locations are known that have not yet been explored; in other districts the detailed structural relations have not yet been worked out. It therefore seems likely that future prospecting on the basis of careful structural studies will uncover new ore bodies.

Placer Deposits

The localization of gold in the placer deposits of the mineral belt is dependent on the location and character of the primary gold-bearing lode deposits, processes of erosion, transportation and deposition, and the structure and character of the bed rock and gravel along the stream valleys. The pyritic gold deposits and, in general, the deposits containing gold associated with other sulphides have given rise to placers in the streams and gulches draining their area of outcrop. In contrast, the gold-telluride deposits are rarely marked by placer ground, except where the tellurides are accompanied by native gold in the primary ore. Although the mineral belt is credited with a substantial output of placer gold in the sixties and seventies; the output has been small since that time, except in a few places where dredging has proved feasible. Floating dredges have operated successfully for many years in the Breckenridge district, but the best ground has been moved long since. In recent years, dredges have been operated along South Boulder Creek near Pinecliff, North Clear Creek near Blackhawk, Clear Creek east of Idaho Springs, and Beaver Creek and the Platte River near Fairplay. By 1942 all these operations had been terminated, owing to the restrictions on gold mining during World War II.

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BRECKENRIDGE DISTRICT, SUMMIT COUNTY*

The Breckenridge mining district is only a few miles northwest of the geographic center of Colorado near the headwaters of the Blue River in Summit County. Rich placer ground was discovered on the north side of Farncomb Hill in 1859, and gold was found in place on this same hill in 1880. Production from the placers of the district has been practically continuous to the present time, and has amounted to about 750,000 ounces of gold. The introduction of gold dredges in 1898 enabled the treatment of large tonnages of deep gravels in the larger gulches, and probably more than $7,000,000 in gold output has resulted from these operations. Narrow but rich veins containing crystallized gold contributed greatly to the output for 10 years after their discovery in 1880, and were the chief source of the gold until dredging began on a large scale. Silver-lead veins were mined in the late eighties and early nineties after the advent of cheap transportation, but after the first flush of production their output showed a downward trend until 1910, when the Wellington mine started active development. This mine operated continuously to March 1929, and yielded the bulk of the lead and zinc ore and concentrates shipped from the district during this period. Since then the zinc and lead production from various mines has been small although lode silver and gold output held up until 1942. Nearly complete figures indicate a lode production to the end of 1942 of about 33,000 ounces of gold, 1,500,000 ounces of silver, 100 tons of copper, 30,000 tons of lead, and 86,000 tons of zinc. Although most of the known lode ore has been exhausted, there are some places where further prospecting is justified by the established relations of ore to geologic structure.

Sedimentary rocks in the Breckenridge district include formations from Pennsylvanian (?) to Upper Cretaceous age. These lie in an assymetric syncline about 10 miles wide in which the general dip is toward the east. At the edge of this syncline, 5 miles east of Breckenridge, the sedimentary rocks are bounded by an overturned fold that brings the underlying pre-Cambrian rocks to the surface. This fold passes northward into the Williams Range thrust fault.

Within the most productive part of the district the pre-Cambrian rocks of schist, gneiss, and granite, are exposed only in two small areas. The sedimentary rocks exposed include the Maroon formation, the Morrison formation, the Dakota quartzite, the Benton shale, the Niobrara formation, and the Pierre shale. These are much faulted and intruded by early Tertiary monzonite and quartz monzonite porphyries (see pl. 12) typical of the general northeast-trending zone of weakness that forms the porphyry or mineral belt of the Front Range.

The veins follow pre-mineral faults of small displacement and most of them strike between N.30°E. and N.80°E. The more pro-

*Abstracted from references 5 and 6 of the bibliography, page 298, and records of the Geological Survey and Bureau of Mines.

ductive veins lie in a short, narrow, northeast-trending belt that extends from Little Mountain to Mineral Hill. With the exception of the rich narrow gold veins of Farncomb Hill, very few veins outside this belt have contributed materially to the output of the district. Most of the ore has been found where the vein walls are monzonite porphyry or Dakota quartzite, but veins cut all of the bedrock formations. The physical character of the wall rocks has been the main factor in the localization of ore shoots as shown by the formation of open and mineralized fault breccias in the porphyry, quartzite, and silicified shale, whereas the unaltered shaly rocks yielded tight and impervious clay-filled fissures. Certain limy layers in the Cretaceous beds, however, were replaced by ore next to some of the larger veins.

Although the placers and veins are by far of greatest importance, contact metamorphic deposits and stock works occur in the district. The contact metamorphic deposits, found chiefly in the limy beds of the Niobrara and Morrison formations, are small and of little value, though some contain copper and gold. The stockworks lie in the northeast part of the district outside of the most productive area and are valuable chiefly for low-grade pyritic gold ores that were appreciably enriched near the surface.

The only ore minerals found in sufficient abundance to be of commercial importance are gold, silver, sphalerite, galena, and pyrite. The chief gangue minerals are ankerite, calcite, quartz, and sericite. High-grade lead ore shoots near the surface were formed by leaching of the soluble zinc and iron sulphides by descending surface waters, but there is little or no evidence of secondary deposition of galena. The enrichment of gold ores was accomplished also by surface waters moving downward toward the water table.

MONTEZUMA AND ARGENTINE DISTRICTS, SUMMIT AND CLEAR CREEK COUNTIES*

The Montezuma and Argentine districts comprise about 75 square miles in the Montezuma quadrangle, which straddles the Continental Divide in the Front Range along the line of the mineral belt. The town of Montezuma lies 2 miles northwest of the Divide in Summit County and is the principal mining center of a mineralized area at the headwaters of the Snake River, an eastern tributary of the Blue River.

Silver was first discovered in the district in 1864 on Glacier Mountain and the Argentine district was then organized. Several mines were worked successfully for many years. Discoveries of argentiferous lead ores in the Snake River drainage basin followed, and a large number of small lodes were located and mined. After 1888, however, the output fell off steadily and the activity has been intermittent. Only a few mines have produced continu-

*Abstracted from reference 7 of the bibliography, page 298, and records of the Geological Survey and Bureau of Mines.

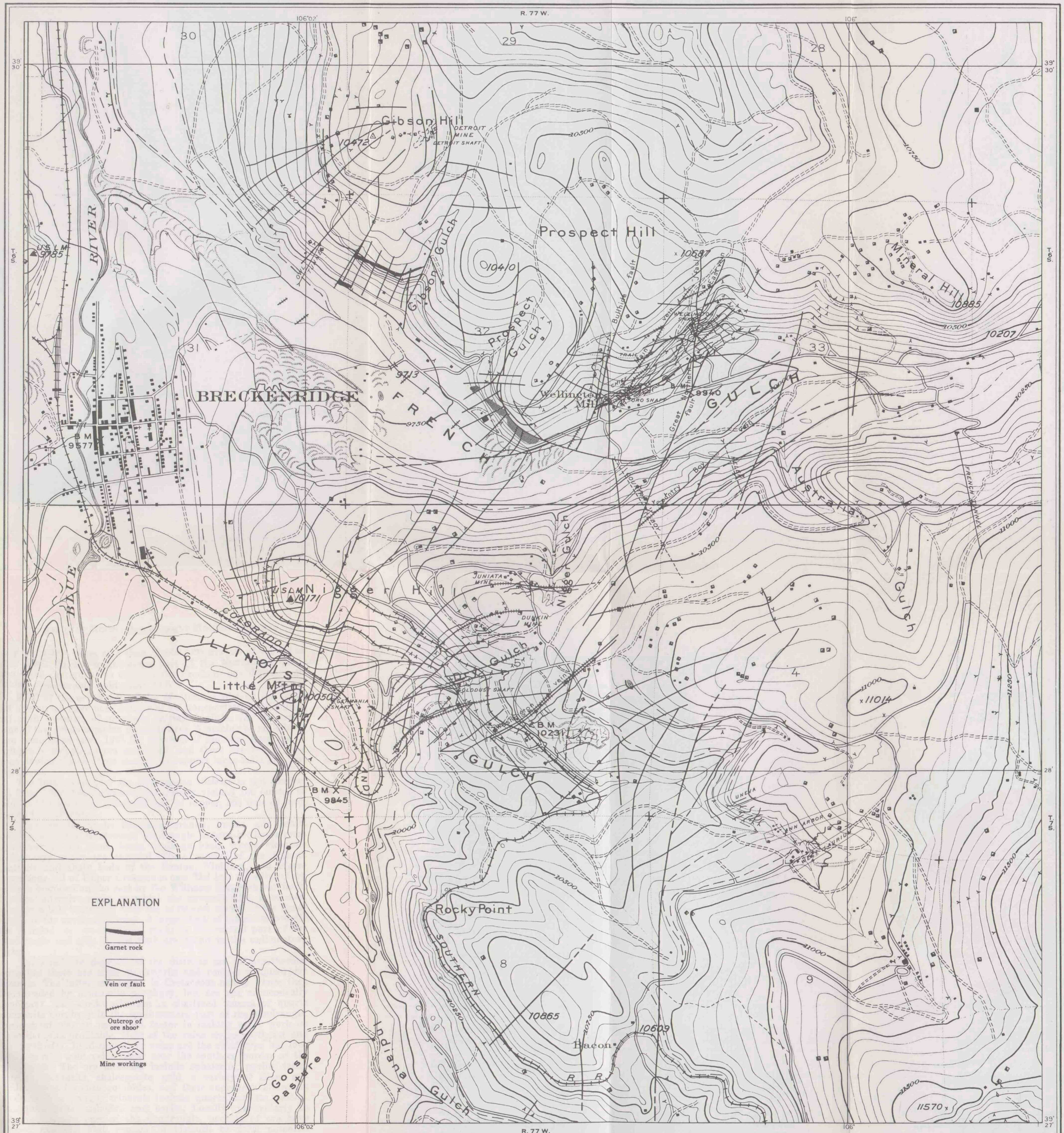


PLATE 12.

MAP OF THE MOST PRODUCTIVE PART OF THE BRECKENRIDGE MINING DISTRICT, SHOWING SOME OF THE PRINCIPAL MINE WORKINGS AND KNOWN FAULTS AND VEINS

(Plate 1, U. S. Geol. Survey Prof. Paper 176) ously for a few years at a time. Auriferous gravels of the Swan River Basin in the southwestern part of the Montezuma quadrangle are contiguous to those of the Breckenridge district and yielded considerable gold after 1905.

Most of the ore shoots of the Montezuma district are small and operations have been hampered by transportation difficulties and until recently, of adequate milling facilities for the treatment of low-grade complex sulphide ores. A number of mills have been remodelled since 1938 for flotation of the ores. Reserves of high-grade shipping ores are small, and there are few if any veins having shoots large enough to support large-scale low-cost operations.

The total output of the Montezuma district is not known, but from 1932-1942, inclusive, the district yielded 136 ounces of gold, 75,893 ounces of silver, 13 tons of copper, 555 tons of lead, and 85 tons of zinc.

Pre-Cambrian rocks including granite, gneiss, and schist cover most of the Montezuma quadrangle, except in the extreme southwest in the Swan River drainage basin where Mesozoic sedimentary rocks are exposed. These consist of the Dakota quartzite and shaly beds of the Benton, Niobrara, and Pierre formations, all of Upper Cretaceous age. The belt of sedimentary rocks is bounded on the east by the Williams Range thrust fault. Tertiary intrusive rocks, to which the mineralization is related, occur in a belt extending from the southwest corner of the quadrangle to the northeast corner. A large stock of quartz monzonite has invaded the pre-Cambrian rocks in the central part of the quadrangle and sills of this rock are found in the sedimentary rocks.

The chief ore deposits of the districts are in mesothermal veins but there are some stockworks and contact metamorphic deposits. The latter are found in Cretaceous shales where they are invaded by monzonite porphyry, but are not economically important. The stockworks are in shattered masses of quartz monzonite porphyry in the southwestern part of the quadrangle. Enrichment was an important factor in making early work on these deposits profitable. Most of the veins strike northeast and dip northwest. Lead-zinc-silver veins are the chief type but low-grade pyritic gold veins occur near the southern border of the quadrangle. The ore minerals include sphalerite, pyrite, tetrahedrite, tennantite, chalcopyrite, gold, a variety of silver sulphides, some bismuth sulphides, and their supergene alteration products. The gangue minerals include quartz, sericite, calcite, manganosiderite, ankerite and barite. Locally, particularly in the southeastern part of the quadrangle, pockets of ore have yielded material high enough in bismuth to form potential though probably minor sources of this metal. Galena is commonly most abundant in the upper parts of veins, and the copper content increases slightly with depth. The silver content of ores show little relation to depth in veins of the pre-Cambrian area. Rich secondary gold and silver ores bottom at much shallower depths in the pre-Cambrian rocks than in the sedimentary rocks of the western part of the quadrangle and in the Breckenridge district. On the high Flattop peneplain rich gold extended only to a depth of 25 feet, where it changed abruptly to low-grade pyrite. But in veins that crop out on the lower Rocky Mountain peneplain rich secondary gold and silver ore extended to much greater depth.

The largest ore shoots in the district range from 600 to 1,100 feet in length and have a vertical extent of 400 to 850 feet. The vertical range of ore deposition was at least 2,000 feet and probably more than 3,000 feet. The walls of persistent ore shoots are usually formed of hard, strong rocks such as granite, gneiss, pegmatite, and intrusive porphyry. Rarely are extensive ore shoots formed in the softer rocks such as mica and hornblende schists. Ore shoots are common at the intersections of veins, near junctions of branching veins, and where abrupt changes in dip or strike of the veins occur.

Reserves of high-grade ore are small, but there are many veins that might yield small but profitable amounts of ore if mined by lessees. Some of the barite lead-zinc ores might be profitably concentrated in a flotation mill. Moderately large bodies of low-grade (auriferous) disseminated zinc-lead ores occur in stockworks near Tiger.

SILVER PLUME-GEORGETOWN DISTRICT, CLEAR CREEK COUNTY*

Introduction

The Silver Plume-Georgetown district occupies an area of about 25 square miles in the west-central part of Clear Creek County, surrounding the towns of Silver Plume and Georgetown. Most of the principal mines are on the south slope of Republican Mountain, just north of Silver Plume, but there are some important mines to the southwest, northeast and northwest of Georgetown. The district is well watered by Clear Creek and its tributaries and is very rugged, ranging from 8,400 to 12,400 feet in altitude. A paved highway down Clear Creek connects both towns with Idaho Springs and Denver.

History and Production

Precious metals were first discovered in the district in 1859, and the rich surface ores were worked chiefly for gold. During 1865 and 1866, many of the rich silver-bearing veins were discovered near Silver Plume and Georgetown. The most active period of silver-lead mining commenced in 1872, reached its peak in 1894 and gradually declined thereafter. During both world wars interest was aroused in the zinc and lead of the silver-lead deposits, and many of the old mines were reopened and actively worked. During 1943-44, the Pelican-Bismark, Mendota and Smuggler mines were reopened and lead-silver-zinc ore was treated in two mills at Silver Plume and one at

*Abstracted from references 3 and 8 of the bibliography, page 298.

Georgetown. The total value of output in the Silver Plume-Georgetown district has amounted to more than $30,000,000, but exact figures for many years are lacking.

Geology

The earliest rocks of the district are the pre-Cambrian schists and gneisses of the Idaho Springs formation, and these contain small widely scattered bodies of gneissic hornblende quartz diorite. The foliation of these rocks is much contorted in places; in general it strikes from north to northwest and dips 45-85°NE., but in the eastern part of the district the strike is northeast. At the south edge of the district the schist is cut by a large body of quartz monzonite gneiss, and in the eastern part of the district there are irregular bodies of fine-grained granite gneiss related to a batholith of Boulder Creek granite, whose northern end lies just east of the district. The schists and gneisses of the district have been cut by irregular stock-like bodies and dikes of Silver Plume granite and its associated pegmatites and aplites. This granite is for the most part a crosscutting intrusive, but locally it has been intruded parallel to the schistosity.

The pre-Cambrian rocks have also been cut by dikes of dacite, quartz monzonite porphyry, and alaskite porphyry of early Tertiary age. There are no early Tertiary stocks in the mineralized part of the district, but a large stock of quartz monzonite porphyry crops out on Lincoln Mountain just north of the district and a small stock of granite porphyry and one of alaskite porphyry lie south of Pains Mountain, 2 to 3 miles south of the mineralized area. The porphyry dikes strike both northeast and northwest and most of them dip steeply. Several of these dikes are bordered by very productive veins, notably, a strong persistent dike of alaskite porphyry bordered by the Pelican-Bismark vein system, just north of Silver Plume, and a granite porphyry dike bordered by the Colorado Central veins, about 1½ miles south of Georgetown.

Structure

The ore deposits of the district are fissure veins, which belong to 3 main systems. In the area just north of Silver Plume, the fissures belong mainly to two systems, one having an average trend of N.70°W. and the other an average of N.70°E. (See pl. 13.) A few fissures in this area, and most of the fissures elsewhere in the district belong to a system having an average trend of N.50°E. Exceptions include many of the veins on Democrat and Columbia Mountains, in the northern part of the district, which belong to the N.70°W. system. Nearly all the vein fissures have moderately steep to vertical dips. It is believed that the N.70°W. system was formed earliest, as the majority of the dikes have this trend; in fact, the Pelican-Bismark fissure of this system was first opened in the breccia reef period of faulting. This system was apparently reopened at approximately the same time that the N.70°E. system was developed, as valuable silver ores were deposited in both systems. The N.50°E. system was apparently the latest formed, for practically all the pyritic gold veins have that general trend, and at Empire they were definitely later than the lead-zinc veins. Displacement along most of the vein fissures was small, ranging from a few feet to 15 feet, but on some, such as the Colorado Central vein, it was as much as 100 feet. In the Silver Plume region the movement was nearly horizontal; along the fissures of the N.70°W. system the northeast wall moved northwest and down at a slight angle, and along those of the N.70°E. system, the southeast wall moved southwest. Along the Colorado Central vein fissure, the northwest wall moved southwest and down at an average pitch of 20°. On other veins in the district grooves and slickensides range in pitch from horizontal to vertical, but no data indicating the direction of movement are available. Along many of the veins in the district there has been post-ore movement, but in most places it has been small and has not greatly dislocated the ore.

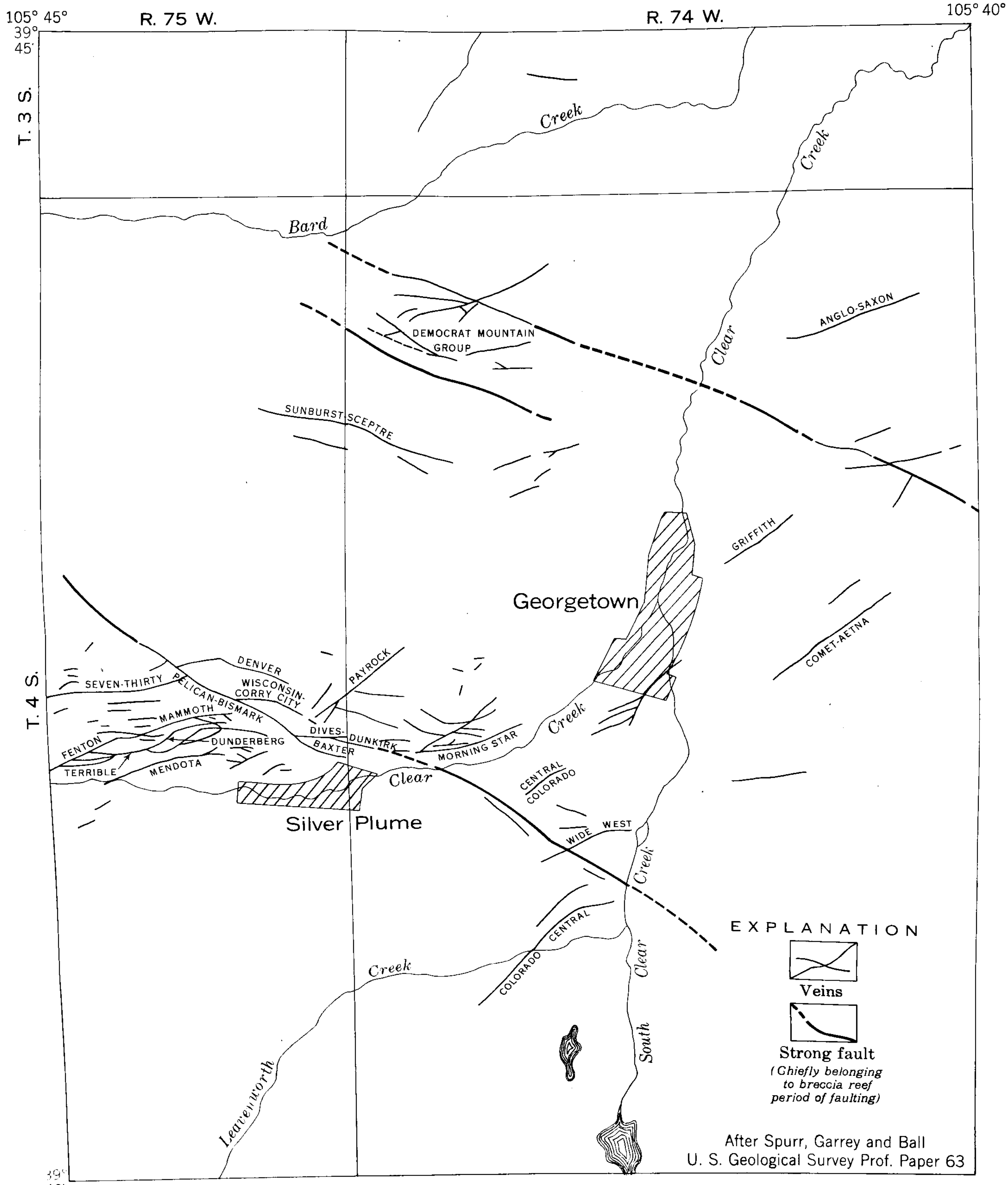
Ore Deposits

The ore deposits of the Silver Plume-Georgetown district are of two types: (1) the silver-lead-zinc veins and (2) the pyritic gold veins. In the very productive area just north of Silver Plume, the veins contain silver, lead, and zinc almost to the exclusion of gold, and the same is true of the veins on Republican and Democrat Mountains, 1½ to 2½ miles to the north-northeast. In these areas, nearly all the veins belong to either the N.70°W. or the N.70°E. system. Another important silver-mining area is that of the Colorado Central group, 1½ to 2 miles south of Georgetown. This silver belt is represented farther to the northeast by the Comet-Aetna and Magnet veins, about one mile east of Georgetown. In this belt the predominant strike is northeast. Between the two silver belts is a narrow gold belt about three-fourths of a mile wide extending from Leavenworth Mountain, 1½ miles south of Georgetown, northeastward to Saxon Mountain. In this belt the important veins all trend northeastward. On Lincoln Mountain, 3½ miles northwest of Georgetown, both silver veins and pyritic gold veins are present.

The most abundant ore minerals of the silver-lead-zinc ores are galena and sphalerite, with considerable pyrite in places. The galena and to a less extent the sphalerite are argentiferous. However, the chief silver minerals in the ore are polybasite, argentiferous tetrahedrite, argentite, pyrargyrite, and proustite, and locally native silver. The chief gangue mineral is quartz, but brown carbonates are abundant in places; sericite, barite, cherty silica, and locally kaolinite are also common.

The chief minerals in the pyritic gold deposits are pyrite, chalcopyrite, gold and small amounts of silver and quartz. Galena and sphalerite also are generally present in small amounts. Tetrahedrite and soft black chalcocite are common but not abundant. Free gold visible to the naked eye is found in places, but native silver is rare. The gangue minerals are quartz and small amounts of brown carbonates and barite. Fluorite is present in some of the veins of the gold belt.

PLATE 13.



STRUCTURE MAP OF THE SILVER PLUME—GEORGETOWN DISTRICT
SHOWING THE PRINCIPAL VEINS AND FAULTS

0 1 2 MILES

The grade of the silver-lead ores is extremely variable. Much of the ore mined has commonly contained between 20 and several hundred ounces of silver to the ton, though some shipments have contained as little as 10 ounces and small streaks of unusually rich ore are reported to have contained more than 1000 ounces to the ton. Some of the richest ore came from the Colorado Central vein, where first-class ore averaged 700 to 800 ounces of silver to the ton and the average silver content of ore mined over a 16 year period is reported to have been 200 ounces to the ton. In some of the veins in the area just north of Silver Plume, the silver content seems to be decreasing with depth. For example, in the South Frostberg vein, the ore contained 200-400 ounces of silver to the ton on the upper levels, 40-50 ounces just above the Mendota tunnel level, and 10-15 ounces on the lowest levels. The base-metal content of the silver-lead ores is as variable as the silver content. Ore shipments on which data could be obtained have contained from 2 to 50 percent of lead and from 4 to 40 percent of zinc. The gold content of these veins commonly ranges only from 0.01 to 0.22 ounce of gold to the ton, and in places gold is absent. Ore mined from the Pelican-Bismark vein in 1896 contained 150 ounces of silver and 0.1 ounce of gold to the ton, 14 percent of lead, and 20 percent of zinc; these quantities are believed to be fairly representative of much of the silver-lead ore mined from the district in the past. The pyritic gold ore has commonly contained from 0.9 to 2 ounces of gold and from a few to 30 ounces of silver to the ton.

In the Silver Plume-Georgetown district, as in many other localities of the mineral belt, the northwesterly pre-mineral faults seem to be the master fissures responsible for the localization of the district. This is particularly well shown in the highly productive area just north of Silver Plume, where the strong, northwesterly Pelican-Bismark vein, which was first opened in the breccia-reef period of faulting, is believed to be the trunk channel along which the ore-forming solutions moved from depth. Most of the productive vein systems of this area either branch from or approach within close proximity of the Pelican-Bismark vein and nearly all the output has come from within half a mile of this strong lode. Elsewhere in the district the control of trunk channels is not so well exhibited, though there is a suggestion that other strong northwesterly faults and veins, such as the Sunburst-Sceptre vein, may have exercised a similar control. A variety of structural factors influenced the localization of individual ore shoots. Some ore shoots are plainly due to structural features of the vein fissures, such as abrupt changes in strike or dip, branches or splits in the vein or intersection with other veins. Other ore shoots seem related to the character and structure of the wall rock. The most favorable wall rock is granite, though porphyry is commonly favorable; schist is generally unfavorable. In places dikes of porphyry or of granite lying across the vein served to impound the solutions and cause deposition. Vein junctions were effective in controlling ore shoots in some parts of the district, but in others seem to have had little effect. Abrupt changes in strike or dip seem to have been the controlling factors in many mines, and these changes were apparently influenced by the character of the wall rock. Veins passing from schist into granite or from granite into porphyry tended to change their course abruptly. In veins of northwest trend, where the northeast wall moved northwest, as the Pelican-Bismark, the more favorable parts are the more westerly-trending parts. On veins of northeast trend, like the Mendota, where the southeast wall moved southwest, the more eastward-trending parts of the vein are more favorable than the more northeastward-trending parts. In reverse faults like the Colorado Central, the flatter parts of the vein were the most favorable for the localization of ore, and in normal faults, the steeper parts were more favorable. Most of the ore shoots in the district are localized in places where both the wall rock and the structure of the vein were favorable for the formation of openings.

Many of the ore shoots in the district are fairly large. In some of the larger mines, ore shoots have been followed rather continuously from the surface to depths between 600 and 1500 feet. Stope lengths of several hundred feet are not uncommon and several compound ore shoots have stope lengths of more than 1000 feet. The veins, however, are in general narrow, and in most places the ore bodies have had a thickness of only 1 to 3 feet, though locally they have widened to as much as 10 or even 15 feet. In some of the larger mines, also, there are indications that the ore bodies are becoming smaller and less continuous with depth and that the silver content is decreasing with depth. In no place, however, is there evidence that the lower limit of mineralization has yet been reached and, even in the deeper mines, future exploration seems warranted where structural conditions are favorable. Contrary to popular belief, there are apparently no large bodies of zinc ore left in the stopes of the mines just north of Silver Plume, though there are still appreciable amounts of sphalerite in some of the dumps, notably those along the Mendota vein.

EMPIRE DISTRICT, CLEAR CREEK COUNTY*

The Empire district occupies about 8 square miles in the vicinity of Empire, in the north-central part of Clear Creek County. It ranges in altitude from 8,500 to 11,500 feet and is readily accessible by automobile from Idaho Springs and Denver. The district was first opened after the discovery of the oxidized parts of the Silver Mountain ore zone in 1862. This gossan material was washed in sluices and treated in the same way as placer gravels, and for several years the district was prosperous. Lode mining has been intermittently productive since the seventies. The district attained new prominence with the development of the Crown Prince-Atlantic group of veins by the Minnesota

*Abstracted from references 3 and 8 of the bibliography, page 298.

Mines, Inc. in 1934. This company operated the mine and a 250-ton mill continuously until 1943, when operations ceased owing to World War II. The total output of the district has probably amounted to more than $5,000,000.

The chief pre-Cambrian rock in the district is the Boulder Creek granite, but it encloses several bodies of schist and a few of quartz monzonite gneiss. The Silver Plume granite is exposed in the southern part of the district and some pegmatite is found here and there in places. The pre-Cambrian rocks are cut by stocks and dikes of early Tertiary porphyries. A fairly large stock of monzonite occupies the western part of the district and a small monzonite stock crops out in the north-central part. The intrusion of the small stock probably played an important part in forming some of the most productive fissures in the district, those of the productive Minnesota mine and the Silver Mountain ore zone. In various parts of the district there are porphyry dikes ranging from quartz diorite to alaskite in composition.

The ore deposits of the district are almost entirely of the pyritic gold type. The chief minerals of the veins are pyrite, chalcopyrite and quartz. The veins have a general northeasterly trend and a steep dip to the southeast. The gold seems to be chiefly associated with the chalcopyrite and fine-grained pyrite. The average tenor of the ore in the district ranges from about 0.2 to 0.4 ounces of gold to the ton, although small lots have contained as much as 7 ounces. In much of the ore the silver content is only a few ounces to the ton, but in some shipments it is as high as 20 ounces.

LAWSON-DUMONT DISTRICT, CLEAR CREEK COUNTY*

The Lawson-Dumont district occupies about 10 square miles in the north-central part of Clear Creek County. It lies along Clear Creek from 4 to 8 miles N.70°W. of Idaho Springs and includes the towns of Lawson and Dumont. It ranges in altitude from 7,900 to 9,500 feet.

Schist and gneiss of pre-Cambrian age are the most abundant rocks in the district. Schists of the Idaho Springs formation occupy most of the eastern part of the district, but contain scatered lenses and dikes of granite gneiss and pegmatite. The western part of the district is chifly occupied by quartz monzonite gneiss, but this includes lenses of schist and is cut by dikes of gneissic quartz diorite and irregular bodies of Silver Plume granite. The foliation of the schists and gneisses has a general northeasterly trend and moderate dip to the northwest.

The pre-Cambrian rocks are cut by early Tertiary dikes of monzonite porphyry, quartz monzonite porphyry and bostonite, and by a small stock of bostonite in the southeastern part of the district.

*Abstracted from references 3 and 9 of the bibliography, page 298.

The ore deposits include lead-silver veins and pyritic gold veins. The lead-silver veins have a general northeasterly trend and are found chiefly in the western part of the district. The chief ore minerals of these veins are galena, sphalerite and pyrite. Silver minerals such as proustite, pearcite, and polybasite occur in varying amounts and are abundant in the highgrade silver ores. The lead-silver ores in general range in grade from 50 to 1,000 ounces of silver to the ton, from a few to 30 percent lead and from a few to 20 percent zinc. Their gold content is commonly a few hundredths of an ounce to the ton.

The pyritic gold veins are limited to the eastern part of the district in the vicinity of Dumont. The majority have an east trend, but some strike northeast and some northwest. The chief constituents of these veins are pyrite and quartz; chalcopyrite is commonly present and in places is abundant enough to be of commercial interest. Galena and sphalerite are present in small amounts in a few places. Gold seems to be contained chiefly in the chalcopyrite, but in places is associated with fine-grained pyrite. This ore commonly contains from 1 to 10 ounces of gold to the ton and from a few to 16 ounces of silver to the ton.

In general the veins of the Lawson-Dumont district have had a relatively small output compared with those of the Silver Plume-Georgetown district or the Central City-Idaho Springs district, but a few, such as the Jo Reynolds and the veins of the Red Elephant group, have had an output of over a million dollars.

CENTRAL CITY-IDAHO SPRINGS DISTRICT, CLEAR CREEK COUNTY*

(Including the Freeland-Lamartine District),

Introduction

The Central City-Idaho Springs district, about 30 miles west of Denver, has an area of about 25 square miles in the southern part of Gilpin County and the northern part of Clear Creek County. The principal towns, Idaho Springs, Central City and Blackhawk, are connected with Denver and Leadville by good auto roads, and practically all the important mines can be reached by automobile and truck throughout the year. The district is a dissected rolling upland, ranging in altitude from 7,600 to 10,600 feet. It is well watered by Clear Creek, Fall River, North Clear Creek, and their tributaries.

History and Production

Placer gold was discovered in January 1859 near the mouth of Chicago Creek and, a few months later, the first vein was discovered by John H. Gregory just east of the site of Central City. In 1865 the first smelter in Colorado was built at Blackhawk, and in 1866 the district began a long period of increasing output from lode ores. In 1872 a narrow-gauge railroad was completed connecting Blackhawk with Denver. The silver veins of Silver Hill, near Blackhawk, were discovered in 1877 or 1878.

*Abstracted from references 3, 8, and 9 of the bibliography, page 298.

In January 1904, the 4½-mile Argo tunnel was begun with the object of intersecting many of the largest veins in the district at depth. Several profitable ore shoots were found at the tunnel level, 1,200 to 1,600 feet below the outcrop, but most of the veins proved to be disappointing at depth. Activity in the district slowly declined until 1918, when the end of World War I was followed by a period of very marked decline, but the sudden increase in the price of gold in 1933 stimulated new activity in the gold mines and led to a marked increase in output. World War II caused the cessation of much of the gold mining but stimulated activity in those mines containing silver-lead and zinc ores.

The total output of the district has probably amounted to between $100,000,000 and $150,000,000. Although substantial amounts of silver, lead, zinc, and some copper have been produced, most of the ore shipped has been valued chiefly for its gold.

Geology

Schists and granite gneiss of pre-Cambrian age are the most abundant rocks in the district. Central City is on the axis of a northeastward-trending anticline that exposes a core of granite gneiss, about 2 miles wide, containing numerous stringers and lenses of schist and bordered on both sides by schist. Schist predominates in the Idaho Springs region, but includes numerous lenses of granite gneiss, and pegmatite. The schistosity has a predominant northeast strike and dips 45°-75°NW. Scattered through the district are numerous dikes, sills, and irregular bodies of pegmatite, a few small masses of Silver Plume granite and hornblende gneiss, and lenses of lime-silicate rock belonging to the Idaho Springs formation.

Early Tertiary intrusive porphyries are abundant in the mineralized area. These porphyries form numerous dikes and small irregular stocks, the largest of which is only half a mile in diameter. The majority of the dikes strike northeast, but some strike northwest and a few short dikes trend eastward. Sodic monzonite and quartz monzonite porphyries are the most abundant, forming dikes and stocks largely confined to the eastern and south-central parts of the district. A few dikes of alaskite are also present. Dikes of bostonite and bostonite porphyry are abundant in the western part of the district and three small dikes of granite porphyry occur half a mile north of Idaho Springs. In the southwestern part of the district several short dikes of biotite latite crop out in a narrow zone about 3 miles long, trending N.55°E.

Structure

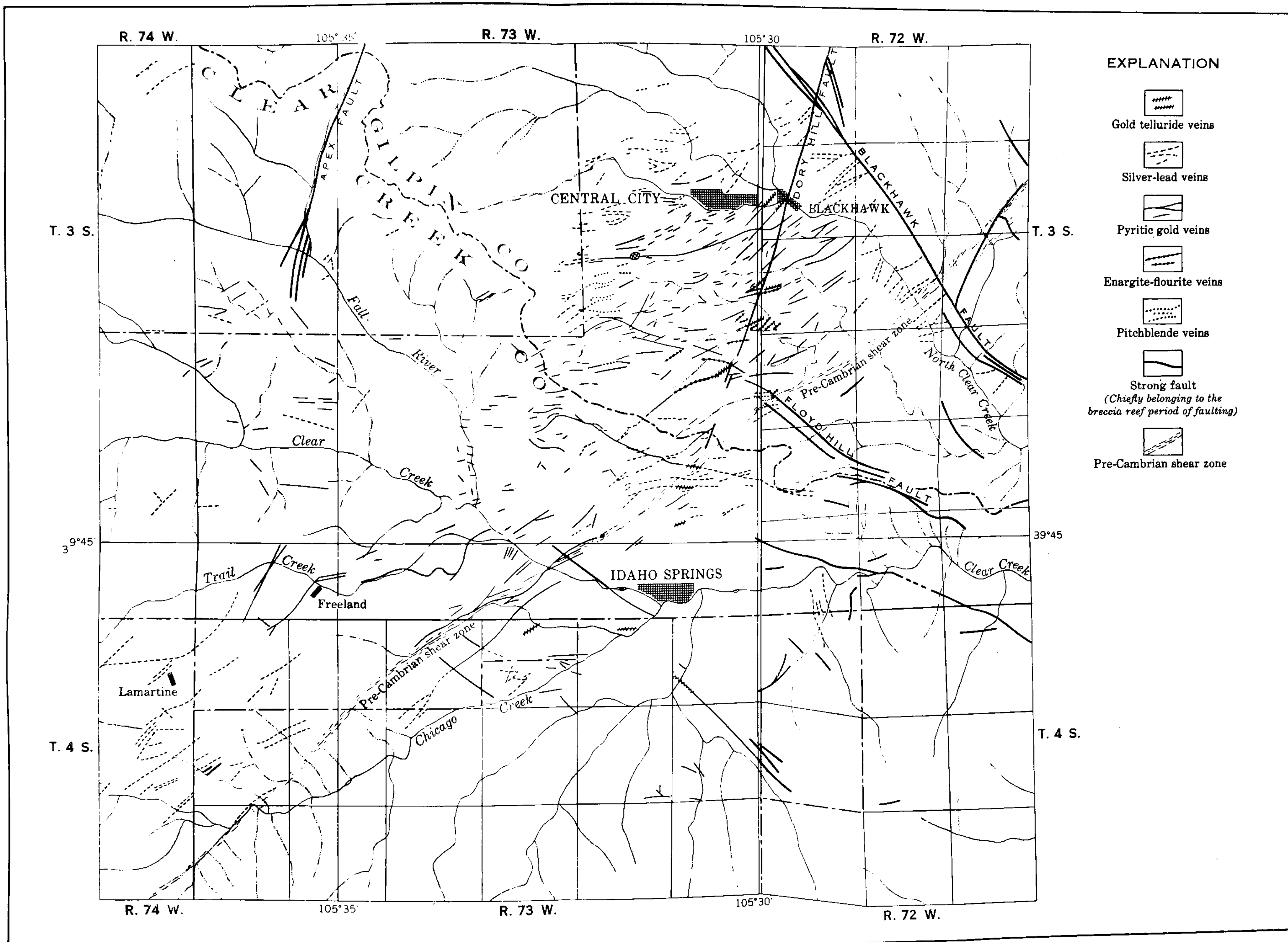
Pre-Cambrian structure has had considerable influence on the distribution of structural features formed in Laramide time. Many dikes and pre-mineral fault fissures follow pre-Cambrian contacts or trends of foliation. Near the southeast border of the district, a strong pre-Cambrian shear zone of northeasterly trend has influenced the intrusions of some of the pre-Cambrian rocks, and of early Tertiary porphyries, as well as the distribution of some of the vein fissures.

Faulting occurred both before and after the intrusion of the porphyries. The earliest Laramide fractures are strong northwesterly breccia-reef faults, some of which can be traced for miles beyond the limits of the district. The most prominent of these breccia reefs is the Blackhawk fault (see pl. 14), which trends about N.40°W. and forms the northeastern border of the district. Segments of the Floyd Hill fault, of N.60°W. trend, extend into the central part of the district, and another prominent breccia reef, also of N.60°W.-trend, lies about 2 miles south of the district. Along the Blackhawk fault, the northeast wall moved up and northwest at an angle of 60°, its total displacement being several hundred feet.

A later set of fault fissures strikes from east to northeast, dips steeply, and contains most of the veins of the district. These faults are much more numerous but far less extensive than the northwesterly breccia-reef faults. Some of these fissures were present before the intrusion of the early Tertiary porphyries, whose distribution was influenced by these planes of weakness. Later faulting along the early fractures displaced the porphyries and created channels for ore deposition. The displacement along these vein fissures of northeasterly trend has been little studied, but in most places the movement was small, rarely exceeding 20 feet. Postore movement was common along many of the veins, but was small.

Ore Deposits

Gold, silver, copper, lead, zinc, and uranium ores occur in the Central City-Idaho Springs district, but most of the ore shipped has owed its value mainly to gold and silver. The ore deposits are veins and stockworks formed in Laramide time and are genetically related to the intrusive porphyries. The veins are parts of a complicated network composed of master veins connected by oblique cross veins, each major fracture having numerous smaller branches and spur veins. Few of the individual veins can be definitely followed for more than 3,000 feet, though some, such as the California-Mammoth, are as much as 2 miles long. Many of the smaller veins pinch out at moderate depth, but several of the large veins have been mined successfully to depths of 1,000 to 1,500 feet. The California shaft is 2,200 feet deep along the vein. The stockworks are pipes or chimneys of irregularly fractured and brecciated rock cemented by ore minerals. The most notable of these is the Patch about a mile southwest of Central City. The Patch has an oval surface outline measuring about 750 feet by 400 feet and extends from the surface to the Argo tunnel, a depth of 1,600 feet, without decrease in size, but with marked decrease in mineralization. Some parts of the Patch are heavily mineralized and others are nearly barren. The chief output has consisted of pyrite-chalcopyrite-gold ore from workings well above the Argo tunnel level. The nature of the fracturing and brecciation leads the writers to believe that they were caused by the upward punch of an underlying igneous body following an earlier shear zone.



STRUCTURE MAP OF THE CENTRAL CITY—IDAHO SPRINGS DISTRICT SHOWING THE PRINCIPAL VEINS AND FAULTS

The ore deposits are of four types: (1) pyritic gold ores, (2) galena-sphalerite ores, (3) composite ores (pyritic-galena-sphalerite ores transitional in character between the first two), and (4) telluride ores. As shown in figure 5, the most widely distributed ores of the region are the pyritic gold deposits. These consist predominantly of pyrite and quartz, with subordinate amounts of chalcopyrite, tennantite, gold, and in places enargite. In these ores the gold greatly predominates in value over the other metals. The gold and silver are chiefly associated with the chalcopyrite and tennantite, though some gold is associated with the pyrite. The average gold content of the direct smelting ores is generally between 1 and 3 ounces and the average silver content between 4 and 8 ounces to the ton. The copper content in most of the ores is below 1.5 percent, but in some ores it may amount to 15 or 16 percent.

In the galena-sphalerite ores the predominant sulphide minerals are galena, sphalerite, and pyrite, with subordinate amounts of chalcopyrite, tennantite, and bornite. The common gangue minerals are quartz and either calcite or siderite. In these ores also, the gold is associated with the chalcopyrite and tennantite. Silver increases with the percentage of tennantite and galena, but locally chalcopyrite and sphalerite are notably rich in silver. In general the galena-sphalerite ores are poorer in gold and copper and richer in silver than the pyritic-gold ores. The gold content commonly ranges between 0.15 and 3 ounces to the ton and the average silver content between 5.50 and 40 ounces. The average percentages of copper, lead, and zinc range from less than 1 percent up to 17 percent of copper, 54 percent of lead, and 32 percent of zinc.

The composite ores may be the result of dual mineralization, first with minerals of the pyritic type and later with minerals of the galena-sphalerite type. Veinlets of the galena-sphalerite type cut sharply across pyritic ore in several mines in the district, but there are numerous transitions from the composite ores to one or the other of the simple types. Some ores composed of nearly solid pyrite with some chalcopyrite have been brecciated and cemented by galena, sphalerite, chalcopyrite, and quartz. The metal content of the ores of the composite type varies greatly with the proportion of the two types present.

The telluride ores are found in a narrow northeastward-trending zone in the northeastern part of the district. (See pl. 14.) The telluride ores consist of gold and silver tellurides in a gangue of horn quartz with small amounts of fluorite, ferruginous calcite, and fine-grained pyrite. Krennerite, petzite, sylvanite, altaite, and coloradoite are the telluride minerals found in the Jewelry Ship mine, and these are believed to be typical of the rich ores of this group. The telluride veins are commonly made up of a network of small veins and veinlets of telluride ore. The ratio of gold to silver in the telluride ore shipped from the War Dance mine commonly ranged between 1:1 and 3:1, and the average grade for 36.8 tons was 16.31 ounces of gold and 13.06

ounces of silver to the ton. Smelting ore shipped from the East Notaway mine in 1909 and 1910 contained from 0.27 to 13.3 ounces of gold and from 1.8 to 15.25 ounces of silver to the ton.

Pitchblende occurs as a minor component of the pyritic gold ores in several mines on the south slope of Quartz Hill, notably the Alps, Belcher, Calhoun, German, Kirk, Leavenworth, Mitchell, Pewâbic, Wood, and Wyandote mines. For many years a small, intermittent output of pitchblende ore has come from this group and has been used mainly for specimens and for experiments. Most of these mines, however, have been worked primarily for gold and silver rather than for pitchblende. The pitchblende is commonly intergrown with pyrite and chalcopyrite and appears to be approximately contemporaneous with those minerals.

Localization of Ore

The localization of the district as a whole seems to have depended largely on the distribution of the breccia reefs and on the position of the vein fissures with respect to them. The Floyd Hill fault, which can be traced with interruptions into the central part of the district, apparently served as a trunk channel along which the ore-forming solutions rose from depth, and it seems likely that other persistent northwesterly fault fissures such as the Gem-Freighters Friend also served such a purpose. The Blackhawk fault, however, apparently served as a dam or baffle to the ore-forming solutions, for the district in large part ends abruptly against this strong fault. The narrow telluride belt seems to be related to the north-northeastward-trending Dory Hill fault, and the great length of the zone together with its extreme narrowness suggests a linear source not far below the present ore bodies. The much greater width of the pitchblende ore zone suggests that this source is at a greater depth than that of the tellurides.

Most of the ore shoots in the district are apparently due to the presence of open spaces in the pre-mineral faults. The most open places along these faults are in brittle wall rocks and at the junction of the main faults with branch fissures or cross fractures. The most favorable wall rocks in the order of favorability seem to be granite gneiss, pegmatite, injection gneiss, and porphyry. Many fractures are well mineralized in the granite gneiss but become barren where they enter the schist. Most of the well-mineralized veins end along the strike and in depth by "horse-tailing", that is, by breaking up into smaller and smaller branch veins; this structure is particularly common where they leave the stronger wall rocks and enter schist, whose foliation is sub-parallel to the vein fissure. Although the appearance of this type of fracture generally marks the disappearance of a vein, it also quite commonly marks the transition zone between two overlapping master fissures.

In some veins, a junction of a northeasterly vein with a northwesterly cross shear zone is marked by the development of valuable ore shoots. In many places the thin wedge between the main vein and a branch or spur vein was shattered and became the site of important ore deposition; this structure is well illustrated by one of the richest ore shoots in the Hubert mine. The localization of ore in the vein fissures was also caused by abrupt changes in strike or dip of the veins; this factor was commonly effective in conjunction with favorable wall rock.

Outlook

The future of the district is uncertain. Many of the smaller veins have been found to pinch out at moderate depths and in general the results of a deep exploration through the Argo tunnel have been disappointing. Some of the larger veins, however, have been successfully mined to depths of 1,000 to 1,500 feet, and many of the mines of the district have not yet reached that depth. In many places in the district there are favorable structural conditions that have not yet been explored, and it seems probable that by careful scientific prospecting many new ore shoots will be uncovered.

ALICE-YANKEE HILL DISTRICT, CLEAR CREEK COUNTY*

The Alice-Yankee Hill district is in the northeastern part of Clear Creek County and the southwestern part of Gilpin County, about 7 miles N.75°W. of Central City. It ranges in altitude from 10,000 to 11,500 feet, but the productive mines are easily accessible by automobile. The most notable ore deposit of the district is the large pyritic stockwork of the Alice mine, which was first worked in the early '80's by hydraulic methods but was abandoned for many years after the rich ore near the surface had been removed. With the increase in the price of gold in 1933, the lower part of the supergene sulphide zone (enriched from above) became commercial and a considerable output was made during the next few years.

The chief pre-Cambrian rock of the district is schist of the Idaho Springs formation, but some bodies of quartz monzonite gneiss and Boulder Creek granite interfinger with the schist. Three-quarters of a mile southwest of the town of Alice the quartz monzonite porphyry stock that contains the Alice ore body is exposed. The foliation of the schist has a general northwesterly trend and a dip to the northeast.

In parts of the district there are many veins of northeasterly trend, but none of them have been very productive. Most of them are of the pyritic gold type and consist chiefly of quartz and pyrite. In these oxidized zones, near the surface, their average gold content ranged between 1 and 2½ ounces to the ton, but some ore is said to have contained as much as 7 ounces. The unoxidized ore has in general been of too low grade to be worked.

In the Alice mine, a large irregular body of mineralized rock has been developed by open pit and irregular underground workings. The ore body is in a stock of quartz monzonite por-

*Abstracted from references 3 and 9 of the bibliography, page 298.

phyry, and is about 300 feet long and 120 to 200 feet wide. Pyrite and chalcopyrite are the chief primary ore minerals, but secondary chalcocite is common in places. Quartz and brown siderite are the principal gangue minerals. The ore and gangue minerals are disseminated, being more or less localized along abundant minute fractures throughout the porphyry mass. The ore is said to average between .13 and .18 ounce of gold to the ton, but local pockets have averaged as much as .43 ounce.

NORTH GILPIN COUNTY DISTRICT*

The North Gilpin County district comprises an area of about 35 square miles in the north-central part of Gilpin County. Numerous veins of the pyritic gold type are widely scattered throughout the district, but in general they are of minor importance. The most productive mines are just south of Apex and in the vicinity of Gilpin. Only small settlements are present in the district.

The most abundant rocks in the district are schist of the Idaho Springs formation and quartz monzonite gneiss. These have been cut by small stocklike bodies of Boulder Creek granite in the eastern part of the district and of Silver Plume granite in the southern part. Several irregular pegmatite bodies are also scattered through the area. The foliation of the schist and gneiss has a general northerly to northeasterly trend. In the central part of the district the pre-Cambrian rocks are cut by large irregular stocks of monzonite porphyry. On the north and southeast sides of this is a radial system of dikes of the same rock. In the southeastern part of the district there are several dikes of bostonite porphyry which have a general N. 30° W. trend. Three strong faults of the breccia-reef type penetrate the district; the northward trending Apex fault cuts through the south-central part of the district; in the eastern part, the northwesterly Blackhawk fault terminates in a series of veins; and in the northern part, the Junction Ranch breccia reef feathers out into a group of veins.

The veins of the district are scattered through a large area, and few are credited with even a moderate output. Some, such as those near Phoenix and south of Perigo, are found at the northwesterly termination of the breccia reefs; others are apparently unrelated to any breccia reef. The veins all belong to the pyritic gold type. The most of them have a northeast strike and steep southeast dip, but some strike west or northwest. The chief primary constituents of the veins are quartz and pyrite with variable amounts of chalcopyrite, but most of the commercial ore is close to the surface and has resulted from superficial supergene enrichment. The primary ores commonly contain less than half an ounce of gold and an ounce or less of silver to the ton, but some fairly high-grade ore has come from the enriched upper parts of the veins.

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*Abstracted from references 3 and 9 of the bibliography, page 298.

The most remarkable ore deposit in the district is in the Evergreen mine near Apex. It has been worked chiefly for copper. Chalcopyrite and bornite are the chief ore minerals. The output has not been large, but the deposit is of interest because of the unusual occurrence of its ores. The ore minerals are found in and adjacent to monzonite porphyry dikes, and the occurrence has been attributed to magmatic differentiation modified by other processes. The ore shipped is said to have averaged about 3 percent copper.

ELDORA DISTRICT, BOULDER COUNTY*

The Eldora district includes a small group of veins just south of Eldora, about 3 miles west of Nederland, and another small group at Lost Lake, 2½ miles farther west. The district has had only a small output and is chiefly of interest because of its gold telluride ores, which were discovered in 1896 and were actively developed during the following decade. Since 1906, the camp has been comparatively inactive. The only mine credited with a noteworthy output is the Enterprise, about a half mile south of Eldora.

The chief rocks in the vicinity of Eldora are schists of the Idaho Springs formation and small lenticular bodies of quartz monzonite gneiss. In the western part of the district is a large stock of monzonite porphyry and a small stock of quartz monzonite porphyry.

The veins just south of Eldora have a general easterly trend and those at Lost Lake strike northeasterly. Both groups dip steeply. The chief ore minerals are the gold tellurides, sylvanite and petzite; horn quartz is the chief gangue. The veins are commonly from 1 to 3 feet wide and consist of sheeted zones containing several narrow seams of ore. Some ore taken from the Enterprise vein averaged about 2 ounces of gold to the ton, but 1,800 tons of crude ore milled in 1896 and 1897 contained only 0.54 ounces of gold to the ton.

CARIBOU-GRAND ISLAND DISTRICT, BOULDER COUNTY*

The Caribou-Grand Island district lies in the west-central part of Boulder County between altitudes of 9,500 and 10,000 feet. It is about 20 miles west of Boulder and about 4 miles north-northwest of Nederland, from which it is easily accessible by road. The rich silver ores of the district were discovered in 1869. Several mines have contributed substantially to the output, but the Caribou and No-Name veins have been by far the most productive. This district is best known for the substantial output of high-grade silver ore from these two veins, but in recent years the district's output has consisted chiefly of complex lead-silver-zinc ore from the Boulder County vein situated 2 miles east of Caribou. The total value of the district's output amounts to several million dollars.

*Abstracted from references 3, 9, and 11 of the bibliography, page 298.

The small settlement of Caribou is near the eastern edge of a composite porphyry stock composed of late Cretaceous gabbro, monzonite, and quartz monzonite porphyries, with minor quantities of titaniferous magnetite and related mafic rocks. Most of the titaniferous magnetite bodies are small, but one dikelike mass has a length of 1,500 feet and contains as much as 4½ percent of titanium oxide. The eastern part of the district is made up of pre-Cambrian rocks; schists of the Idaho Springs formation and some quartz monzonite gneiss cut by a stock of Boulder Creek granite in the northeastern part.

The No-Name vein, the strongest and most persistent in the district, strikes northeast, dips 55-60° NW., and cuts and displaces the eastward-trending Caribou vein. Other easterly veins join the No-Name vein but do not cross it. The ore minerals in the Caribou group are galena, argentite, cerargyrite, native silver, gray copper, and chalcopyrite in a quartz gangue. Much of the rich silver ore contained from 50 to 1,000 ounces of silver to the ton, but milling ore commonly contained from 20 to 50 ounces. Most of the rich silver ore was mined from the zone of oxidation within 100 to 300 feet of the surface but silver ore was mined from a depth of as much as 1,000 feet in the No-Name vein. In the Boulder County vein the ore minerals are chiefly galena, sphalerite, pyrite, and chalcopyrite, with appreciable amounts of gold and silver. Native gold and wire silver were visible in the oxidized zone. The primary ore from the tunnel level averaged only a few ounces of silver and about 0.6 ounce of gold to the ton.

MAGNOLIA DISTRICT, BOULDER COUNTY*

The Magnolia district is about 5 miles west of Boulder and about a mile south of Middle Boulder Creek. Most of the productive veins crop out in an area of less than one square mile and the outcrops range in altitude from about 7,000 to 7,700 feet. The district is accessible over a good automobile road from Boulder.

Gold telluride ore was found on the Magnolia vein in 1875 and during the next two years nearly all the productive veins in the district were discovered. The total value of the district's output is estimated to have amounted to between $2,000,000 and $3,000,000.

The country rock of the district is the pre-Cambrian Boulder Creek granite, whose gneissic structure strikes northeast and dips steeply northwest. The Livingstone breccia reef, one of the early persistent northwesterly faults, trends about N. 25° W. through the district and passes about one-quarter of a mile west of the town of Magnolia. In this vicinity the breccia reef is paralleled by an early diabase dike known as the "Iron dike".

*Abstracted from references 3 and 12 of the bibliography, page 298.

Nearly all the output of the district has come from gold-telluride veins, though some tungsten ore has been mined from the Kekionga vein. This district is noted for the variety of telluride minerals found. The chief ore mineral is sylvanite, but petzite, hessite, altaite, calaverite, lionite, magnolite, nagyagite, coloradoite, henryite, tellurite, ferro-tellurite and native tellurium are also found. Other minerals found in the district are native gold, ferberite, molybdenite, roscoelite, and small amounts of galena, sphalerite, pyrite, marcasite, calcite, and fluorite. Horn quartz is the chief gangue mineral and most of the veins are made up of interlacing seams of horn quartz in sheared or altered granite.

Most of the gold telluride veins strike west or northwest and dip steeply. Many of the veins are only a few hundred feet long and few persist for more than 1,000 feet. The longest vein is the Kekionga, which is about 6,000 feet long. The veins commonly range from a few feet to several feet in width. The gold telluride ores are found over a vertical range of about 1,600 feet but the greatest proved vertical range of a single ore shoot is about 400 feet. Tungsten ore has been mined over a vertical range of about 1,250 feet, but the maximum extent of a single shoot has been about 100 feet. Most of the ore shoots are small and pockety. The largest shoot in the district, in the Keystone mine, is reported to be 500 feet in pitch length, 150 feet in stope length, and as much as 20 feet in thickness. Most of the ore shipped from the district has contained from 1.5 to 5 ounces of gold and from 1 to 6 ounces of silver to the ton, but some shipments of high-grade ore have contained from 30 to 250 ounces of gold to the ton, and a few very small shipments may have been of much higher grade. Tungsten ore shipped from the Kekionga vein averaged about 2 percent WO_3. Ore was also shipped from the Kekionga mine for its vanadium content; some of it contained as much as 6.28 percent vanadium oxide and a moderate tonnage averaging 2 percent was blocked out.

The best ore bodies in the district have been found close to intersections of cross veins or to junctions of converging veins, but some have been localized by abrupt changes in strike or dip of the vein. It seems likely that the ore-forming solutions rose from depths along the Livingstone breccia reef and spread out into the more open vein fissures nearby.

The mines of the district are comparatively small, most of them being only a few hundred feet deep and only a few as much as 500 feet deep. Future exploration will probably uncover new ore bodies in the district, but the smallness of the ore bodies and lack of persistence of the vein fissures make it seem unlikely that any large mines will be developed in the district.

WARD DISTRICT, BOULDER COUNTY*

The Ward district, including the mines around Sunset and Copper Rock, comprises about 12 square miles in the western part of Boulder County, 9 to 13 miles northwest of Boulder. The district ranges in altitude from 7,500 to 10,000 feet and is accessible over good automobile road from Boulder.

Gold was found in the district in 1861 and nearly all the principal mines were discovered before 1870. According to Worcester (16), the value of the camp's output from 1885 to 1919 amounted to about $3,000,000 and that of the total output may have been as much as $9,000,000.

The southern part of the district is occupied by pre-Cambrian schists and gneisses of the Idaho Springs formation, whose foliation trends east to northeast and dips steeply north. In the northern part of the district the chief rock is Silver Plume granite of pre-Cambrian age which encloses lenticular bodies of schist. Several moderately extensive early Tertiary stocks of diorite and monzonite porphyry and a few small irregular bodies of sodic andesite and diorite porphyry occur south and east of Ward. Porphyry dikes ranging from diabase to alaskite in composition are common throughout the district but are most abundant in the northern half.

The district is approximately bounded on the east by the northwestward trending Livingston breccia reef; another strong fault of northwest trend is exposed in the Free Coinage workings near the southern border of the district. Most of the veins of the district trend west-northwest and dip steeply north. The most productive veins belong to the early breccia-reef fault system and are unusually persistent along the strike. In the deepest mines the veins have been followed to depths of more than 1,000 feet below the surface and at this depth they are still strong. At Copper Rock, near the southeast border of the district, there is a broad zone of fractured and brecciated rock more than a mile long containing disseminated pyrite and a little chalcopyrite. This breccia zone was apparently formed by the upward force exerted by a porphyry intrusion.

Gold, silver, and lead are the chief metals that have been produced from the Ward district, but some copper, zinc, and tungsten have also been mined. Most of the mines of the district contain pyritic gold-silver whose chief metallic minerals are pyrite and chalcopyrite. Most of the gold and silver are associated with the chalcopyrite but some gold occurs with the pyrite. Some ore from the Sunset area contained enough cholcopyrite to be shipped as copper ore. Molybdenite and wolframite are found in some of the veins but not in commercial quantities. Most of the primary pyritic gold-silver ore contains from 0.1 to 0.5 ounce of gold to the ton, but where this ore has been enriched in the oxidized zone, at depths of 50 to 250 feet below the surface, it may contain 3 or more ounces of gold to the ton. The average ratio of silver to gold by weight is about 10:1. Lead-silver ore

*Abstracted from references 3 and 16 of the bibliography, page 298.

is largely confined to the White Raven vein system. The chief primary ore mineral is galena, but sphalerite and tennatite are found in places. Both silver and gold are associated with galena. Later than all these minerals is abundant supergene wire silver. Gold telluride ore has been found locally in some of the mines, chiefly in the eastern part of the district. The wide zone of fracturing and brecciation at Copper Rock contains disseminated pyrite and is reported to contain from 0.01 to 0.04 ounce of gold to the ton. The Orphan Boy mine in this zone contains rich free-gold ore which was apparently formed by secondary enrichment of the lean pyritic material.

GOLD HILL DISTRICT, BOULDER COUNTY*

Introduction

The Gold Hill district comprises about 12 square miles in the central part of Boulder County, from 3 to 8 miles northwest of Boulder. It includes the camps of Sunshine and Salina as well as the greater part of what was formerly known as the Sugarloaf district. Gold Hill, the chief town, in normal times has a population of about 125. The district ranges in altitude from 5,900 to 8,400 feet and is readily accessible by automobile over a good gravel road from Boulder.

History and Production

Placer gold was discovered in the district in January 1859, and in the next few years several lodes were prospected. In 1872 the first gold-telluride ore was discovered at the Red Cloud mine, and in the next 5 years most of the principal mines of the district were opened. During the early part of the Twentieth Century, there was a gradual decline of activity in the district, but in the fall of 1933 the sudden rise in the price of gold gave a great impetus to mining activity. As a result, the gross value of the district's output, including that of in Sugarloaf district, jumped from $79,368 in 1933 to $450,995 in 1934 and to $816,929 in 1939. The district continued to be very active until 1942, when nearly all operations ceased owing to World War II. The total value of the district's output is estimated to have amounted to between $12,000,000 and $14,000,000.

Geology

The Gold Hill district is in the northern part of a small batholith of Boulder Creek granite of pre-Cambrian age. (See pl. 11.) Just north of the district and in its western part strongly foliated biotite and quartz-biotite schists of the Idaho Springs formation wrap around the batholith and interfinger with the granite. The foliation of the schist dips steeply and trends nearly north in the western part of the district, but east-northeast along the north border of the granite. The foliation or gneissic structure in the granite trends north to northeast and dips steeply west throughout most of the district, except in the northern part where it strikes east-northeast and dips steeply

*Abstracted from references 3 and 17 of bibliography, page 298.

south. This foliation in the granite has had an important influence on later geologic structure, such as the trend of pegmatite dikes and the strike of many of the faults and veins. Pre-Cambrian dikes of several kinds cut the granite and adjacent schist. Pegmatite dikes are abundant throughout the district and most of them are parallel to the gneissic structure in the granite. A large dike of Silver Plume granite cuts the north-central part of the area and dikes of gneissic granite aplite and hornblende diorite are found in places.

The early Tertiary igneous rocks are less abundant in the Gold Hill district than in most other districts of the Front Range mineral belt. No stocks are present, but dikes of diabase, intermediate quartz monzonite, alaskite porphyry, bostonite porphyry, biotite monzonite and latite porphyries, and biotite latite intrusion breccia are sparingly scattered through the district. All the porphyry dikes dip steeply and with the exception of the "Iron" diabase dike, which is 30 to 50 feet wide, they all range from a few feet to 30 feet in width.

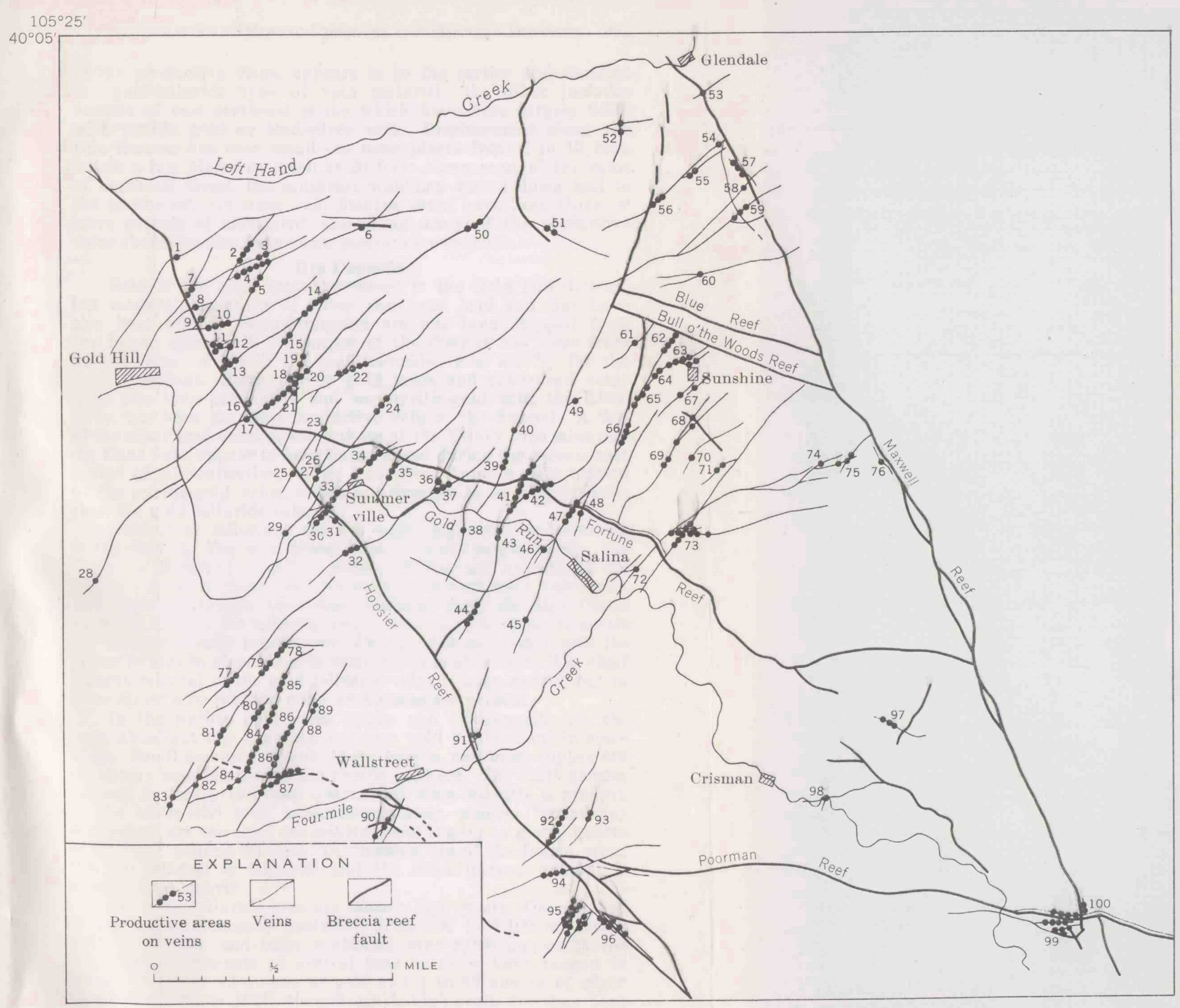
Structure

The dominant structural features of the Gold Hill district are the strong persistent Laramide faults or breccia reefs locally known as "dikes." (See pl. 15.) Their marked influence on the distribution of the ore deposits in the district has long been recognized by the local mining men. The distribution of some of these breccia reefs has been controlled by pre-Cambrian shear zones, which are relatively inconspicuous. Vein fissures are abundant throughout the district and are younger than the breccia reefs. The breccia reefs range in character from narrow, strongly sheared fault zones to wide zones of slight shear, and in many places they show varying degrees of silicification. Some, like the Hoosier reef, are commonly marked by large veins of bull quartz 5 to 30 feet wide, and others, like the Blue reef, contain veins of nearly barren horn quartz. Nearly all the breccia reefs are characterized by a reddish or purplish coloration due to finely disseminated hematite. In a few places, however, they are colored greenish by chloritic material.

The strongest and most persistent of the breccia reefs are the Hoosier and the Maxwell reefs, which strike N. 25°-50° W. across the district and dip almost vertical. Another group of prominent but less persistent faults includes the Poorman, the Blue, and Bull O'the Woods reefs, which strike N.70°-80°W. and dip almost vertical. A third group includes the Fortune reef and a few small inconspicuous faults that strike N. 60-75° W. and dip 30-45° NE. A fourth group includes a number of small faults that strike N. 5°-30° E., dip steeply to the northwest, and are largely obscured by mineralization.

Vein fissures are scattered abundantly throughout most of the district. They nearly all strike northeast and dip steeply northwest, but a few strike northwest and a few others dip at low angles. The northeast-striking fissures can be divided into two main sets; one, of north-northeast trend and including most

PLATE 15.



STRUCTURE MAP OF THE GOLD HILL DISTRICT, COLORADO
SHOWING THE PRINCIPAL VEINS AND THE AREAS THAT HAVE BEEN PRODUCTIVE

LIST OF MINES

1. New Discovery
2. Prussian
3. Twin
4. Klondike (correct spelling is Klondyke)
5. Slide
6. Helena
7. Cold Spring and Red Cloud
8. Alturas
9. Gold Ring
10. Alamakee
11. Times
12. Winona
13. White Cloud
14. Horsfal
15. Columbus
16. Who Do
17. Bellvue
18. Cash group
19. Mack
20. St. Joe
21. Ready Cash
22. Black Cloud
23. Atlanta
24. Big Horn
25. King
26. First National Bank
27. Morning Glory
28. Myrtle
29. Tammany
30. Evans
31. Dana
32. Grant
33. Goldsmith Maid
34. Victoria
35. Scotia
36. Valley Forge
37. Belle
38. Golden Eagle
39. Fairfax
40. Minneapolis
41. Richmond
42. Ingram
43. Three Brothers
44. Melvina
45. Critic and Railroad Boy
46. Baron
47. Sunshine
48. Atchison
49. Sussex
50. Snowbound
51. Belle of Memphis
52. Delaware group
53. St.Louis
54. Washington Irving
55. Cleveland
56. Tillie Butzel
57. Sun and Moon
58. Hidden Treasure
59. Nil Desperandum
60. Dolly
61. Gillaspie
62. American
63. Interocean
64. Osceola
65. White Crow
66. Grand View
67. Washburn
68. White Eagle (Archer)
69. Golden Harp
70. Richard
71. Plough Boy
72. Home Sweet Home and Little Johnny
73. Emancipation group
74. Minnie Bell
75. New York-Union
76. Pilot
77. Sakhrat
78. Gold Lode
79. Great Britain
80. Lucky Star
81. Emerson
82. Concord
83. Forest
84. Franklin
85. Gillard
86. Gray Copper
87. Wood Mountain group
88. Last Chance
89. Doss
90. Gladys
91. Tambourine (Patented name is Temborine)
92. Dime
93. Evening Star
94. Grand Republic
95. Logan
96. Yellow Pine
97. King
98. McKnight Placer
99. Poorman group
100. Bell

of the productive veins, appears to be the earlier and contains the gold-telluride type of vein material; the other includes fissures of east-northeast strike which have been largely filled with pyritic gold or lead-silver ores. Displacement along the vein fissures has been small—in most places from 2 to 10 feet, but in a few places as much as 20 feet. Along most of the veins of northeast trend, the southeast wall has moved down and to the southwest. On some vein fissures there have been three or more periods of movement, and along many of the productive veins there has also been some post-ore movement.

Ore Deposits

Gold is the chief metal produced in the Gold Hill district, but moderate amounts of silver and some lead and zinc have also been mined. Some tungsten ore has been shipped from the Logan mine. All the output of the district has come from fissure veins, of which the gold-telluride veins are by far the most abundant. Some pyritic gold veins and silver-lead veins have also been productive and one pyritic-gold vein, the Klondyke, has been the most productive vein in the district. A few of the silver-lead veins, notably those of the Yellow Pine mine and the Dana lode, appear to have been formed during the breccia-reef period of mineralization. Other lead-silver deposits seem related to the pyritic-gold veins, which are thought to be slightly later than the gold telluride ores.

Gold-silver tellurides are the most important ore minerals in the district. The most abundant are petzite and sylvanite, but hessite is abundant in a few places. Altaite and coloradoite are locally present in very small amounts and tetradymite, calaverite, and native tellurium have been reported from the Red Cloud mine. In most of the telluride ores, two or more telluride minerals are microscopically intergrown. Free gold is associated with the telluride ores in places and in some mines is abundant. The chief gangue mineral in the gold telluride veins is horn quartz, but in some mines ankerite and other carbonates are present.

In the pyritic gold veins pyrite and chalcopyrite are the most abundant ore minerals, but free gold is abundant in some veins. Small amounts of sphalerite, galena, and gray copper are commonly associated with the pyritic gold ore. The chief gangue mineral is sugary to glassy quartz, but some ankerite is present. In the silver-lead ores, argentiferous gray copper (tennantite) and galena are the chief ore minerals and sugary to glassy quartz is the chief gangue mineral. In tungsten ore of the Logan mine, the ore mineral is ferberite and the chief gangue mineral is a dense horn quartz.

The gold telluride ores are mostly high grade. Ore shipped in small lots commonly contained from 100 to 1,100 ounces of gold to the ton and some contained over 2,000 ounces to the ton. Many shipments of several tons or more have ranged in grade from 1 to 12 ounces of gold and 1 to 60 ounces of silver to the ton. Since 1900, though much high-grade ore has been mined, the average grade of telluride ore shipped in ton lots has ranged from 0.5 to 2 ounces of gold and 1 to 10 ounces of silver to the ton. The pyritic gold ore of the district is mostly low-grade and commonly contains from 0.25 to 1.0 ounce of gold to the ton, but in a few places pyritic gold ore has contained as much as 5 ounces to the ton in large lots. Some ore mined at the Grand Republic mine contained as little as 0.15 ounce of gold to the ton. The silver-lead ores show a wide range in grade. Ore from the Yellow Pine mine contained from 33 to 1,440 ounces of silver to the ton. Numerous samples taken from the Victoria mine by Arthur J. Hoskin assayed from 5.94 to 218 ounces of silver and 0.12 to 3.08 ounces of gold to the ton, 0.52 to 5.60 percent of lead, a trace to 2.50 percent of copper, and a trace to 9.00 percent of zinc.

Most of the productive veins in the district are more than a half mile, and a few are between one and 1¾ miles in length. Many have been followed to depths ranging from 300 to 600 feet below the surface and the deepest workings, those in the Slide and Ingram mines, are about 1,000 feet deep. The veins commonly range in width from 1 to 5 feet, but a few locally attain widths of 30 feet or more. Most of the veins are made up of an interlacing network of quartz veinlets from a fraction of an inch to one foot in width, and the ore minerals are chiefly confined to these veinlets. In mining high-grade ore it is common practice to sort the high-grade veinlets from the nearly barren wall rock.

The ore bodies of the district are commonly small and most of the very high grade ore comes from small pockets. Most of the ore bodies range in length from 100 to 400 feet, in breadth from 50 to 300 feet, and in thickness from 1 to 5 feet. The most persistent ore shoot was in the Slide vein and extended from the surface to the 1,000 foot level. In several mines, for example the Ingram, several small pockety shoots are grouped together to form a relatively large compound shoot.

Structural Control of the Ore

It is apparent from a study of plate 15 that the breccia reefs exercised a strong structural control on the ore deposits of the district. In many of the veins the ore occurs within a few hundred feet of a breccia reef, and very little ore has been mined from areas more than 3,000 feet away. It seems likely that these strong persistent fissures served as deep channels for the circulation of the ore-forming solutions. Apparently most of of the solutions rose along the Hoosier reef and then spread out into subsidiary reefs and other fractures. Some solutions may have circulated along the Maxwell reef, but in general this reef appears to have served as a dam to solutions that reached that far. Other breccia reefs also served as dams and provided local structural conditions favorable to the deposition of ore.

The distribution of ore within the vein fissures seems to have been dependent chiefly on local structural conditions that favored the formation of openings. The most important are vein junctions which can be classified into three types: (1) junctions of productive veins with breccia reefs, (2) junctions of two productive veins, and (3) junctions of productive veins with barren gougy fissures. Other factors are the junctions of veins with pre-Cambrian or early Tertiary dikes. Abrupt changes in the direction of strike or dip of the veins have also been effective, commonly in combination with other factors. In veins of northeast trend whose southeast walls have moved southwest, as is true of most of the veins in the district, the more eastward-trending parts of the veins tend to be more open and therefore more favorable to the deposition of ore. In veins where the hanging wall has moved down, the steeper parts of the veins tend to be open, but where the hanging wall has moved up, the less steep parts are likely to be open.

Outlook

In view of the large increase in production in the Gold Hill district during the period 1933 to 1942, the future of the district seems hopeful. Two properties, the Grand- Republic and the Klondyke, were very little explored prior to 1933 but later became two of the most productive mines in the district; furthermore, mines that were productive in the early days, notably the Ingram and the Poorman, have been reopened and have supplied ore as rich as that taken out in the early days. These successes would seem to offer promise to other ventures based on careful prospecting. Though most of the mines in this district are less than 600 feet deep, in nearly every one where exploration has extended to greater depth, good ore has been uncovered and mined. Though the deepest workings are little more than 1,000 feet below the surface, ore has been mined in the district through a vertical range of about 2,500 feet, and, where structural conditions are favorable, it seems likely that in many of the mines ore will extend to greater depth than the present workings.

JAMESTOWN DISTRICT, BOULDER COUNTY*

Introduction

The Jamestown district is in the central part of Boulder County, 9 miles northwest of Boulder, and is easily accessible to automobile over a fair gravel road. Jamestown, the only town in the district, has a population of about 190. The district includes approximately 36 square miles and ranges in altitude from 6,300 to 8,600 feet.

History and Production

Gold was discovered in the district in the summer of 1865, and 10 years later the first telluride ore was found on the John Jay property. In 1885, lead-silver ore was found in the Buckhorn and Argo properties. The fluorspar deposits were first developed in 1903 and the output of this commodity reached a peak of 22,810 tons in 1918. During the following years, activity in all the mines declined until the latter part of 1933, when the rise in the price of gold gave a great impetus to gold mining. The Buena mine

*Abstracted from references 3, 18 and 19 of bibliography, page 298.

became one of the chief producers in the county, until early in 1942, when gold mining was suspended owing to World War II. The war, however, greatly stimulated fluorspar mining, and the fluorspar output in 1943 exceeded 36,000 tons of crude ore.

The total output of all commodities from the district up to and including 1943 is estimated to have amounted to about seven million dollars, of which approximately $3,500,000 has come from telluride ores, $1,300,000 from fluorspar, $1,200,000 from pyritic gold ores, and about $1,000,000 from lead-silver ores. The total output of fluorspar from the district from 1903 to 1944 has amounted to 65,838 tons of metallurgical grade, averaging between 80 and 85 percent of CaF_2, and 33,826 short tons of acid grade containing about 98 percent of CaF_2*.

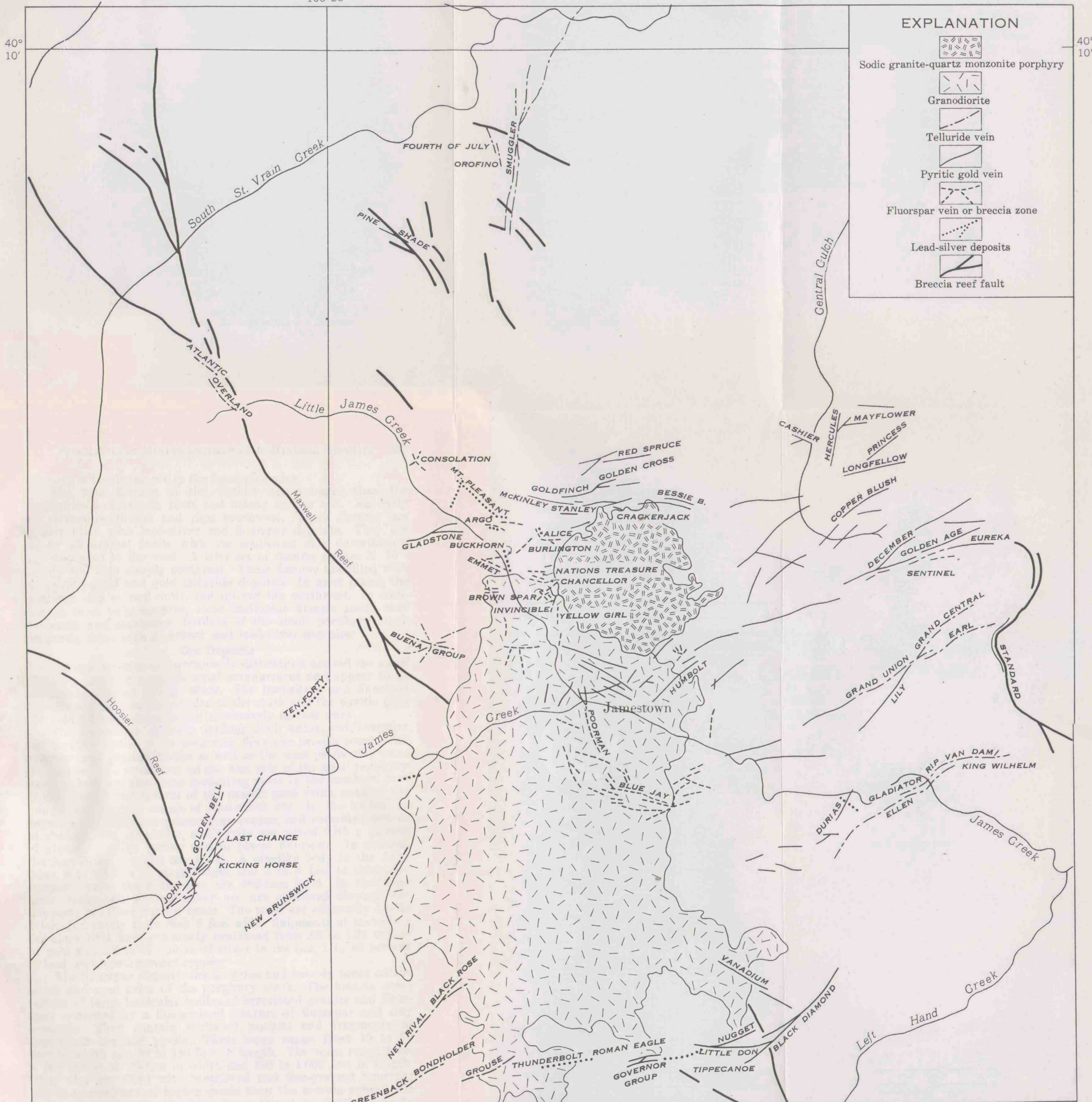
Geology

The Jamestown district lies in the pre-Cambrian complex of the Front Range at the extreme northeastern end of the Front Range mineral belt. Schists of the Idaho Springs formation have been intruded by the Boulder Creek and Silver Plume granites. Small amounts of the Swandyke hornblende gneiss are associated with the schist in the northeastern part of the area. The foliation of the schist and gneiss has a general northeast strike and steep southeast dip, except in the southwestern part of the area where it strikes nearly north and dips steeply west. The pre-Cambrian rocks have been cut by a series of stocks and dikes of early Tertiary age, ranging from diabase to alaskite in composition. The "Iron" diabase dike, the earliest of these intrusives, trends northwestward through the southwestern corner of the district. The central part of the district was invaded by a large roughly rectangular stock of hornblende granodiorite and this was followed by a small stock of sodic granite-quartz monzonite porphyry on the north side of the larger stock. Surrounding the two stocks, but mostly on the east side, is a series of porphyry dikes of northeast strike and steep southeast dip, most of which appear to be younger than the stock. Linear structures in the stocks seem to indicate that the granodiorite was intruded upward from the south at an angle of about 65° and that the smaller stock came up along the underside of the north border at an angle of about 55°.

Structure

The rocks of the district are cut up by three strong faults of the breccia-reef type. (See pl. 16.) The Maxwell reef crosses the central part of the district where it strikes N. 30°-40° W. and dips steeply, but in the south-central part it is cut out by the granodiorite stock. In the western part of the district, the Hoosier reef strikes N. 20°-60° W. and dips 66°-84° W.; in the eastern part, the Standard reef strikes about N. 24° W. and dips 15°-20° W. In the north-central part of the district there are several small faults of northwest strike and steep dip that are believed to belong to the breccia-reef period of faulting. One of these, the Careless Boy "vein" was

*Data furnished by H. W. Davis, U. S. Bureau of Mines.



STRUCTURE MAP OF THE JAMESTOWN DISTRICT, COLORADO

SHOWING THE DISTRIBUTION OF THE PRINCIPAL VEINS AND FAULTS effective in localizing ore in the Smuggler mine.

The vein fissures of the district are younger than the porphyries and breccia reefs and belong to two sets. An early set strikes northwest and dips southwest. These fissures are largely filled with lead-silver and fluorspar deposits. They are nearly all normal faults with the southwest side downthrown and displaced to the west. A later set of fissures strikes N. 10°-80° E. and dips steeply southeast. These fissures are filled with the pyritic gold and gold telluride deposits. In most places the southeast side moved down and toward the southwest. In addition to these vein fissures, some lenticular breccia zones near the south and southwest borders of the small porphyry stock are partly filled with fluorspar and lead-silver deposits.

Ore Deposits

The ore deposits are irregularly distributed around the small porphyry stock in a rough zonal arrangement and appear to be genetically related to the stock. The lead-silver and fluorspar deposits are close to the border of the stock and the pyritic gold and gold telluride deposits are successively farther away.

The lead-silver deposits include both veins and irregular and pipelike bodies in or bordering fluorspar breccia zones. The irregular and pipelike bodies as well as the most productive veins are confined to a small area on the west side of the small porphyry stock. There are also some lead-silver veins in the southern part of the district and several of the pyritic gold veins, notably the Longfellow, contain seams of lead-silver ore. In the lead-silver deposits, argentiferous galena, gray copper, and variable amounts of chalcopyrite, sphalerite, and pyrite are mixed with a gangue of glassy to milky quartz and in places fluorspar. In general, the lead-silver deposits are small. A pipelike body in the Alice mine, 8 to 20 feet in stope length and 3 to 8 feet in thickness, extended from the surface to the 400-foot level. In the Argo mine, fragments of lead-silver ore are scattered through the fluorspar in rather narrow zones. The veins are commonly one to 3 feet and rarely more than 5 feet wide. Shipments of lead-silver ore since 1901 have commonly contained from .06 to 1.29 ounces of gold and 2.8 to 47 ounces of silver to the ton, 1 to 40 percent of lead, and 0 to 5 percent copper.

The flourspar deposits are in veins and breccia zones on the south and west sides of the porphyry stock. The breccia zones consist of large lenticular bodies of brecciated granite and fluorspar cemented by a fine-grained mixture of fluorspar and clay minerals. They contain scattered pockets and fragments of lead-silver ore and pyrite. These zones range from 10 to 70 feet in width and 50 to 350 feet in length. The veins range from a few inches to 20 feet in width and 150 to 1,000 feet in length. They also are filled with brecciated and fine-grained fluorspar but in general are of higher grade than the breccia zones. The larger fluorspar deposits have been mined to depths ranging from 150 to 480 feet. In recent years crude ore containing 45 to 73 percent of CaF_2 has been mined and milled.

The pyritic gold veins fill some of the later fault fissures that trend northeast and dip southeast. The chief ore minerals are pyrite and chalcopyrite in a quartz gangue. Galena and sphalerite are present in some veins and are locally abundant. The gold is free or is intimately associated with chalcopyrite and in small amounts with pyrite. The veins commonly range in width from a few inches to 3 feet, but some form mineralized zones 10 to 30 feet wide. The grade of the pyritic gold veins is extremely variable. Rich free-gold ore from the Golden Age mine is said to have contained from 500 to 2,000 ounces of gold to the ton, but most of the pyritic gold ore has ranged from 0.3 to 5 ounces of gold to the ton. The silver content is commonly about the same as that of the gold, but some of the ore from the Longfellow mine contained from 35 to 155 ounces of silver to the ton. Pyritic gold ore from the Nugget group in the southern part of the district contained from .14 to .24 ounce of gold and .03 to .05 ounce of silver to the ton.

The telluride veins also fill fissures of northeast trend and steep southeast or northwest dip. They range in width from a fraction of an inch to as much as 10 feet and in the Buena mine some ore bodies at vein junctions are as much as 30 feet wide. The telluride veins contain gray jaspery (horn) quartz, finely disseminated pyrite and a variety of telluride minerals. Appreciable amounts of free gold are associated with the tellurides. The veins are commonly made up of numerous interlacing seams of horn quartz, in which the telluride minerals are unevenly distributed. The most abundant telluride minerals are krennerite and petzite, but sylvanite and altaite are fairly abundant, and hessite, coloradoite, native tellurium, and rickardite (?) are locally present in small amounts. In most of the veins, two or more telluride minerals are microscopically intergrown. The telluride ores show great range in grade. Large shipments have commonly contained from .5 to 15 ounces of gold and from .5 to 25 ounces of silver to the ton. High-grade telluride ore which is sorted and shipped in sacks commonly contains from 10 to 286 ounces of gold and from 10 to 40 ounces of silver to the ton.

Most of the ore shoots in the district are small, commonly ranging from 50 to 200 feet in length, 30 to 100 feet in breadth, and from 1½ to 10 feet in thickness. Outstanding exceptions are telluride ore bodies in the Buena mine that were as much as 150 feet long, 60 feet wide and 30 feet thick, and a compound shoot on the Smuggler telluride vein that had a pitch length of about 500 feet, a stope length of about 200 feet, and a thickness of 1 to 3 feet. In the fluorspar veins and breccia zones high-grade bodies of fluorspar have been small for the most part, ranging from 20 to 150 feet in length, 10 to 100 feet in breadth, and 1 to 20 feet in thickness. In recent years, however, much larger bodies of lower-grade flourspar have been mined from the breccia zones and some of the veins. These range from 150 to 450 feet in length, 120 to 350 feet in breadth, and 5 to 60 feet in thickness, and their full length has not yet been exposed.

Structural Control of the Ore Deposits

As in other districts of the Front Range, the breccia reefs apparently served as deep channels for the circulation of the ore-forming solutions, and the ores were deposited in open ground within easy access to these solutions. The fissures and breccia zones occupied by the fluorspar and the early lead-silver deposits are believed to have been formed by forces accompanying the intrusion of the sodic granite porphyry stock. The fluorspar deposits, however, were rebrecciated, apparently by a gradual collapse of the fluorspar bodies following solution of some of the fluorspar by later solutions. Most of the important ore deposits of the district are confined to areas of mixed schist and granite. Large bodies of granite and granodiorite seem to have resisted the forces that formed the vein fissures, except near the borders. In large bodies of schist only tight gougy fissures were formed. The local distribution of ore within the veins was controlled chiefly by vein junctions, but also by irregularities in the vein and by changes in the character of the wall rock. The most effective type of junction is that in which a vein cuts across an earlier fault or vein; the chief ore bodies in the Buena and Smuggler mines were localized at junctions of this type. Splits or junctions of contemporaneous veins have also formed favorable locations for ore, as in the John Jay and Golden Age mines. In many of the veins ore bodies are found at places where the vein takes a sudden change in strike or dip and ore bodies are also commonly found where the wall rock changes abruptly from schist to granite or from either schist or granite to porphyry. The most ideal conditions for ore deposition were a combination of all three factors, as is illustrated in the "big stope" ore body in the Buena mine.

Outlook

Ores in the Jamestown district have been mined over a vertical range of about 2,350 feet. The deepest workings are only about 500 feet below the surface and in many mines the workings are only 100 to 200 feet deep. In none of the mines accessible to the writer have veins been found to bottom with depth and in most of them the vein is as strong in the bottom level as at the surface. It therefore seems probable that if structural conditions are favorable, ore bodies may be found at considerable depth beneath the present workings. At numerous places in the district there are structural conditions as yet unexplored that appear favorable for the localization of ore, and it seems likely that many new ore bodies will be uncovered in the future comparable in size and grade to those mined in the past.

THE BOULDER TUNGSTEN DISTRICT, BOULDER COUNTY

By Ogden Tweto

Introduction

The Boulder tungsten district is on the eastern slope of the Front Range in Boulder County, Colorado. The tungsten veins lie in a narrow belt that begins about four miles west of Boulder and extends west-southwestward for 10 miles to the vicinity of Nederland. The district is in wooded mountainous country of moderate relief. Altitudes range from 6,500 feet in Boulder Canyon at the eastern edge of the district to 8,700 feet near the western edge. The climate is relatively mild, and mining can be carried on throughout the year. The district is reached by a good road up Middle Boulder Creek from Boulder and by the north-south Peak-to-Peak highway through Nederland. Rail shipping points are at Boulder, and at Rollinsville four miles south of Nederland.

Tungsten was first recognized in the district in 1900 and has been mined almost continuously since then. Peak output was reached in 1917, when 2,707 tons of concentrates containing 60 percent WO_3 was produced. The rate of production declined abruptly at the end of the first war, and from 1918 through 1938 the annual output averaged only about 200 tons of 60-percent concentrates. During the war years from 1939 to 1944, inclusive, the output averaged about 500 tons per year, but with the fall in price in 1944, production declined greatly, and at the end of 1945 only one mine was in operation. The total output from 1900 through 1942 amounted to 22,843 tons of concentrates containing 60 percent WO_3. Output for 1943-1945 is estimated at 1,100 tons, and the total output through 1945 thus amounts to nearly 24,000 tons of concentrates, valued at about $24,000,000. The Boulder district ranked first in total output among the tungsten districts of the United States from 1900 until the second world war, during which output was small compared to that from the large low-grade scheelite deposits of Idaho, Nevada, and California.

Specific features of the tungsten district have been described in several geologic and engineering reports, but the only general descriptions of the district as a whole appear in an early report by George and Crawford[1] and a summary by Lovering[2]. A comprehensive report embodying results of a geologic study by the U. S. Geological Survey in cooperation with the Colorado Metal Mining Fund and the State of Colorado is almost completed and should be available soon.[3]

[1]George, R. D., The main tungsten area of Boulder County, Colorado, with notes on the intrusive rocks by R. D. Crawford: Colorado Geol. Survey, 1st Rept., 1908, pp. 1-103, 1909.

[2]Lovering, T. S., Tungsten deposits of Boulder County, Colo.: U. S. Geol. Survey Bull. 922-F, pp. 135-156, 1940.

[3]Lovering, T. S., and Tweto, Ogden, Geology and ore deposits of the Boulder tungsten district, Colorado: U. S. Geol. Survey Prof. Paper, manuscript in preparation.

Geology

Rocks.—The tungsten district is entirely within the Front Range province of pre-Cambrian granitic and metamorphic rocks. The eastern three-fourths of the district is in granite of the Boulder Creek batholith, and the western part is largely in biotite schist and associated quartzite of the Idaho Springs formation. Aplite and pegmatite form dikes in the granite and small intrusive bodies in the schist. Small bodies of granite are also present in the schist. Most of the intrusive bodies trend northward, parallel to the foliation of the schist. The boundary between the eastern granitic area and the western metamorphic area is marked approximately by the Hurricane Hill breccia reef, which is shown in plate 17.

The pre-Cambrian rocks are cut by a few small porphyry dikes of late Cretaceous or early Tertiary age. Monzonitic and andesitic dikes are most common in the western part of the district. They are cut by the vein fissures, but many of them were intruded while movement along the fissures was still in progress. Small dikes of biotite latite and latitic explosion breccia are found throughout the district, and small dikes of limburgite are present at places. Dikes of both of these rocks cut the quartz veins in places. The "Iron Dike," an early and persistent dike of diabase, trends northwestward across the eastern part of the district.

Structure.—As shown in plate 17, there are two prominent sets of fractures in the district. Fractures of the earlier set trend northwest, and the stronger ones are known as breccia reefs. Fractures of the younger set are occupied by the tungsten veins, and all lie within the northeast quadrant. The breccia reefs are wide shear zones that can be traced for long distances along the east side of the Front Range. They are typically silicified and contain some hematite, but some are chloritized in places and some are gougy. Some of the hematite is disseminated in fine-grained quartz, and pink to purple quartz is characteristic of the reefs. The reefs of the tungsten district include the Hoosier, which marks the eastern limit of the district, the Livingston, the Rogers, the Hurricane Hill, and the Maine-Cross, which mark the western limit of the district. The Maine-Cross reef is well defined only in the area south of Nederland; north of Nederland only minor fractures of the Maine-Cross system are found.

The intervals between the major breccia reefs are broken by many minor fractures related to the reefs. Some of these are parallel to the main reefs, but many are cross fractures that trend about east-west between the reefs.

Although traces of gold, silver, copper, and lead are found at places along the reefs, the quartz-hematite aggregates typical of the reefs are essentially barren. The reefs are of importance, however, because of their seeming influence on the younger tungsten deposits. The 30 most productive tungsten mines, whose locations are shown on plate 17, are clearly grouped near the reefs. Parts of the reefs, and especially of some of the minor connecting reef fractures, were reopened and mineralized during the stage of tungsten deposition and during the closely related stage of gold deposition in the Gold Hill district (see page 319) northeast of the tungsten district. Some of the prominent mines in the eastern part of the district are at a distance from the main reefs (pl. 17), but most of them are on or near cross-fracture reefs. Tungsten is present at places along the main reefs, especially in the marginal part of the district. The Copeland reef, which extends east-west between the Livingston and Rogers reefs near South Boulder Creek, was tungsten-bearing at the Copeland mine (No. 14, pl. 17). The ore was relatively low grade, siliceous, and refractory, but the ore body was comparatively large, and the mine was fairly productive. Some tungsten was mined in the Rogers reef two miles south of the Copeland mine, in the Hoosier reef at two or three localities along the east edge of the district, in the Hurricane Hill reef at the south edge of the district, and in the Rogers reef near the north edge of the district.

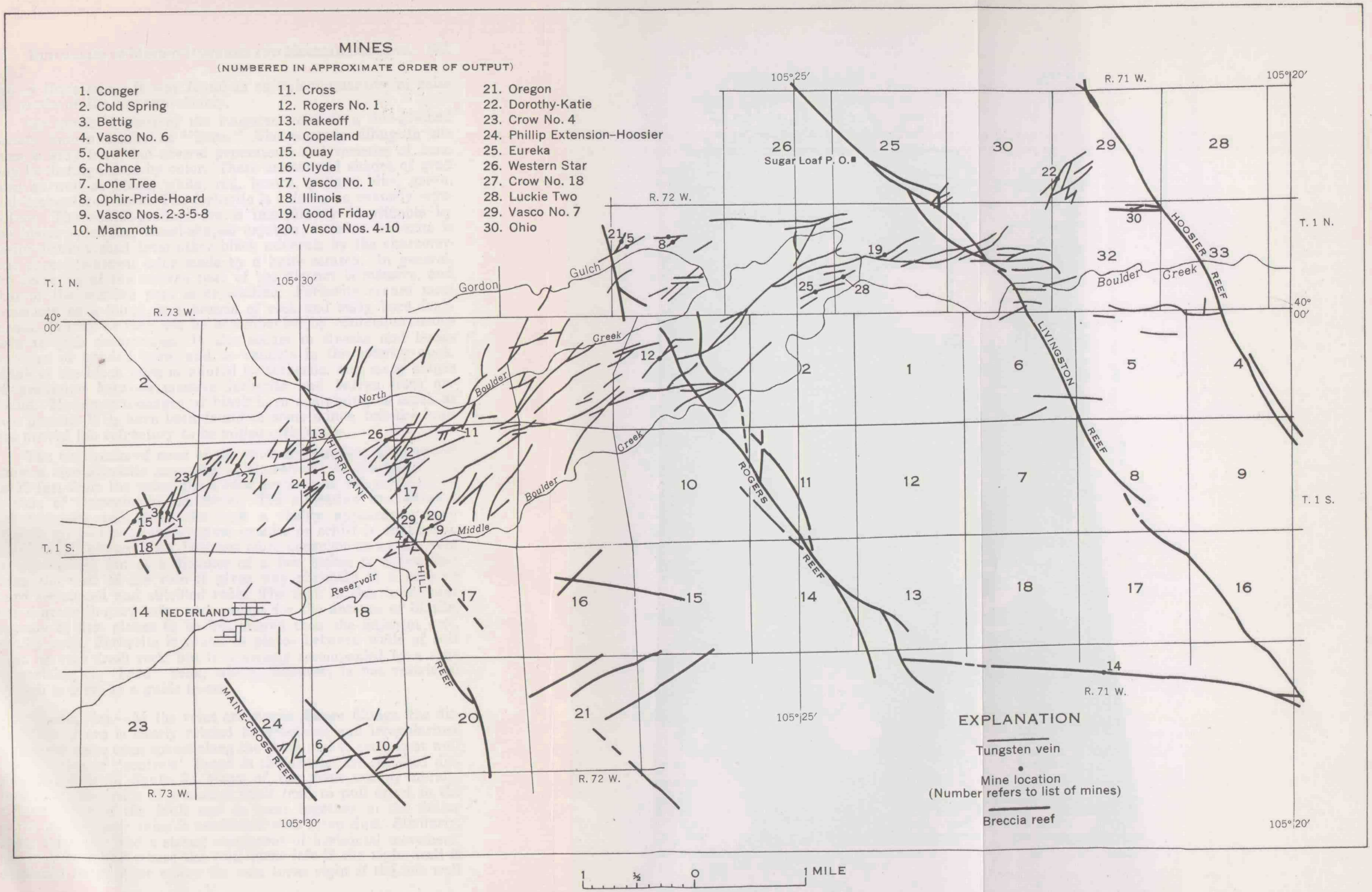
Veins.—Almost all of the tungsten ore of the Boulder district occurs as a fissure filling. The veins follow pre-mineral faults, most of which show small displacements. Repeated brecciation of the successive generations of quartz that preceded and accompanied ore deposition indicates long-continued movement along the veins, but post-ore faults cut the veins in only a few places, and the displacement along such faults is almost negligible.

Two groups of veins can be readily distinguished on plate 17. Short but highly productive veins in the western part of the district trend north to northeast, and most of the productive veins of this group dip easterly. Somewhat longer veins in the central and eastern parts of the district trend northeast to east, and the productive veins dip northward almost without exception. In general, the longest veins have been of little economic importance, and the more productive mines of the central and eastern area are on the shorter veins.

Ore Deposits

Mineralogy.—The tungsten mineral of the Boulder district is ferberite or ferrous tungstate which contains very little of the hubnerite or manganese tungstate molecule. The veins consist almost entirely of quartz and ferberite. Other minerals are found only in minor quantity and are sporadically distributed. These include sulfides of iron, copper, silver, lead, and zinc; the clay minerals dickite, beidellite, montmorillonite, halloysite, and allophane; carbonates of calcium, magnesium, and iron; and adularia, barite, fluorite, opal, magnetite, and hematite. Prior to the second war, scheelite, the calcium tungstate, was recognized only as a mineralogical curiosity in the district, but during the war it was found to be widely distributed as an accessory mineral, and in

PLATE 17.



MAP OF THE BOULDER TUNGSTEN DISTRICT, SHOWING PRINCIPAL VEINS AND LOCATIONS OF THE 30 MOST PRODUCTIVE MINES.

(Modified from plate 25, U. S. Geol. Survey Bull. 922-F) two or three mines it was found in sufficient quantity to raise the grade of the ore appreciably.

The quartz typical of the tungsten veins is a fine-grained variety known locally as "horn." The common filling in the veins is gray horn, but several generations and varieties of horn may be distinguished by color. There are several shades of gray horn as well as black, white, red, brown, yellow, blue, green, and flesh-colored horn. The ferberite is massive to coarsely crystalline. The coarse-grained ore is immediately identifiable by the black, splendent chisel-shaped crystals; massive ferberite is easily distinguished from other black minerals by the characteristic chocolate-brown color made by a knife scratch. In general, the ferberite of the eastern part of the district is massive, and that of the western part is crystalline. Ferberite occurs most commonly as a filling in a breccia of rock and early horn fragments. It may or may not be accompanied by contemporaneous horn in such occurrences. It also occurs in streaks and lenses in veins of banded horn, and as veinlets in the country rock. Much of the black horn is colored by ferberite, and many stages of gradation between massive ferberite and barren horn are found. Moderate tonnages of black horn containing as much as two percent WO_3 have been found in some mines, but the horn has proved too refractory to be milled efficiently.

The wall rocks of most of the veins are strongly altered and show a characteristic sequence of alteration. At distances of 2 to 50 feet from the veins, fresh rock grades into the soft rock in a zone of clay-mineral alteration. The alteration has affected the feldspars and given the rock a chalky appearance, even though the biotite of the original granite or schist is unaffected. This "soft" altered rock becomes more conspicuous as the vein is approached, but at a distance of a few inches to a few feet from the wall of the vein it gives way abruptly to a zone of hard sericitized and silicified rock. The rock in this inner zone has a greenish-gray color and, except for the absence of biotite, appears at first glance to be less altered than the adjacent soft, chalky rock. Ferberite is found in places between walls of soft rock, or even fresh rock, but it is usually accompanied by a zone of sericitic or "hard" rock, which, however, is not restricted enough to serve as a guide to ore.

Localization.—As the veins are simple fissure fillings, the distribution of ore is closely related to structures and irregularities tending to make open spaces along the veins, and to competent wall rocks. Types of "controls" found in the district are sketched diagrammatically in figure 3. Many of the veins occupy normal faults. As the walls of a normal fault tend to pull apart in the steeper parts of the fault and to come together in the flatter parts, ore in many veins is associated with steep dips. Similarly, along veins that had a strong component of horizontal movement, ore may be found where the vein turns left if the right wall is displaced forward, or where the vein turns right if the left wall is displaced forward. Many ore bodies have been found at junctions of veins, but the frequency of ore occurrences at junctions is low, and possibly two or three dozen junctions are found barren for each one found productive.

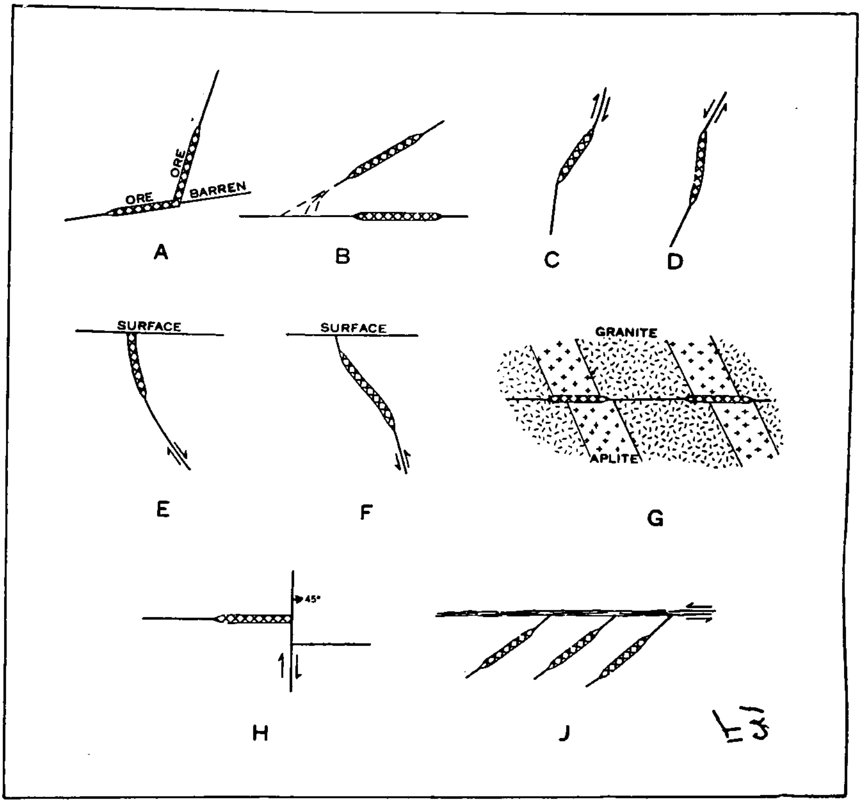


Figure 3.—Diagrammatic sketches showing types of ore occurrences in tungsten veins.

The character of the wall rocks influenced the permeability of the veins and thus affected the distribution of ore. Aplite and pegmatite were not easily altered and, being hard and strong, formed open breccia in the veins. Veins in schist are almost all tight and gougy unless the schist is so strongly injected with granitic material as to become an injection gneiss. In the schist area in the western part of the district the veins are ore-bearing, if at all, only where they cross bodies of granite, aplite, or pegmatite; they are typically barren in the schist. In the granite area the granite itself is the poorest wall rock, and many of the ore shoots are localized where the veins cut aplite or pegmatite dikes within the granite (see fig. 3-G).

Ore controls such as described above are obvious in many mines, but in many others the control is obscure and is not apparent until the ore body has been found and mined. Moreover, even though structural features indicative of openings along the vein may be found in advance of mining, there is no way other than sinking or drifting to determine whether the structure is ore-bearing or is merely filled with barren quartz. A further hazard is added by the capricious distribution of the ferberite; open stretches along many veins were ignored by the ore-forming solutions, and ore shoots therefore occupy only small parts of some bodies of open breccia.

Size and Grade.—The tungsten district is characterized by small bodies of high-grade ore. In comparison to the ore bodies in many mining districts, the tonnage in most tungsten ore shoots is very small, but the smaller tonnage is balanced by greater value. With tungsten at $20 per unit,[5] high-grade ore is worth 60 cents a pound, and 5-percent ore is worth 45 to 90 dollars a ton. The average value of tungsten concentrates produced in the district from 1900 to 1945 was approximately $1,000 a ton in terms of a 60 percent product.

Most of the veins mined are from 4 inches to 3 feet wide, but some ore has been mined throughout widths of as much as 15 feet. During periods of high price for tungsten, smaller veins can be mined; during the second world war one mine was operated profitably for three years along a streak of ferberite that averaged only about one inch in width. The ore shoots vary greatly in size, but perhaps the average shoot has a stope length of 50 to 100 feet and a pitch length of 100 to 200 feet. The largest ore body found in the district—in the Conger mine—had an average stope length of about 400 feet and a pitch length of 625 feet. Lovering[6] has presented figures collected by one mining company showing that the output from 50 ore shoots averaged about 350 tons each of ore containing about eight percent WO_3. The ore shoots are irregular in shape, and if they have a definite elongation and rake, the rake in nearly all is to the east or northeast.

The grade of the ore mined profitably depends upon many factors, chief of which is the prevailing price of tungsten, but most of the ore mined thus far has contained from 2 to 20 percent WO_3. During the war, when the Metals Reserve Company paid $23.50 net per unit of tungsten trioxide in ore containing as little as 0.80 percent WO_3, considerable ore containing about one percent was mined. Normally, however, 1½ to 2 percent is about the lower limit of WO_3 in mined ore, including the "high-grade." High-grade ore is mined selectively and sorted out by screening in order to avoid mill losses and penalties. On a "$20-schedule," a ton of two percent ore may be worth $10, but if one of the two

[5]A unit is 20 pounds of contained WO_3. A ton of 1 percent ore contains one unit; a ton of 60 percent ore or concentrates contains 60 units.

[6]Lovering, T. S., op. cit., p. 152.

units of WO_3 contained in this ton of ore is removed by sorting, the gross value of the ton of ore may be 20 to 24 dollars, depending on the grade of the sorted "high-grade."

Origin and Changes With Depth.—Lovering[7] has presented a hypothesis for the origin of the tungsten deposits. According to this, the source of the tungsten was in the biotite latite magma; the tungsten left the source chamber in an acidic gaseous solution which condensed in the veins; the mineralization began suddenly, if not explosively, and was shortlived; the condensed acid solution reacted with the alkaline wall rocks during its rise; when the solution had become neutral or was only slightly acid, ferberite was precipitated.

According to this reasoning, ferberite would have been deposited through a relatively small vertical range, but there is no means of assessing "relatively small"; it might be a few hundred or many hundred feet. Moreover, the vertical limits might differ in different veins, as each vein was to a certain extent a closed system.

It may be noted that the order of mineral deposition in the veins can be equally well explained by a gradual change in the character of the solution itself—that is, by a change at the source rather than one produced entirely by reaction with the wall rocks. Certain features of the veins are better explained by this hypothesis; for example, the "soft" or clay-mineral zone in the wall rocks should increase downward, and the "hard" or sericitic and siliceous zone should increase upward according to the reaction hypothesis, but in the district as a whole the opposite seems to be true. If there were a gradual change in character of the mineralizing solution at the source, the vertical range of ore deposition might be somewhat greater than if the change were due entirely to reaction with the wall rocks.

Whatever the chemistry of the process, the deep circulation was evidently controlled in large part by the breccia reef fractures, as has been suggested by Lovering.[8]

The mines of the tungsten district are shallow because the general practice has been to stop exploration downward once the bottom of ore shoots followed down from the surface, or from near the surface, is reached. Blind ore shoots that overlap or lie completely below the shoots exposed at the surface have been found in several mines which are significantly the most productive in the district. The deepest mine in the district is the Conger, which is just short of 1,000 feet deep vertically, but the greatest vertical depth to which ore has been mined is about 575 feet—in the Conger and Vasco No. 6 mines. The average depth of the 30 most productive mines (those shown in plate 17) is about 340 feet, but the average depth of the total of 200 or more mines in the district probably does not exceed 100 feet. This larger number is exclusive of the hundreds of trenches,

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[7]Lovering, T. S., The origin of the tungsten ores of Boulder County, Colorado: Econ. Geology, vol. 36, pp. 229-279, 1941.

[8]Lovering, T. S., Preliminary geologic map showing the relations of ore deposits to geologic structure in Boulder County, Colo.: Colorado Sci. Soc. Proc., vol. 13, No. 3, pp. 77-88, 1932.

holes, and "prospects" at the surface.

No progressive change in the ore with depth has been noted. The ore near the bottom of many ore shoots is somewhat more dense and "horny" than the ore higher in the shoot, but ore found in other shoots at greater depths in some of the same veins is of as good quality as the ore in the upper shoots. It is probably significant, however, that the ore in the eastern part of the district, which is one to two thousand feet lower than the western end, is distinctly finer-grained and on the whole more siliceous than the ore in the western part.

Future of the District

There is little doubt that practically all of the ore shoots that reach the surface have been found. A few may remain beneath areas heavily mantled by alluvium, but even most of the covered areas have been prospected by bulldozing. Blind shoots which do not reach the surface have been found in many mines, and doubtless many more remain undiscovered, but the cost of finding them may be high. The only satisfactory method of exploration is by actual mining. Diamond drilling may be helpful, but the ore bodies are easily missed by random drill holes, and results that are possibly conclusive can be obtained only by intensive and costly drilling campaigns. There are several known instances in which drill holes missed profitable ore bodies by as little as a few inches. Other ore bodies were actually pierced by drill holes but were not recognized because core recovery in the soft vein zones was poor. Again, drills have cored rich ore that proved on mining to occur in isolated small lenses with no other ore nearby. Several methods of geophysical prospecting have been tried,[9] but these are useful only in locating veins, not ore. The veins already known aggregate at least a hundred miles in length, and the problem is therefore not to find veins but to find which 50- or 100- foot interval along a mile of vein contains ore, if any does.

Although there is general agreement that at least the shallow mines have passed their prime, even the near-surface zone is not exhausted. By means of a long-range program of planned and coordinated exploration and development, the district might be made to produce a few hundred tons of concentrates annually for many years to come; however, any work done in the district will, as always, depend upon the price of tungsten. Judging by the rate at which mines closed when the price of tungsten fell from $30 to $20 a unit in 1944 (and more importantly, fell from $23.50 to about $5 per unit in low-grade ore), a tungsten price of $20 per unit appears to be about the lower limit at which the mines can be operated when mining costs are as high as in 1944-45.

One remaining possibility for continued productivity has barely been tested. This is the possibility of finding ore at depth. Very few veins have been explored at depths greater than 400

[9]Lovering, T. S., Tungsten deposits of Boulder County, Colo.: U. S. Geol. Survey Bull. 922-F, pp. 154-155, 1940.

feet, and many have been explored to no more than half of this depth. The Conger is the only vein that has been explored at even moderately great depth, but unfortunately this normal-fault fissure flattened and remained flat throughout the lower workings. There was thus little chance for ore to fill the vein, and the absence of ore in the lower part of the Conger was more probably due to this structural feature than to excessive depth. The character of the veins and wall-rock alteration on the bottom levels of most of the other deeper mines is little different than on the upper levels, and, judging by the characteristics of veins near ore, some of the veins appear more "favorable" at depth than they do higher in the mines. If deep exploration should be attempted, it should logically be done in the western part of the district, both because this part has been reduced less by erosion than the eastern part and because it contains more productive veins, both individually and in number.

CENTRAL COLORADO AND CRIPPLE CREEK

LODE DEPOSITS OF ALMA AND HORSESHOE DISTRICTS, PARK COUNTY

By Quentin D. Singewald

Introduction and Conclusions

Gold, silver, and other metals aggregating $37,000,000 in gross value have been produced from lode deposits along the eastern slope of the Mosquito Range, in the extreme northwestern part of Park County. Approximately 95 percent of this output has come from the Alma district and the remainder from the Horseshoe district immediately to the south.

Nearly all the deposits that crop out in these districts have probably been discovered and essentially mined out; however, there remain unprospected areas in which favorable ore horizons lie concealed beneath rocks highly unfavorable to ore deposition. In several places, notably along the footwall of the London fault across Pennsylvania Mountain (see pl. 18) and beneath the summits of Mount Bross and Mount Lincoln, chances for concealed ore bodies may be regarded as good, and in some other places as fair. Prospecting at most of the promising localities, however, will be rather costly because of the depth to favorable ore horizons. The future of the districts, therefore, may be determined by comparison of prospecting costs with value of ore reasonably to be anticipated in any given locality.

General geology, economic geology, and suggestions for prospecting along the eastern slope of the Mosquito range have been set forth in a series of publications derived from 4 seasons of field work by parties of the U. S. Geological Survey, terminating in 1935. These publications form the basis of the brief resumé that follows. The reader is particularly referred to the text and maps of the selected bibliography listed at the end of this paper.

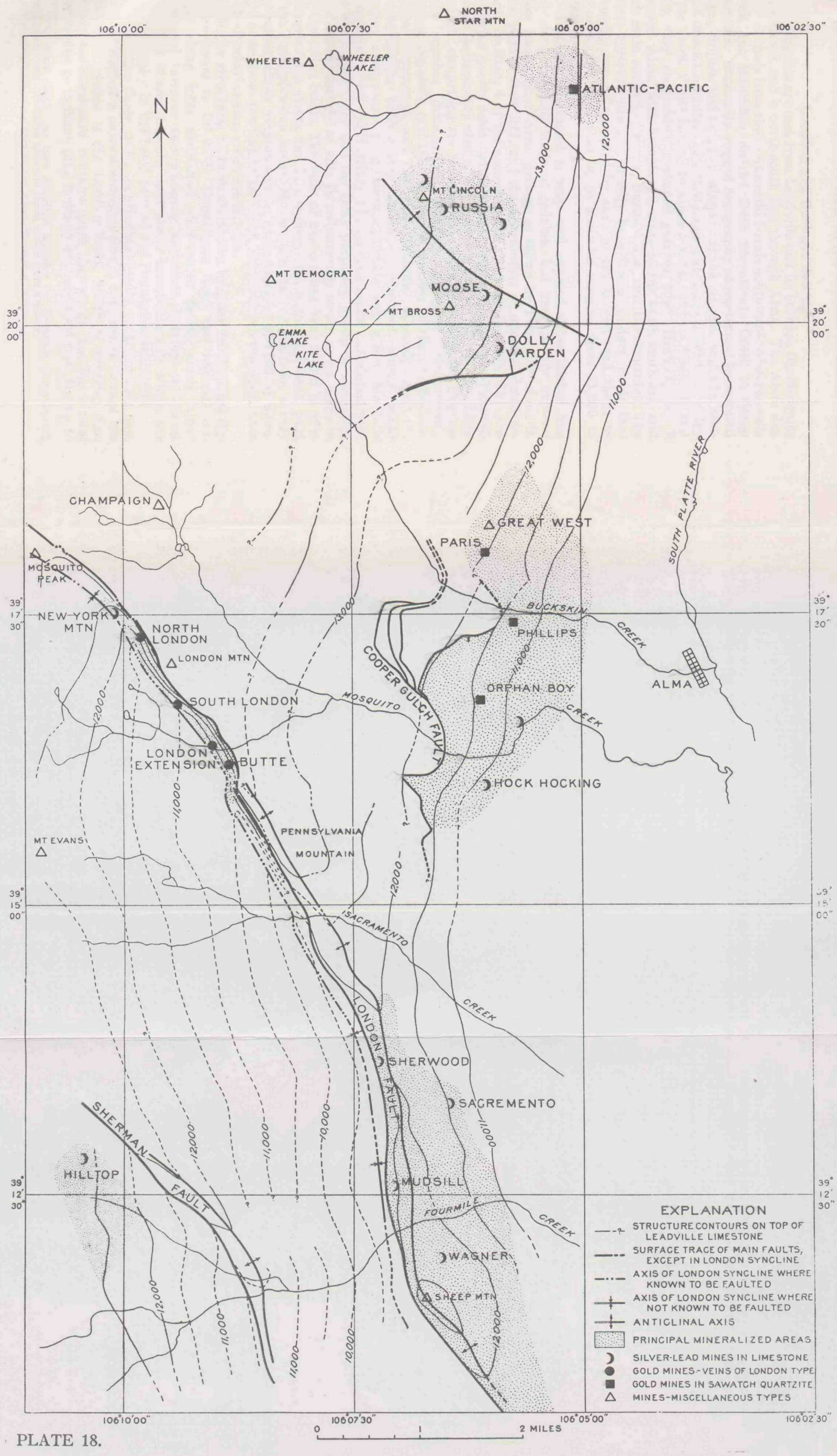

PLATE 18.

GENERALIZED STRUCTURE MAP OF AREA NEAR THE LONDON FAULT, SHOWING RELATION OF ORE DEPOSITS TO MAJOR STRUCTURE.

(From plate 3, U. S. Geol. Survey Bull. 911)

Location and Geologic Setting

The districts are east from Leadville and lie between the Mosquito Range crest and a north-south line through Alma. The Alma district* extends from the Continental Divide southward to Sacramento Creek, the Horseshoe district from Sacramento Creek to Sheep Mountain. Extremely rugged topography characterized by serrated ridges, cirques, and hanging valleys near the range crest grades eastward into a moderately smooth upland that slopes toward the valley of the South Platte River, the upland being cut by a few wide and deep, very steep-sided, U-shaped gulches. State Highway No. 9 connects Alma with Fairplay, 5 miles to the south-southeast, and with main roads to Denver, Buena Vista, and Breckenridge. The mines, however, are served only by a few secondary roads that normally can be travelled by auto or truck westward about as far as timber line; that is, to altitudes ranging from 11,000 to 12,000 feet.

Bedrock in general is very well exposed above timber line and along the cliff walls of gulches, but very poorly exposed below timber line. Areal geology is shown by Plate 1** of U. S. Geol. Survey Bull. 911, and the distribution of unconsolidated deposits by Plate 4 of the same bulletin. Bedrock includes: (1) pre-Cambrian gneiss, schist, granite, and pegmatite; (2) pre-Pennsylvanian sedimentary strata, aggregating 300 to 600 feet in thickness and comprising the Sawatch quartzite, including the Peerless shale member (Cambrian), Manitou limestone (Ordovician), Parting quartzite and Dyer dolomite member of the Chaffee formation (Devonian), and Leadville dolomite (Mississippian); (3) Pennsylvanian sedimentary strata—interbedded clastic rocks ranging from coarse conglomerate to shale, with a few thin beds of dolomite; and (4) Tertiary (?) igneous rocks, correlated with the White porphyry and the Gray porphyry group of Leadville, which occur mainly as sills in sedimentary strata or as dikes in pre-Cambrian rocks. The bulk of the ore has been found in pre-Pennsylvanian strata and in porphyry sills within the basal part of the Pennsylvanian series. Minor quantities of ore from a very few mines whose outputs have a gross value of $50,000 or more, have come from pre-Cambrian rocks. Rocks above the basal beds of the Pennsylvanian series are barren..

Major structural features are shown by plate 18. Regional dip of the strata is 10°-25°E. Departures from this regional dip occur along folds associated with major faults, along minor structural terraces and plunging anticlines, notably on Mount Bross and Mount Lincoln, and above laccolithic sills which are present locally in the basal part of the Pennsylvanian series.

There are three major longitudinal faults, each of which cuts the west limb of a narrow anticline that is overturned toward the west. The largest is the London fault, which is reverse, dips steeply northeastward, contains much clay gouge, and has a total throw (due to faulting plus folding) of some 3,000 feet. Owing to

*The Alma district as here described includes the Buckskin, Consolidated, Montgomery, and Mosquito districts listed under Park County.

**Geologic map in colors of the Alma-Horseshoe district.

an oblique angle between trend of the fault and regional strike of the strata, individual horizons rake southeastward along the fault. The Cooper Gulch fault is reverse, dips 30° eastward, contains very little gouge, and has a maximum throw of 450 feet at Mosquito Gulch. It passes beneath moraine south of Pennsylvania Mountain and splits into several branches that presumably die out north of Loveland Mountain. The Sherman fault may be reverse, but its dip remains unknown because exposures are wanting; its total throw ranges from 500 to 1,000 feet, with the east side relatively up.

Minor faults in the Mosquito Range are particularly profuse within a transverse belt, 2 to 4 miles wide, that extends from Leadville to North Star Mountain. On the eastern slope, within the Alma district, this belt coincides with a generalized pre-Cambrian contact between relatively brittle granite to the northwest and relatively plastic schist and gneiss to the southeast. Many minor faults occur within major longitudinal structural zones, where they form divergent, parallel, and transverse fissures auxiliary to a major fault. Many other minor faults, however, are outside major structural zones; the bulk of them strike northeast, have small displacements, and die out within short distances laterally and vertically, but the largest of them has a throw of 200 feet and extends at least a mile.

Occurrence of Ore

Six areas of principal mineralization (see pl. 18), in which most of the productive deposits occur, are localized in general by major structural features. Within each area individual ore bodies are localized along minor faults in certain favorable types of rocks; furthermore, lateral zoning of ore minerals within most of these areas delineates ground in which one or more types of ore may be expected.

The London mineralized area is localized along the footwall of the London fault where it crosses the transverse belt of profuse minor faults; the Loveland area along the uppermost branch of the Cooper Gulch fault on the southern border of the transverse belt; the Bross-Lincoln area along a plunging anticline where it is crossed by a structural terrace within the transverse belt; the North Star (Atlantic-Pacific) area within the transverse belt, but apart from longitudinal structures; and the Sacramento area at a local reversal of pitch along the anticline on the east side of the London fault, some 2 to 4 miles south of the transverse belt. The Hilltop area, by contrast, is not directly associated with any major structure, though it lies not far west of the Sherman fault and within the general line of a southeastward-trending group of major faults in Iowa Gulch, west of the range crest. Of the total gross output from the east side of the Mosquito Range, approximately 71 percent came from the London area, 17 percent from the Bross-Lincoln area, 4 percent from the Loveland area, 4 percent from the Hilltop area, 2 percent from the North Star area, 1 percent from the Sacramento area, and

1 percent from mines outside areas of principal mineralization, mostly within the transverse belt.

The ore deposits may be classified, in order of value of past output, as follows: (1) gold veins of the London type, (2) silver-lead bedded replacement bodies and replacement veins in dolomites, (3) gold veins and replacement veins in the Sawatch quartzite, and (4) miscellaneous types. The veins of the London mine occupy auxiliary fissures along the footwall zone of the London fault. Most of the ore occurs in veins that strike essentially parallel with the London fault but dip to the southwest, nearly parallel to strata upturned against the main fault, and that occur within a zone of porphyry sills 175-275 feet thick, very close to the base of the Pennsylvanian series. Some ore, however, occurs in veins that have other strikes and dips, and cut the upper beds of the Leadville dolomite as well as the thin layer of Pennsylvanian rocks below the sills. The London ore is composed of quartz with subordinate pyrite, sphalerite, galena, and chalcopyrite; the gold and silver contents, in weight, are nearly equal.

The silver-lead output has come from partly oxidized ores of the "cooler mesothermal"[1] facies, which actually includes several sub-facies deposited at slightly different temperatures. Gangue minerals include iron-bearing dolomite, barite, jasperoid, and quartz; hypogene sulfide minerals include galena and sphalerite, subordinate pyrite, and minor chalcopyrite, tetrahedrite, and freibergite. The bulk of the ore occurs in the upper part of the Leadville dolomite, but none of the pre-Pennsylvanian dolomites is wholly barren. Although some mines have yielded more than a million dollars' worth of ore, the deposits are small and scattered as compared with the larger "blankets" at Leadville.

Gold deposits in the Sawatch quartzite consist of oxidized ores classified as a variety of the "intermediate mesothermal" facies that formed in the presence of a much smaller quantity of ore-forming solutions than the London veins. Hypogene minerals include iron-bearing dolomite, pyrite, sphalerite, galena, chalcopyrite, and quartz. The ratio of gold to silver, by weight, may range from 1:1 to 1:10. It is doubtful whether any single mine yielded as much as half a million dollars' worth of ore. At several times and places, a massive sulfide vein lean in gold has been exploited for pyrite or for zinc and lead.

The miscellaneous types include gold and silver veins in pre-Cambrian rocks, as well as molybdenite, copper, lead and zinc, iron, manganese, and fluorite deposits of very minor economic value.

Outlook

The London veins apparently have been nearly mined out from the northern part of Pennsylvania Mountain to the northernmost limits of gold mineralization south of New York Moun-

[1]Loughlin, G. F., and Behre, C. H., Jr., Zoning of ore deposits in and adjoining the Leadville district, Colorado: Econ. Geol., vol. 29, no. 3, pp. 215-254, 1934.

tain. There remain the possibilities (1) that the vein system continues southeastward across the central and southern parts of Pennsylvania Mountain and (2) that gold deposits may exist in the Cambrian Sawatch quartzite, or even in pre-Cambrian rocks, beneath the productive zone at London Mountain. South of the London-Butte workings the London ore horizons continue, raking steeply southeastward, at depths of 1,000 to 2,800 feet below the surface, where they remain wholly unprospected. Although veins of the London-Butte mine are fewer and less continuous than farther north, no mineralogic evidence suggests that the southern limit of gold mineralization has yet been reached. The Sawatch quartzite, because it contains gold deposits elsewhere in the district, must be regarded as a possible ore-bearing formation that has been only slightly prospected at London Mountain; however, the structural interpretation that the London veins have been localized directly beneath an inverted V, formed by impermeable fault gouge on the east and impermeable Pennsylvanian shale above and on the west, rather discourages exploration in the Sawatch quartzite. Pre-Cambrian rocks at London Mountain ought not be seriously prospected unless considerable ore first is found in the Sawatch quartzite.

Gold veins and replacement bodies in the Sawatch quartzite occur in both the Loveland and the North Star areas. All deposits readily found along the outcrop of the formation have been essentially mined out, but small areas near abandoned mines may contain additional deposits concealed by strata above the Sawatch quartzite. No deposits larger than those already found are reasonably to be anticipated, and the amount of money warranted for prospecting is therefore rather small.

Numerous silver-lead deposits, particularly bedded replacement bodies in the upper part of the Leadville dolomite, have been mined out along the outcrops of pre-Pennsylvanian dolomites on Mount Bross and Mount Lincoln. Some of these deposits have been followed into the mountain for distances of several hundred feet. Beneath parts of the areas capped by Pennsylvanian strata and porphyries on both mountains (see pl. 1 of U. S. Geol. Survey Bull. 911), the Leadville dolomite remains unprospected, though it may contain ore bodies worth as much as a million dollars in gross value. A deposit typical of these areas has been described,[2] but the bulk of the mine workings are inaccessible.

The Hilltop mine, described by Behre,[3] supplied 1 to 1½ million dollars' worth of silver-lead ore, but all other mines in that mineralized area were very much smaller. Unprospected ground within the upper part of the Leadville dolomite, where it is concealed beneath younger rocks, between the Hilltop and Continental Chief mines and east of the Peerless Maud mine

[2]Singewald, Q. D., and Butler, B. S., Preliminary report on the geology of Mount Lincoln and the Russia mine, Park County, Colo.: Colorado Sci. Soc. Proc., vol. 12, pp. 389-406, 1931.

[3]Loughlin, G. F., and Behre, C. H., Jr., op. cit., pp. 236-237, 1934.

(see pl. 1, U. S. Geol. Survey Bull. 911) may contain additional deposits valued at a million dollars or less.

Small silver-lead deposits may be found in dolomites, particularly the upper part of the Leadville dolomite, concealed by Pennsylvanian strata and porphyries (1) east of the Loveland area, (2) east of the Sacramento area, and (3) adjacent to the hanging wall of the London fault with the Sacramento area (see pl. 1, U. S. Geol. Survey Bull. 911).

Prospecting either for individual deposits or for a new area of principal mineralization outside areas mentioned above is more likely to result in financial loss than gain. The most promising localities probably would be (1) between the London fault and the Mosquito Range crest, within the transverse belt of profuse minor faults northeast of Mount Evans, and (2) along the footwall zone of the London fault, opposite the Sacramento area; in both the favorable pre-Pennsylvanian rocks lie unprospected beneath a thick cover of unfavorable Pennsylvanian strata. Though deposits are likely to occur in each locality, the apparent impossibility of closely restricting prospecting at depths of 500 to 2,500 feet below the surface would make their discovery excessively costly. There is also a possibility, though decidedly no assurance, of finding deposits in concealed pre-Pennsylvania rocks somewhere along either (1) the Sherman fault, or (2) a zone of reverse dips that extends from Mosquito Creek north-northeastward on the west side of the South Platte River, but there are no clues for prospecting. Within the transverse belt between the London fault and North Star Mountain, however, all the favorable horizons are so well exposed, except under local areas of slide rock (see pl. 4,* U. S. Geol. Survey Bull. 911), that chances for noteworthy discoveries must be regarded as slight.

No major discovery of lead and zinc, copper, molybdenum, iron, manganese, or fluorite is reasonably to be anticipated, though small commercial deposits of one or more may yet be found.

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LODE DEPOSITS OF THE BEAVER-TARRYALL AREA, PARK COUNTY

By Quentin D. Singewald

The output of the Beaver-Tarryall area has been small, probably aggregating well under $100,000, and future chances of finding ore in the Beaver-Tarryall district are poor, despite the facts that an abundance of small, submarginal, gold-bearing veins occur in the area and that commercially important gold placers have been derived from them downstream.

*Map of the Alma-Horseshoe district showing glacial features in color.

The area is about 6 miles wide, extends from the Continental Divide southward nearly to South Park, adjoins the Alma district to the west, and is within Park County. The principal rock formations are: (1) a clastic sedimentary series, nearly 10,000 feet thick, of Pennsylvanian and Permian age, and (2) igneous sills, laccolithic sills, and stocks of early Tertiary (?) age. Mesozoic sedimentary rocks crop out only in the eastern part of the area; pre-Pennsylvanian rocks crop out in the Alma district. The areal geology is shown on plate 1 of U. S. Geological Survey Bull. 928-A.[1]

Regional dip is eastward. Two major longitudinal folds occur close to the eastern and western margins of the area, and a transverse shear belt crosses the north-central part. Within the transverse shear belt occur the small Montgomery Gulch stock and also the greatest aggregate thickness of sills. Surrounding the stock is a zone of intense contact metamorphism, which grades outward into unmetamorphosed rocks.

The principal area of mineralization coincides with the zone of contact metamorphism. The ore deposits in it include (1) veins and veinlets along fissures, (2) replacement bodies adjacent to fissures in thin, metamorphosed limestone beds that are sparsely intercalated in the clastic strata, and (3) countless veinlets in extensively fractured porphyry or other brittle rock. The deposits are small and scattered, because ore-forming solutions in the absence of master channels spread into innumerable small fissures. The temperature of these solutions, even at the close of effective deposition, was too high to permit deposition of sulfide minerals other than pyrite, except at two places.

The area is not favorable for prospecting, though small ore shoots perhaps could be located by following some of the stronger veins to their intersections with thin limestone beds. The thickest and most persistent limestone bed, at the base of the middle division of the Pennsylvanian and Permian sequence, is too far from the source of metallization along its outcrop and too deep for prospecting in most of the mineralized area. Subsurface prospecting for ore bodies in the Leadville dolomite or other pre-Pennsylvanian strata is not warranted because the formations may not be present beneath the known mineralized area, and even if present they would be at depths ranging from 3,000 to 12,000 feet; and furthermore, the temperature when mineralization took place, as revealed by minerals in deposits at the surface, was so high at that depth that no deposition of gold is likely to have taken place.

[1]Singewald, Q. D., Stratigraphy, structure, and mineralization in the Beaver-Tarryall area, Park County, Colo.: U. S. Geol. Survey Bull. 928-A, 1942.

LODE DEPOSITS OF THE UPPER BLUE RIVER AREA, SUMMIT COUNTY

By Quentin D. Singewald

Introduction—Summary.

Records of output are scarce and incomplete for the area, which includes the western and southern outskirts of the Breckenridge district and all terrain southward therefrom to the Continental Divide. The largest mines, namely the Brooks-Snider and Iron Mask at Shock Hill, the Warrior's Mark at the head of Indiana Gulch, the Ling and Vanderbilt of Monte Cristo Gulch (see pl. 19), and perhaps others are all credited in local mining circles with outputs greatly exceeding $100,000 in value, hence, the aggregate value of output may amount to one or two million dollars. Undiscovered deposits very probably lie concealed beneath unconsolidated materials or barren strata that overlie more favorable ore horizons, but the cost of prospecting for them may prove excessive as compared with value of ore reasonably to be anticipated.

A report setting forth detailed data and conclusions of U. S. Geological Survey field work during 1940-41 is being processed for publication, and a preliminary geologic map[1] of the area, with abstract of the report, will probably be available before the larger report. The reader is particularly referred to the map to supplement data given herewith.

General Setting

The area, which embraces the entire drainage basin of the Blue River and of Indiana Creek between Brekenridge and the Continental Divide, is partly surrounded by the Breckenridge, Kokomo, Climax, Alma, and Beaver-Tarryall districts. Great relief and rugged topography make access to much of the terrain difficult. Many mines west of the Blue River are perched on cliffs that can be ascended only by aerial tramway or by foot, whereas nearly all workings east of the Blue River could be made accessible by road building.

Unconsolidated deposits are widespread and, though locally rich in placer gold, they conceal whatever lode deposits exist beneath them and also conceal stratigraphic and structural features of the bedrock that might lead to discovery of ore bodies.

Five main groups of rocks, each divisible into two or more mappable units, constitute the bedrock: (1) pre-Cambrian gneiss, granite, and pegmatite; (2) pre-Pennsylvanian sedimentary rocks, 250-300 feet thick, divisible into the Sawatch quartzite including the Peerless shale member (Cambrian), Manitou dolomite (Ordovician), and the Parting quartzite and Dyer dolomite members of the Chaffee formation (Devonian), but not the Leadville dolomite (Mississippian); (3) Pennsylvanian and Permian clastic strata, with intercalated calcareous beds, which aggregate more than 9,000 feet in thickness southwest of the northwestward-

[1]Singewald, Q. D., Geologic map of the upper Blue River area, Summit County, Colorado: U. S. Geol. Survey Preliminary Map Series, in process of publication.

trending fault through Boreas Pass (see pl. 19) but less than 1,500 feet northeast of the fault; (4) Mesozoic sedimentary rocks, 1,000-1,500 feet thick, including the Entrada (?) sandstone (Jurassic), Morrison formation (Jurassic), Dakota quartzite (Cretaceous), and Benton shale (Upper Cretaceous); and (5) late Cretaceous or early Tertiary igneous rocks, called "porphyries", which occur abundantly as dikes in pre-Cambrian rocks and as sills, sill zones containing intercalated sedimentary layers, laccolithic sills, and irregular crosscutting bodies in all the sedimentary rocks. Generalized areal distribution of each main group except the "porphyries" is shown in plate 19 of this article and the distribution of each mappable unit is described in the forthcoming abstract to accompany the preliminary map.

Deformation during pre-Cambrian time produced longitudinal and transverse zones in which strikes and dips of foliation are highly variable, drag folds are numerous, and granite and pegmatite bodies are abundant. Some of these zones localized later structural features of economic significance. Laramide deformation which followed the Mesozoic era resulted in regional eastward tilting of all the sedimentary strata, three major longitudinal faults associated with major folds, a belt of prominent transverse and oblique faults that trends southwestward from Breckenridge toward Kokomo, and a host of minor faults. Igneous intrusion and subsequent ore deposition were closely associated with the Laramide orogeny.

Ore Occurrence

Ore deposits occur as simple and composite veins in pre-Cambrian rocks, fissure and replacement veins in the Sawatch quartzite, bedded replacement bodies and replacement veins in the Manitou dolomite and Dyer dolomite member of the Chaffee formation, the calcareous beds of the Pennsylvanian and Permian sequence, veins in sandy beds near the top of the Pennsylvanian and Permian sequence and in contact metamorphosed beds of the Morrison formation, innumerable, irregularly distributed stringers in the Dakota quartzite, and veins in "porphyries." Individual ore bodies are localized along minor faults.

In geographic distribution the ores are almost wholly restricted to two general areas. The western area includes all of North Star Mountain, a roughly triangular-shaped tract with apex in upper Sawmill Gulch to the north, and a prong that extends northeastward to the Fredonia mine. This area contains an inner core of gold deposits and an outer envelope of silver deposits. The gold-producing part has yielded commercial tungsten and iron and contains many molybdenum prospects. Minor quantities of lead, zinc, copper, and silver doubtless were extracted from a number of gold mines; during World War II, lead and zinc ore from the Monte Cristo mine, on the outer fringe of gold deposits, was shipped to the Golden Cycle mill in Colorado Springs. Most of the silver deposits contain considerable lead and many contain zinc. The zonal center lies near the inter-

PLATE 19.

Geology by Q. D. Singewald, R. E. Stoiber
R. E. Fellows, and J. M. Broughton.
1940-1941

PLATE 19.

GENERALIZED GEOLOGIC MAP OF THE UPPER BLUE RIVER AREA

SUMMIT COUNTY, COLORADO

section of the two belts, one longitudinal and the other transverse, of relatively intense pre-Cambrian deformation. The Hoosier Pass structure, which includes a major longitudinal fold and an inferred fault, crosses the eastern part of the area; it doubtless had some influence on the general distribution of ore, yet it cannot be regarded as the dominant controlling structure.

The eastern mineralized area embraces the western, southwestern, and southern outskirts of the Breckenridge district and a southward extension of it along the Boreas Pass fault. Most of the deposits have been worked for silver and lead or both, but gold was a noteworthy constituent of several and iron of one; though sphalerite was doubtless abundant in nearly all the ores prior to oxidation, few have contributed noteworthy amounts of zinc. Evidence of zoning is not conspicuous, but detailed mineralogic studies indicate slightly decreasing temperatures of deposition away from major longitudinal faults and also southward from Breckenridge.

At the head of Mayflower Gulch, west of the Tenmile Range crest, is a relatively small mineralized area localized in general proximity to the Mosquito fault. The eastern fringe of this area slightly overlaps the western fringe of the North Star Mountain area, thereby accounting for the subordinate gold content of ore at the Maximus mine.

Outlook

Within the western mineralized area new ore bodies exceeding a few hundred thousand dollars each in gross value cannot reasonably be anticipated; accordingly, the amount of money justified for prospecting is distinctly limited. Possible extensions of ore zones in certain of the mines will be discussed in the forthcoming report of the U. S. Geological Survey. Away from the known deposits, undiscovered ore bodies are most likely to be found in pre-Pennsylvanian strata, and also in the pre-Cambrian rocks below, immediately to the east of their outcrop belt (see pl. 19) between North Star Mountain and McCullough Gulch. There, the favorable horizons lie concealed at increasingly greater depth eastward beneath the barren lower division of Pennsylvanian and Permian strata and also, at most places, beneath a mantle of unconsolidated deposits. Somewhat less likely to contain undiscovered ore bodies are calcareous zones of the middle division of Pennsylvanian and Permian strata. One prominent zone, at the base of this division, includes the ore-bearing bed in the Governor and Bemrose mines; it is concealed by unconsolidated material at most places between the Bemrose mine and McCullough Gulch, but is almost continuously exposed by placer workings and road cuts between the Bemrose mine and Hoosier Pass. Another prominent zone, some 1,500 feet stratigraphically higher, includes the ore-bearing bed at the Fredonia mine; it is intermittently exposed for half a mile northward from the mine and very well exposed for two miles southward, but does not afford any indications of new ore bodies. Gold deposits and perhaps minor deposits of tungsten, iron, and molybdenum may be anticipated in the central part of the mineralized areas, and silver-lead-zinc deposits in the outer part.

Although chances of finding ore within the eastern mineralized area are difficult to evaluate, the likelihood of discovering new ore bodies much larger than in the western area does not seem particularly good. The most promising ground, empirically, is in the immediate vicinity of mines that have had relatively large outputs. Concealed ore in Dakota quartzite may possibly exist beneath alluvium east of Shock Hill, beneath alluvium and Benton shale north of Shock Hill, and beneath moraine both to the north and to the south of the Germania mine. South-southeast of Breckenridge, close to the Boreas Pass fault, ore bodies may lie concealed beneath unconsolidated materials that cover most of the terrain for a distance of three-quarters of a mile northward from the Twin Sisters mine and also at a few other places. Within a mile north of Breckenridge, unconsolidated materials likewise may conceal at least small deposits. Undiscovered deposits near the Germania and possibly near the Sultana mine (a mile north of Breckenridge) may contain noteworthy quantities of gold, but elsewhere in the eastern area silver-lead-zinc deposits are to be anticipated.

PLACERS OF NORTHWESTERN PARK COUNTY

By Quentin D. Singewald

Introduction—Summary

Placers of northwestern Park County have supplied nearly 6½ million dollars in gold, of which approximately 60 percent came from the South Platte valley, 30 percent from Tarryall Creek and its tributaries, and most of the remainder from Beaver Creek. Future possibilities are good, particularly in the South Platte and Tarryall valleys downstream from the points at which they issue from the mountains into the northern part of South Park.

A comprehensive report on the placer deposits is now being processed for publication. Meanwhile, the reader may refer to placer data already given in two publications dealing primarily with lode deposits. Reproduced herewith, as plate 20, is a previously published map that adequately illustrates the geologic distribution of the gold, though it does not include all the productive terrain.

General Setting

The area embraces (1) a mountain province, including the northerly-trending Mosquito Range and the northeasterly-trending Continental Divide, and (2) the mountain park province of South Park. In the mountain province, erosion during a long pre-glacial period established the general drainage pattern, after which ice action greatly modified the valley form

Singewald, Q. D., and Butler, B. S., Suggestions for prospecting in the Alma district, Colo.: Colorado Sci. Soc. Proc. vol. 13, no. 4, pp. 116-117, 1933.
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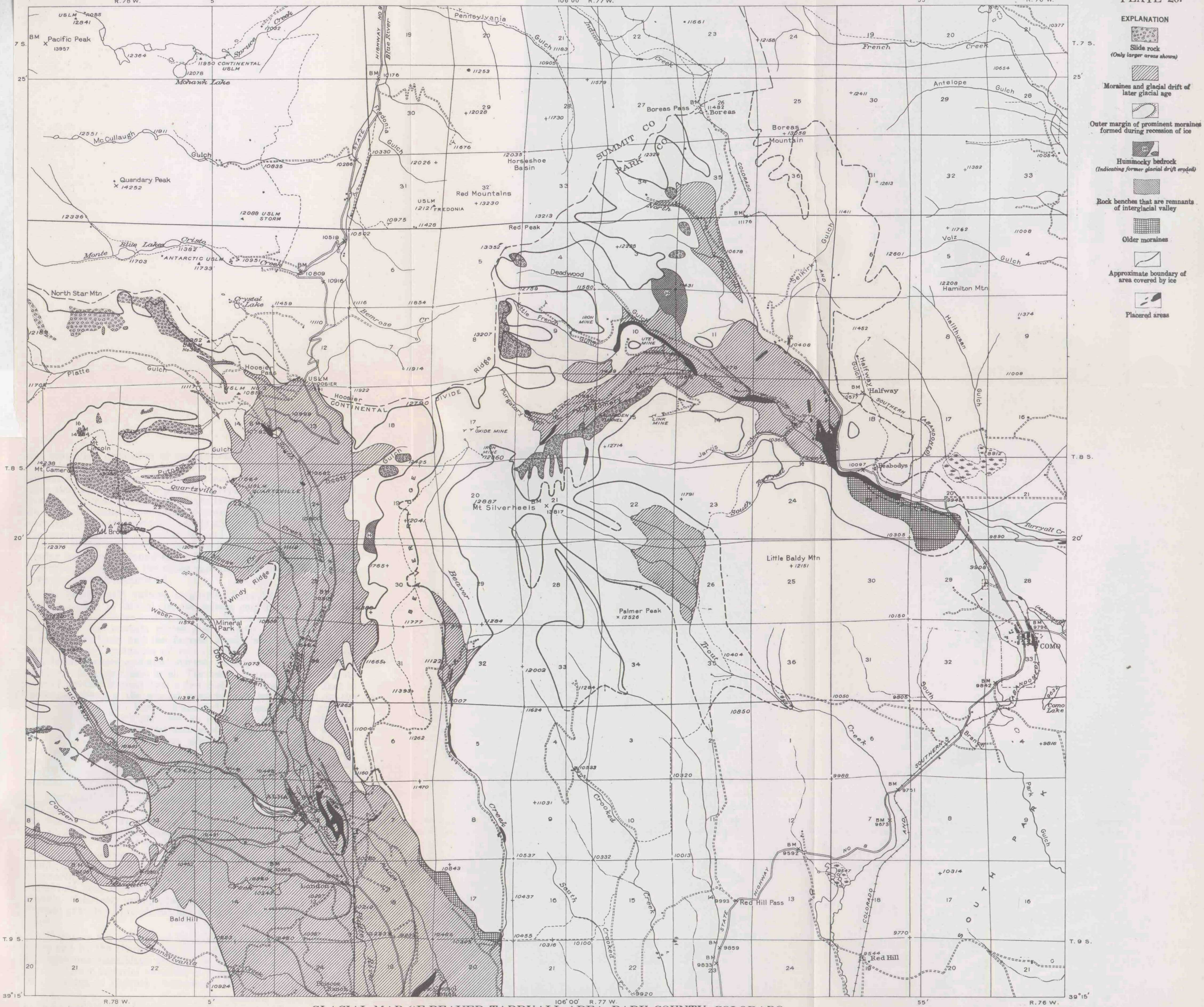

From Bulletin 928 Plate 4,
United States Department of the Interior,
Geological Survey

GLACIAL MAP OF BEAVER-TARRYALL AREA, PARK COUNTY, COLORADO

Scale $\frac{1}{31,680}$

1 0 3 Miles

1941

and controlled deposition of unconsolidated material. As shown by Capps,* there were at least two stages of Pleistocene glaciation, separated by a very long interglacial stage. Moraines deposited by early glaciers have been swept away except above the sides of, and downstream from the margins of the latest—those of the Wisconsin stage; in contrast, moraines deposited by the Wisconsin glaciers remain almost uneroded, except along narrow stream gorges. The maximum limits of former ice and the areas now covered by moraine in the area under consideration are shown by plate 20; similar features are found along the South Platte valley south of this area, except that the older moraines are not differentiated from the younger moraines.†

In South Park, valleys in general have become broad and shallow owing to lateral erosion across soft bedrock upstream from barriers of more resistant rocks. There are two main drainage basins that contain placer gold, namely the South Platte-Beaver Creek basin and the Tarryall-Park Creek basin. Each retains uneroded remnants of two extensive, pre-glacial terraces that formed where ancestral streams issuing from the mountains attained temporary base level. The terraces are covered by a veneer of gravel ranging from a few feet to several tens of feet in thickness. During the glacial period, each ice advance in the mountains doubtless was accompanied by deposition of outwash aprons in South Park and each ice retreat by stream erosion, but only the results of the last two glacial stages now are visible. Deposits of pre-Wisconsin age occur locally as narrow and low benches. Deposits of the Wisconsin stage, on the contrary, form the present valley floors, which are trenched only slightly by shallow stream channels; these deposits are outwash gravels that grade downstream into more typical stream gravels.

The most productive placer deposits are outwash gravels that extend downstream from the lowermost Wisconsin moraines in the South Platte, Tarryall, and Beaver valleys. (See fig. 1 and also pl. 5 of U. S. Geol. Survey Bull. 911.) Next in productivity are the outer parts of the moraines themselves. Decidedly subordinate, yet noteworthy in productivity, are prominent temporary stands or readvances during the general ice retreat. Likewise noteworthy are pre-W'sconsin outwash gravels and materials containing gold derived by erosion and redeposition of terrace gravels. Relatively unimportant are lateral and ground moraines. Terrace gravels of pre-glacial age are everywhere of submarginal value.

Moraines are recognized by their characteristic hummocky forms and by the character of their materials, which consist of a heterogeneous assemblage of more or less angular boulders, cobbles, and finer material unsorted as to size. The bulk of the gold lies adjacent to bedrock; commonly, there are two other pay

*Capps, S. R. Pleistocene geology of the Leadville quadrangle, Colo.: U. S. Geol. Survey Bull. 386, pp. 8-25, 80-89, and pl. 1, 1909.

†Singewald, Q. D., and Butler, B. S., Ore deposits in the vicinity of the London fault of Colorado: U. S. Geol. Survey Bull. 911, pl. 5, 1941.

streaks, each about a foot thick, above bedrock, but they are leaner and much more lenticular than the one on bedrock. Pre-Wisconsin moraines have not been worked, presumably because their favorable terminal lobes have either been completely eroded or else partly eroded and covered by later outwash.

Outwash aprons are composed of the same materials as the moraines immediately upstream. Their boulders are slightly flatter and rounder, however, and extremely large sizes are absent. They exhibit no stratification and surprisingly little obvious evidence of sorting, though they commonly are shingled. There is a gradual diminution in size of boulders and in content of gold, away from the moraine. The gold is not uniformly distributed over bedrock, but occurs in definite channels, commonly associted with channels in the bedrock surface, that must be located by prospecting.

Outlook

In 1939 the wide valley floor of the South Platte River below the lowermost moraine (see pl. 5 of U. S. Geol. Survey Bull. 911) remained unprospected except in the immediate vicinity of Fairplay. The surface materials of this floor consist of glacial outwash gravels that change very gradually downstream into typical stream gravels. Underlying the surface gravels there may be older gravels that were not entirely eroded prior to the advance of the Wisconsin glacier. Workings collectively known as the Fairplay placer extended continuously from Sacramento Creek to a point 2 miles southeast of Fairplay. Although much of the gold in these placers came from morainal material, a great deal more came from outwash gravels beyond. Within the outwash gravels, dredging followed the present stream channel except at the southeast end, where it made a V-turn and extended a third of a mile across the southwest bank. Dredging operations were terminated, according to local reports, partly because of controversy with ranchers regarding water pollution and partly because of decrease in gold content of the gravel. Thus, there remained an outwash plain 0.5-1.0 miles wide immediately to the southwest of the dredge cut, and an even wider valley below in which one or more channels of pay gold might be found. Subsequent to 1939, all this ground has been prospected and partly exploited. In addition, a bench of slightly eroded outwash gravel covering an area of about a square mile, located 2 miles east of Fairplay and on the northeast side of the river, merits prospecting.

In the South Platte valley above the Fairplay placer there are numerous workings within moraine, as shown by plate 20. The largest are at Alma and at the McConnell ranch. The Alma placer lies within a secondary terminal moraine of the Wisconsin glacier, and the McConnell (Snowstorm) placer in prominent ice-border channels just outside an earlier secondary terminal moraine. There seems little doubt that additional placer ground will be developed within moraine between Alma and Fairplay, but in aggregate this ground will supply much less gold than the area below Fairplay. The most favorable localities are (1) along the outer fringes of and immediately below moraines formed by minor ice stands, and (2) along ice-border channels, as will be discussed in detail in the forthcoming placer report.

In Tarryall valley, the bulk of the output has come from the adjoining Fortune and Peabody placers, located 2.5-5.0 miles northwest of Como. These workings, as is apparent from plate 20, are partly in Wisconsin moraines and partly in outwash gravel beyond. Almost immediately east of them Tarryall valley abruptly opens, becoming more than 2 miles wide; still farther downstream (3 miles east of the border of pl. 20) it again narrows. Surface materials at different places include (1) stream alluvium that presumably forms a thin veneer over outwash gravel, (2) outwash gravel of Wisconsin age, and (3) outwash gravel of pre-Wisconsin age. All three are likely to contain gold placer channels, yet the only workings in the entire area are those of the Cline Bench placer, which is in a local area of pre-Wisconsin outwash extending eastward from a point 1.2 miles north-northeast of Como. Thus, as in the South Platte valley, a large area of promising ground downstream from the lowermost glacial moraine remains unexploited. The gold content of outwash gravel, of course, may be expected to diminish gradually away from the mountains; however, there remains a further, more speculative possibility that gold may have accumulated in commercial quantities along Tarryall Creek, to distances of as much as 5 miles eastward from Como, by the reconcentration of material eroded from pre-glacial terraces.

Upstream from the Fortune placer are several workings, shown in plate 20, in moraine. The most productive are closely associated with secondary terminal moraines. Additional localities doubtless may be found, but in aggregate are likely to supply even less gold than new localities within moraine of the South Platte valley.

The Wilson placer, located 6 miles east-southeast of Como, is along Park Gulch just above its confluence with Tarryall Creek and upstream from a range of granite hills that acted as an erosion barrier. The gold has been reconcentrated from eroded preglacial terraces. Further productivity is limited to possible extensions upstream.

Along Beaver Creek the only noteworthy placer is in glacial outwash directly north of Fairplay. The gold was carried by ice of the South Platte glacier, which spilled across the divide and down the western slope of Beaver Creek valley. Promising unprospected ground is restricted to (1) a small triangular area of outwash gravel above the confluence of Beaver Creek with the South Platte River and (2) the moraine itself.

A small alluvial placer on Pennsylvania Mountain, well above the margin of the Wisconsin glacier that occupied Mosquito Creek, may be noted as being unlike any other placer of the region. Its possible reserves are far less than in areas discussed above.

LEADVILLE MINING DISTRICT, LAKE COUNTY*

By G. F. Loughlin† and C. H. Behre, Jr.

Introduction and Selected Bibliography

The information here presented is condensed from Professional Paper 148 of the U. S. Geological Survey, published in 1927, and from more recent papers published in the Proceedings of the Colorado Scientific Society and in other scientific journals. Readers interested in a more complete account of the Leadville district are referred to the publications listed below in the order of publication.

Emmons, S. F., Geology and mining industry of Leadville, Colo. (with Atlas): U. S. Geol. Survey Mon. 12, 1886.

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*Largely quoted with up-to-date changes from a chapter by the same authors in Guidebook 19 ("Colorado"), XVI International Geological Congress, 1932.

†Deceased, Oct. 22, 1946.

Behre, C. H., Jr., Preliminary geological report on the west slope of the Mosquito Range in the vicinity of Leadville, Colo.: Colo. Sci. Soc. Proc. vol. 14, pp. 49-79, 1939. (Explanatory text to accompany the map listed above, together with suggestions for prospecting in the outlying areas around Leadville.)

Chapman, E. P., Newly recognized features of mineral paragenesis at Leadville, Colo.: Am. Inst. Min. and Met. Eng., Tech. Pub. 1105, 12 pp., 1939.

Hedges, J. H., Possibilities of manganese production at Leadville, Colo.: U. S. Bur. of Mines Inf. Circular 7125, 23 pp., 1940.

General Setting

The Leadville mining district, one of the most productive in Colorado and ranking sixth in the United States through 1940, lies on the west slope of the Mosquito Range, in Lake County. The city of Leadville, at an altitude of 10,150 feet, lies in the western part of the district and is the site of the Arkansas Valley smelter, where most of the sulfide ores have been treated. It is also the site of gravity-separation, floatation, and sink-float mills, in which large quantities of low-grade ore from mines and dumps have been concentrated, especially in recent years. The mines of the district are at altitudes ranging from 10,100 to 12,000 feet, and a few in the outlying areas near the crest of the range are at altitudes of as much as 13,000 feet; the summits of the highest peaks exceed 14,000 feet. The western slope of the range, especially in the mining district, consists of a number of spurs, each of which has been cut into a series of steps; adjacent steps are separated by short gulches or shallow depressions along faults of moderate displacement. (See pl. 21.)

The Leadville district is by far the largest of a number of districts located in Lake County. Of these the Mosquito or Mosquito Range district occupies the highest slopes east of the Leadville district; the Alicante, Birdseye, Buckeye, Chalk Ranch, English Gulch, and French Gulch districts lie to the northeast; and the Empire Gulch, Thompson Gulch, Union Gulch and Weston Pass districts lie to the south. Geologically, they may be regarded as outlying areas of the Leadville district; the same is true of the Hill Top and Peerless mines, which lie just east of the crest of the range, in Park County. Several small districts in Lake County, such as the Tennessee Pass, Sugarloaf, and Twin Lakes districts, lie on the eastern slope of the Sawatch range, across the Arkansas Valley, northwest, west, and southwest of Leadville. These minor districts have been intermittently productive on a small scale, but their combined output is small compared with that of the Leadville district.

According to the annual volumes of Mineral Resources of the United States and the Minerals Yearbook, the total value of gold, silver, copper, lead, and zinc produced from mine and placers in the Leadville district from the earliest placer operations in 1859 to the end of 1944 amounted to $462,597,906. This value represents

2,811,095 ounces of gold (including 344,258 ounces from placers), 236,609,972 ounces of silver, 51,437 tons of copper, 1,033,454 tons of lead, and 714,038 tons of zinc. The total quantity of ore mined, including reworked dumps, amounted to 21,245,883 tons.

Besides these metals the district has at times contributed pyrite for the manufacture of sulfuric acid, small quantities of bismuth, iron ore for fluxing, and a rather steady output of manganese-iron for use in the manufacture of steel and in fluxing. Up to 1939, inclusive, the quantity of metallurgical manganese-iron ore shipped to steel mills amounted to 936,024 tons and the quantity of fluxing ore, much of it of metallurgical grade, amounted to 2,576,514 tons.[1] The value of these minor products may have totalled about $15,000,000.

Glacial Deposits and Terraces

Much of the bedrock of the Leadville district, particularly in its western part where the topography slopes off toward the valley of the Arkansas River and its tributaries, is concealed beneath deposits of glacial origins. The district has been affected by as many as three stages of glaciation. The crest of the range is flanked by cirques and the larger U-shaped valleys (Iowa Gulch, Evans Gulch, and the East Fork of the Arkansas) are bordered by lateral moraines that coalesce into terminal moraines. Only moraines of the last glacial stage are well preserved in the vicinity of Leadville; those of the earlier stages have been largely removed or concealed beneath deposits of the last glacial stage or the interglacial stage that preceded it.

The western base of the range is largely bordered by extensive alluvial aprons, formed partly during the earlier glacial stages, partly before those times. These aprons slope gradually westward to the valley of the Arkansas River. Along the lower courses of the larger gulches they have been removed by stream and late glacial erosion, and their remaining parts form the high terraces of the region. The city of Leadville is situated on one of these high terraces. Similar but lower terraces below Leadville represent chiefly the outwash of the last glacial stage.

The high-terrace gravels overlie an obscure formation of fine sand, clay, and marl, called "lake beds." These beds are not naturally exposed within the district, but they do crop out here and there south and southwest of the district, notably at the mouth of Union (Weston) Gulch, and they have been cut by several shafts in the immediate vicinity of Leadville. They may have been formed in a lake, or they may represent fine stream alluvium deposited in late Pliocene or early Pleistocene time. They have been elevated to their present position above the Arkansas Valley by a continuation of the intermittent faulting that was most pronounced in Miocene time.

[1]Hedges, J. H., Possibilities of manganese production at Leadville, Colo.: U. S. Bur. of Mines, Inf. Circular 7125, p. 4, 1940.

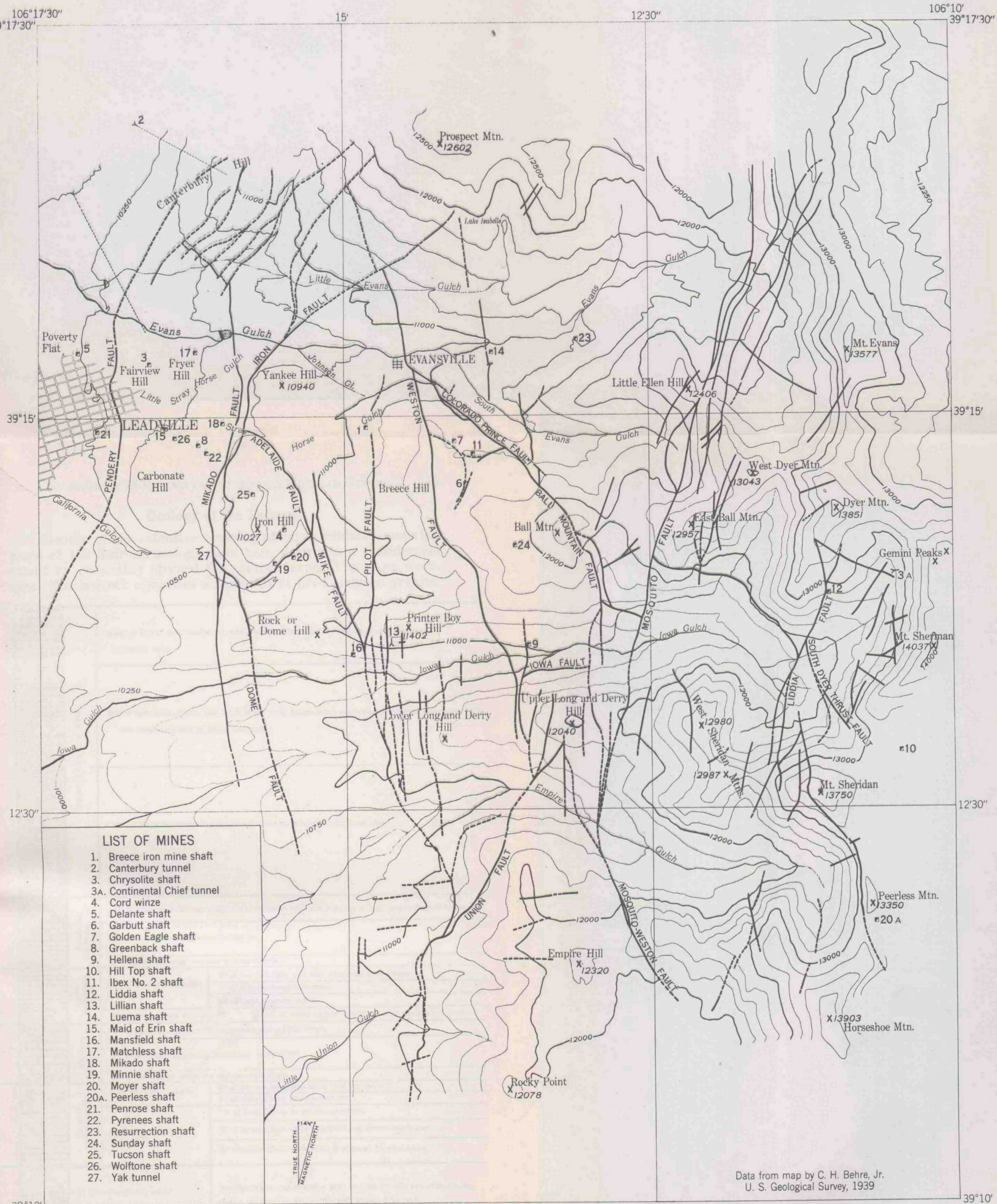


PLATE 21. MAP OF THE WEST SLOPE OF MOSQUITO RANGE, IN THE VICINITY OF LEADVILLE, COLORADO

SHOWING TOPOGRAPHY AND PRINCIPAL FAULTS AND MINES

1 0.5 0 1 MILE

1000 0 1000 3000 5000 7000 9000 FEET

Contour interval 250 feet

(Datum is mean sea level)

Geology of the Bedrock

Because of the extensive covering of unconsolidated material, maps of the bedrock geology have been drawn to a considerable extent by projecting upward the contacts exposed in mine workings. The bedrock comprises a basement of pre-Cambrian granite,

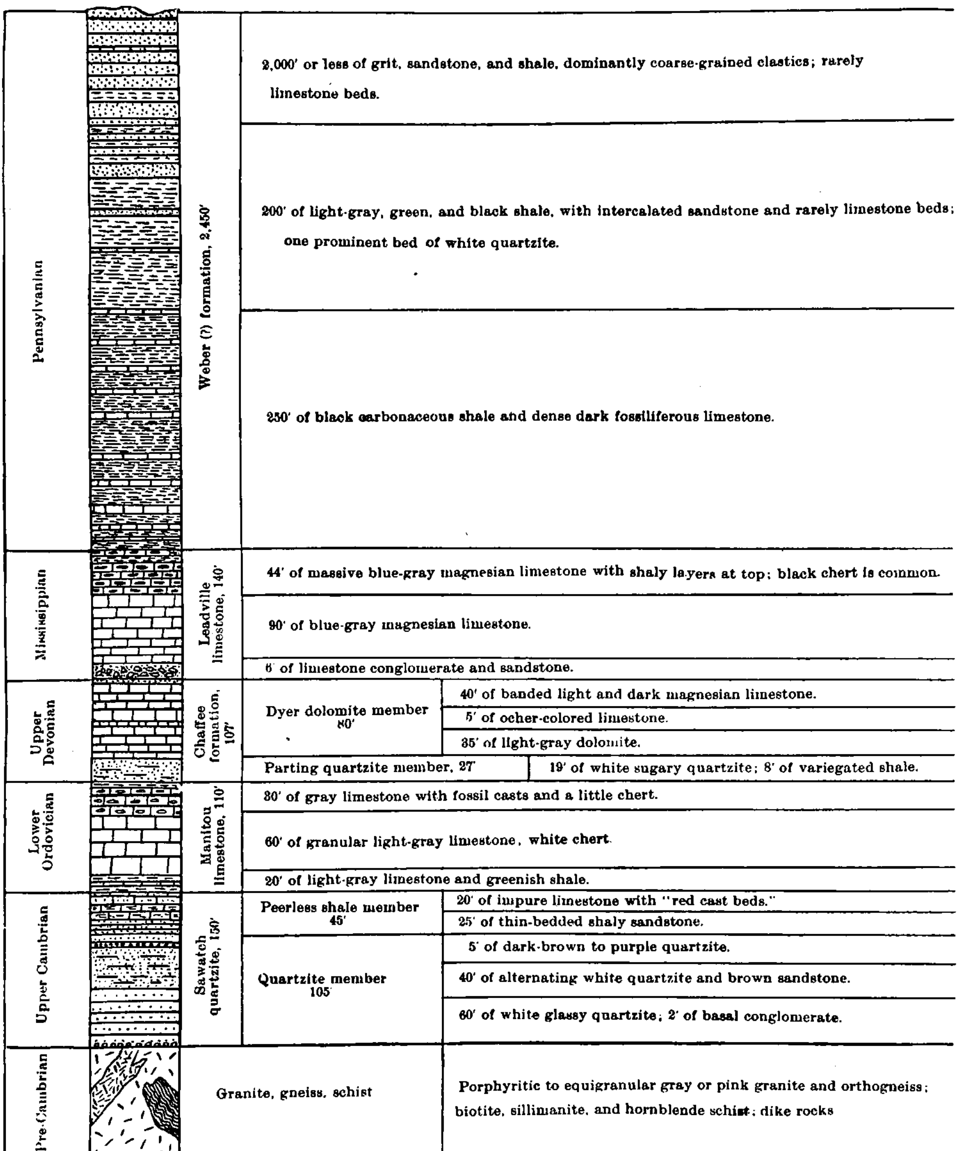


Figure 4. Columnar stratigraphic section of west slope of Mosquito Range near Leadville, Colo. (Reprinted from Econ. Geology, vol. 29, p. 219, 1934.)

schist, and gneiss, and sedimentary formations of Ordovician, Devonian, Mississippian and Pennsylvanian age; also many sills and dikes and a few stocks of porphyry, and a few pipe-like bodies of volcanic breccia. The sedimentary formations and their average thicknesses are shown in tabular form in figure 4.

Pre-Cambrian basement.—The pre-Cambrian complex of granite, gneiss, and schist is well exposed over much of the surrounding territory, but very little of it crops out within the Leadville district; however, it is cut by many of the mine workings. By far the greater part of the pre-Cambrian rock exposed in and near the mines is medium-grained granite, pink where fresh but grayish where weathered or otherwise altered. It is characterized by prominent feldspar crystals in roughly parallel arrangement. This variety of granite is probably to be correlated with the Silver Plume granite or the Colorado Front Range. The Pikes Peak granite, more coarsely granular, more micaceous, and of a darker pink color, occupies much of the upper western slope of the Mosquito Range.

Paleozoic sedimentary rocks.—The Sawatch quartzite of Upper Cambrian age includes a thick lower quartzite and a thinner upper shaly member. It rests upon a smooth pre-Cambrian surface. The quartzite contains a few beds that have a matrix of sericite or calcite, and these beds are impregnated at several places with sulfides, principally pyrite; but the only ore mined in much quantity from the quartzite in the Leadville district was in veins that cut across the bedding. The upper member of the Sawatch, called the Peerless shale member, consists mainly of alternating thin layers of shale and light-gray to white magnesian limestone. Originally designated the "transition shales," it is still so called by the miners, because it suggests a graduation from the quartzite below into the Manitou dolomite or "White limestone" above. Where mineralization has been intense the limestone in the shale has been replaced by low-grade ore.

The Manitou dolomite, or "White limestone," differs from the Peerless shale member of the Sawatch quartzite in consisting mainly of beds of light-gray to white dolomite or dolomitic limestone separated by thin partings of shale. Thin layers, streaks, and small nodules of light gray to white chert are conspicuous in certain beds. Because of the abundance of its shale partings, the Manitou dolomite is less subject to persistent fissuring than the Devonian and Mississippian dolomites, which constitute the overlying "Blue limestone," and it has accordingly been thoroughly permeated and replaced by large ore bodies only in the vicinity of the main channels along which ore-forming solutions were introduced. Such replacement deposits are conspicuous under impervious covers, notably sills of porphyry and the shaly beds at the base of the overlying formation in the Breece Hill, Iron Hill, Carbonate Hill, and Downtown areas; none of commercial interest have been found in the outlying districts.

The Chaffee formation comprises the Parting quartzite and the Dyer dolomite members. The Parting quartzite member is prevailingly a coarse, uneven-grained rock with local shaly beds, especially at the base. It was deposited on an erosion surface of the Manitou dolomite. It has been replaced by ore at a few places along channels of intense ore deposition.

The Dyer dolomite, or upper member of the Chaffee formation, was formerly regarded as the lower part of the "Blue Limestone" or the Leadville dolomite, but it is now known to be the equivalent of limestone or dolomite of Devonian age in neighboring areas, whereas the upper part of the "Blue limestone" is of Mississippian age. It is generally distinguished on weathered surfaces by its gray, buff, or fawn color, which is in strong contrast to the dark bluish outcrops of the Leadville dolomite. Its beds are mostly 2 to 4 feet thick. Its susceptibility to replacement by ore is less than that of the Leadville dolomite, but mainly for structural rather than lithologic reasons; its thin, somewhat shaly beds are not subject to the continuous, regular fractures that characterize the higher formation and there furnish access to mineralizing solutions.

Although the upper part of the "Blue limestone" has been commonly called the Leadville limestone (as now restricted) in stratigraphic descriptions, it is more correctly called a dolomite in the Leadville district; in fact, the Leadville is a more nearly pure dolomite than either the Manitou or the Dyer. The Leadville has a basal member, about 8 feet in maximum thickness, composed of sandstone and a limestone breccia of sedimentary origin. The sandstone may form one thick bed or several thin beds. Locally it is absent and the base of the formation is marked only by limestone breccia. The dark-blue rock above this basal member is nearly pure dolomite. The uppermost 30 feet of the Leadville dolomite is coarse-grained and contains prominent nodules, streaks, and lenses of black chert weathering yellow or brown and local layers of gray to black shale. The Leadville dolomite has been far more extensively replaced by ore than any of the other formations, not only along the channels of most intense mineralization but also and especially along persistent zones of closely spaced fractures that extend across those channels—notably in the Iron Hill, Carbonate Hill, Fryer Hill, and Downtown areas. In the outlying areas the only productive replacement deposits of noteworthy size have been found in the uppermost part of the Leadville dolomite. One most effective factor to account for this general localization of large replacement bodies is the thick impervious cover of White porphyry or the thinner yet similarly acting layers of "Weber shale" at the top of the Leadville dolomite. Because of their much greater thickness and continuity, these overlying rocks have been far more effective barriers to ascending solutions than any of the shaly beds or porphyry sills in lower stratigraphic positions.

The Weber (?) formation, though extensive in the eastern part of the district and the outlying areas, has been largely eroded in the western, most productive part. There thick sills of White porphyry and the Gray porphyry group, which originally intervened between the Leadville dolomite and the Weber (?) formation, form by far the greatest part of the bedrock surface. The lower member of the Weber (?) formation consists of black shale with some beds of impure coal and a few lenses of magnesian limestone. The upper member consists of gray, medium-to-coarse-grained micaceous feldspathic sandstone ("grit") and white micaceous quartzite. Ore in the "Weber grits," as in other siliceous rocks of the district, is mainly confined to veins that cut across the bedding, but exceptionally replacement bodies of ore spread several feet outward from the veins.

Intrusive igneous rocks.—The sedimentary rocks were invaded during the Laramide revolution (late Cretaceous to early Tertiary) by porphyry of two distinct kinds. The earlier was at first called White porphyry by Emmons. Originally all white porphyry was lumped together, but recent work by Behre in the outlying areas has disclosed similar rock intruded in the form of dikes late in the igneous history of the region. Similar dikes have been mapped by Q. D. Singewald in the Alma district, 6 miles northeast of Leadville. The two light-colored porphyries, though similar in appearance, are therefore distinguished by restricting the formal name White porphyry to the earlier porphyry and referring to the later porphyry by the informal designation later White porphyry. The intrusions of these two porphyries were separated by several intrusions of rocks collectively known as the Gray porphyry group, because their colors are generally darker than those of either of the white porphyries. The porphyries of the Gray porphyry group are, however, divisible into different varieties. Still later than most of the intrusions of the later white porphyry dikes, and also later than ore deposition, explosive eruptions occurred at a few places in the eastern part of the district and in the outlying areas, forming plugs or funnel-shaped bodies and dykes of rhyolite agglomerates. The distinctive features of the different rocks are obscured by alteration, particularly in the Breece Hill area where the different porphyries and the Weber (?) formation as well are bleached.

The White porphyry is equivalent to a muscovite granite in composition. In the Leadville district it forms an immense sill or intrusive sheet between the Weber (?) formation and the Leadville dolomite, though in some places a few feet of the basal black shale of the Weber (?) formation underlie the sill. Several thinner and less extensive sills of the White porphyry occur in lower stratigraphic positions.

The Gray porphyry group includes four recognized varieties which differ mainly in texture and in the presence or absence of distinctive large crystals (phenocrysts), particularly of feldspar. All the varieties are essentially quartz monzonites. The most striking variety, called the Lincoln porphyry from its prominence at Mt. Lincoln on the eastern slope of the Mosquito Range, contains pink crystals of orthoclase (potash feldspar) as much as 2 inches long, and smaller, double-ended pyramids of quartz. The variety most closely associated in time with the period of ore deposition is called the Johnson Gulch porphyry, after Johnson Gulch on the lower northwest slope of Breece Hill. It is characterized by an abundance of light-gray to white crystals of plagioclase (soda-lime feldspar) one-eighth to one-half of an inch long and by a few widely and irregular spaced large crystals of orthoclase like those in the Lincoln porphyry. Gray, glossy crystals of quartz and remnants of altered flakes of black mica are also characteristic on close inspection.

The varieties of the Gray porphyry group were intruded at different times, but as regards their structural relations to ore bodies they may be considered as one group. They form a number of sills, some of which are very irregular. Outcrops of these sills are best seen in the Evans Amphitheater, northeast of Leadville, where the thickest is 650 feet and approaches a laccolith (mushroom-shaped body) in form. The most extensive of these sills overlies the sill of White porphyry that tops the Leadville dolomite; it forms the bedrock surface on Breece Hill and in the vicinity of Evans and Little Evans Gulches. Other sills are found, particularly in mine workings, in the Leadville, Chaffee, Manitou, and Sawatch formations; one of them, in the Rock Hill area, lies between the White porphyry sill and the Leadville dolomite. They decrease in number westward, and only one, in the Leadville dolomite, extends into the Downtown area beneath the city of Leadville. They increase in thickness and complexity in the southern parts of Iron Hill and Breece Hill and are accompanied by dike-like offshoots of considerable size.

Dikes and stocks of the Gray porphyry group are not uncommon. In particular, two stocklike bodies similar to the Johnson Gulch porphyry are exposed—one in the Yak tunnel beneath Breece Hill, and the other in Iowa Gulch southeast of Rock Hill. East of the stock in Iowa Gulch and south of the Breece Hill stock, both sedimentary rocks and porphyry sills are cut by a number of dikes, also similar to the Johnson Gulch porphyry. Some of the fissures occupied by the dikes were later mineralized, but few if any ore bodies of noteworthy size have been mined along them.

The bodies of rhyolite agglomerate are not well exposed at the surface within the Leadville district, but a similar rock may be seen about 10 miles northeast of Leadville, on the highway to Climax. Within the district five irregular but roughly funnel-shaped pipes of agglomerate have been partly outlined by mine workings; in places they cut off ore bodies. These bodies occur at the northwest base of Breece Hill and in the floors of upper Evans and South Evans Gulches. Several small dikes of rhyolite, similar in appearance to the later White porphyry, also seem to belong to the same period of igneous activity. Two of the agglomerate pipes have tapering ends extending for some distance along faults that were either reopened or newly formed subsequent to ore deposition. Besides the irregular bodies, one of dikelike form and northeasterly trend has been mapped near the head of California Gulch, and other bodies, too small to be mapped separately, have been found in certain mines—for example the Hellena mine, in Iowa Gulch, where agglomerate occupies the same fault fissure as the Hellena vein.

Structure.—The intrusion of the irregular sills and dikes of the Gray porphyry group greatly disturbed the sedimentary rocks, particularly the Leadville dolomite. Blocks of limestone were thrust aside here and there, with abundant local fracturing, and some large slabs were enclosed in the thick sill of White porphyry. This disturbance marked the earliest and most obscure of four periods of faulting. The three subsequent periods included reverse faulting, minor premineral normal faulting, and major postmineral faulting. Some faults were subjected to movement during more than one period and have been designated composite faults. The larger faults are shown on plate 22.

After the intrusion of sills of the Gray porphyry group, the region was subjected to folding and reverse faulting. The principal folds formed in and around Leadville were anticlines of north-northwesterly trend, with gently dipping eastern limbs and steep or even overturned western limbs. The western limbs were broken by reverse faults of moderate to steep northeasterly dip. The largest of these reverse fault movements took place along the part of the Weston fault that lies south of Long and Derry Hill; along the Mike fault south of Printer Boy Hill; along the Mosquito fault near the head of Evans Gulch and farther north; and along the London fault on the east side of the Mosquito Range. Two of these faults belong to the composite group. The part of the Mike fault that lies north of Printer Boy Hill was subjected to so much postmineral movement in an opposite direction along the west side of a local depressed block that its present attitude is normal. The same is true of the part of the Weston fault that lies north of Iowa Gulch.

Within the Leadville district several smaller reverse faults have also been recognized—notably the Colorado Prince fault, along the northeastern edge of Breece Hill, the Bowden fault exposed in the Ibex mine and the Yak tunnel in the Breece Hill area, and the Tucson-Maid fault, exposed in mines of Iron and Carbonate Hills. Of these three, only the Colorado Prince fault can be traced on the surface; the others coincide with bedding. Southeast of the main Leadville district, beyond the Mosquito fault, several other reverse faults, some of unusually gentle dip, have been mapped along the walls of the amphitheaters at the head of Iowa Gulch.[1] After the formation of the reverse faults, fissures and small normal faults were formed at right angles to them and in places offset them for short distances.

In adjacent parts of central Colorado the period of folding and reverse faulting was followed by the intrusion of well-defined

[1]Behre, C. H., Jr., Revision of structure and stratigraphy in the Mosquito Range and the Leadville district, Colo.: Colorado Sci. Soc. Proc., vol. 12, p. 39, 1929.

stocks and batholiths of monzonitic rock which are associated with contact-metamorphic ore. No comparable intrusive bodies have been clearly outlined in the Leadville district, but the distribution of ore bodies, particularly those containing magnetite, implies that both the altered stock at Breece Hill and the small stock in Iowa Gulch belong to this group. While these stocks were being intruded, or shortly afterwards, more minor normal faults were formed, many of them with radial arrangement around the Breece Hill stock.

The whole sequence of events, from the intrusion of the White porphyry to and including the deposition of ore, took place during the Laramide revolution. In middle to late Tertiary time normal faulting ensued on a large scale and divided the district into several fault blocks. In general, the trends of these faults are northerly and the dips westerly. Some of the movements of this period consisted of renewed faulting along lines already determined by the earlier reverse faults, notably the Mosquito, Weston, and Mike faults, and by some of the mineralized faults. (See pl. 22.)

Ore Deposits

Although a few mines which have yielded a substantial output have been worked elsewhere in Lake County, by far the largest mines, credited with nearly the entire output of the county, lie within the area bounded on the north by Evans Gulch, on the south by Iowa Gulch, and on the east by the Ball Mountain fault. (See pl. 21.) By far the larger part of the tonnage has come from replacement bodies in dolomite. The first ores mined were placers. The bedrock ores mined in the early days were oxidized and valuable mainly for silver and lead. Before many years, however, sulfide ores were reached and were found to contain large percentages of zinc, which at the time was of little value and was even a cause of penalizing by the smelting companies. Still later, after the demand for zinc grew to substantial proportions, the principal zinc mineral, sphalerite, in large part a ferriferous variety, proved an obstacle to milling, and not until the flotation process and the recently developed sink-float process were established did the separation of lead and zinc in sulfide ores attain a marked degree of success. Oxidized zinc ore, although exposed during some of the earlier work, escaped recognition as material of commercial value until 1910. Thereafter it was mined in increasing quantity for several years, but since 1925 its output has been very small. Gold ore in the Breece Hill area was discovered in 1893 and since then has formed a substantial though minor fraction of the tonnage produced. It is restricted mainly to areas such as Breece Hill, where it occurs along crosscutting veins in siliceous rocks and in relatively thin layers of dolomite between sills of porphyry.

In the outlying areas the output of ore has consisted mainly of oxidized silver-lead ore, though substantial quantities of oxidized zinc ore have also been produced from a few mines, notably the Hilltop which lies northeast of Mt. Sheridan, just beyond the eastern boundary of Lake County. Small quantities of gold ore have also been mined along faults and fissures in pre-Cambrian granites and Cambrian quartzite.

The distribution, shape and size of the ore bodies, whether sulfide or oxidized, are governed mainly by structural conditions; the mineral composition is related largely to the influence of the country rock. In the paragraphs that follow, the original sulfide deposits will be considered first, and then the oxidized ores.

Original (hypogene) deposits.—The original deposits in the main Leadville district are conveniently classified into three main groups which, in order of increasing commercial importance, are (1) silicate-oxide deposits, formed at relatively high temperature in dolomite; (2) mixed sulfide veins, formed at moderate temperatures, mainly in siliceous rocks; and (3) mixed sulfide replacement bodies, formed at moderate temperatures, chiefly in dolomite. In the outlying areas the largest ore bodies are generally like those of class 3, but the relative proportions of the different sulfide minerals in the ore, as well as the characteristic gangue minerals, imply that they were formed at lower temperatures than the bodies in the main district.

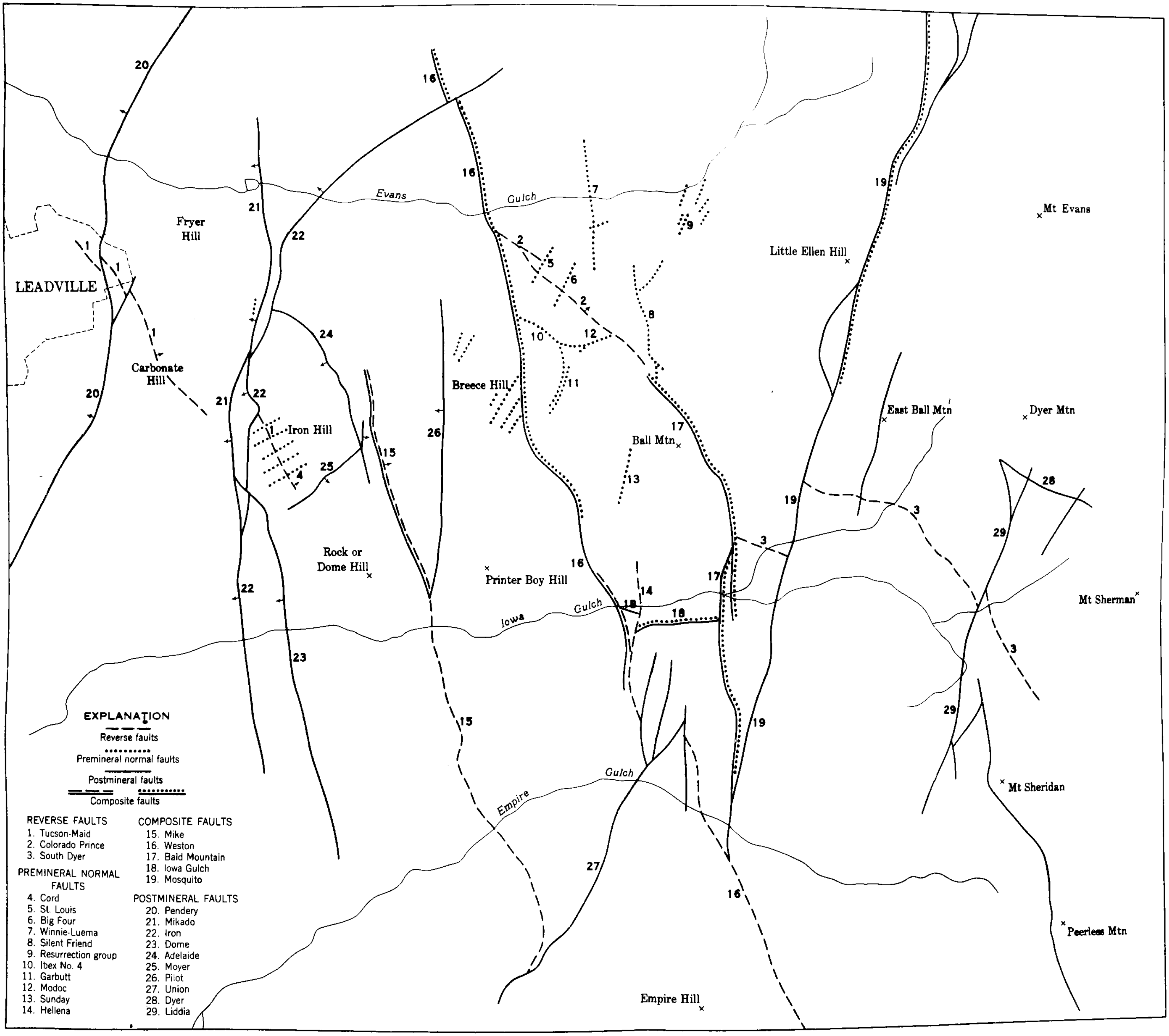
1. The silicate-oxide deposits are of little commercial interest. They consist of mixtures of magnetite and hematite in a gangue composed mainly of serpentine. Magnetite-hematite ore was shipped from the Breece iron mine for smelter flux in the early days, but with this exception only the ore cut by pyritic gold veins and thus enriched in gold to a workable tenor has been mined. Ore of this class is practically restricted to dolomite which has been replaced by ore minerals in the immediate vicinity of the obscure intrusive stock of Breece Hill. Fragments of similar ore have been found on the dump of the Mansfield shaft, sunk in the small stock in Iowa Gulch, and the ore penetrated here evidently represents a similar deposit near the margin of that stock.

2. The veins of mixed sulfides occur mainly in siliceous rocks, which predominate in the eastern part of the district, because of the abundance and complexity of the sill-like bodies of porphyry near the Breece Hill stock and the prevalence of the Weber (?) formation east and south of the Ibex mine. Veins within the stock have been produced only in their shallow enriched parts. The largest veins outside of the stock have been productive down to the level of the Yak tunnel, 1,300 feet below the surface, but even their deepest workings show some evidence of sulfide enrichment.

The Garbutt vein fills a fault of northerly trend that cuts grits and shales of the Weber (?) formation and a thick irregular mass of porphyry. Cambrian quartzite has been found near it on the west side, but shales in the lowest workings on its east side are believed to be part of the Weber (?) formation.[2] The largest vein of the Ibex mine, a little west of the Garbutt, also fills a fault, along which the Leadville dolomite has been extensively replaced by ore.

[2]Tweto, Ogden, written communication, 1946.

PLATE 22.



SKETCH MAP SHOWING CLASSIFICATION OF FAULTS IN THE LEADVILLE DISTRICT

1 MILE

Just west of the Ibex mine, in the Golden Eagle workings, veins that are too narrow to be mined where they cut porphyry sills expand into small replacement bodies where they cut intervening slabs of the Manitou dolomite. (See fig. 5.) These replacement bodies have been profitably mined mainly for gold, which is restricted to siliceous pyritic ore close to the vein itself. The pyritic ore grades outward into siliceous zinc-lead sulfide ore containing 10 to 15 ounces of silver to the ton. The narrow veins in the porphyry sills serve as guides to related replacement deposits in dolomite nearby.

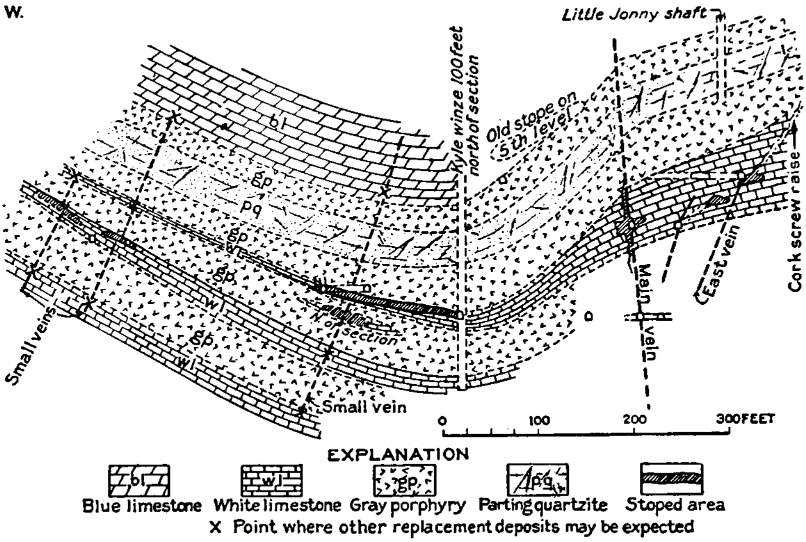


FIGURE 5.—East-west section 20 feet north of Little Jonny shaft, showing relation of veins to blanket ore bodies in the Golden Eagle workings, Breece Hill. Blue limestone includes Devonian (Dyer) and Mississippian (Leadville) dolomite; White limestone is equivalent to Manitou dolomite; Parting quartzite is the lower member of the Chaffee formation. (From fig. 55, U. S. Geol. Survey Prof. Paper 148).

One of the largest and best-defined veins in the district, the Winnie-Leuma, fills a fault that crosses all the dolomite formations, but its walls are so well protected by gouge that the dolomite walls have escaped replacement. One fair-sized replacement body in the upper part of the Leadville dolomite was mined a little east of this vein, but no connection with the vein was found. The replacement body tapered and ended downward along a veinlet about 260 feet east of the large vein.

The most noteworthy vein in the outlying area is the Hellena in Iowa Gulch. It lies nearly due south of the Sunday vein, which has been worked on the southwest slope of Ball Mountain. Both of these veins occupy faults walled by porphyry and the Weber (?) formation, and both have been worked mainly for their contents of silver and gold, though each has contributed some lead and zinc.

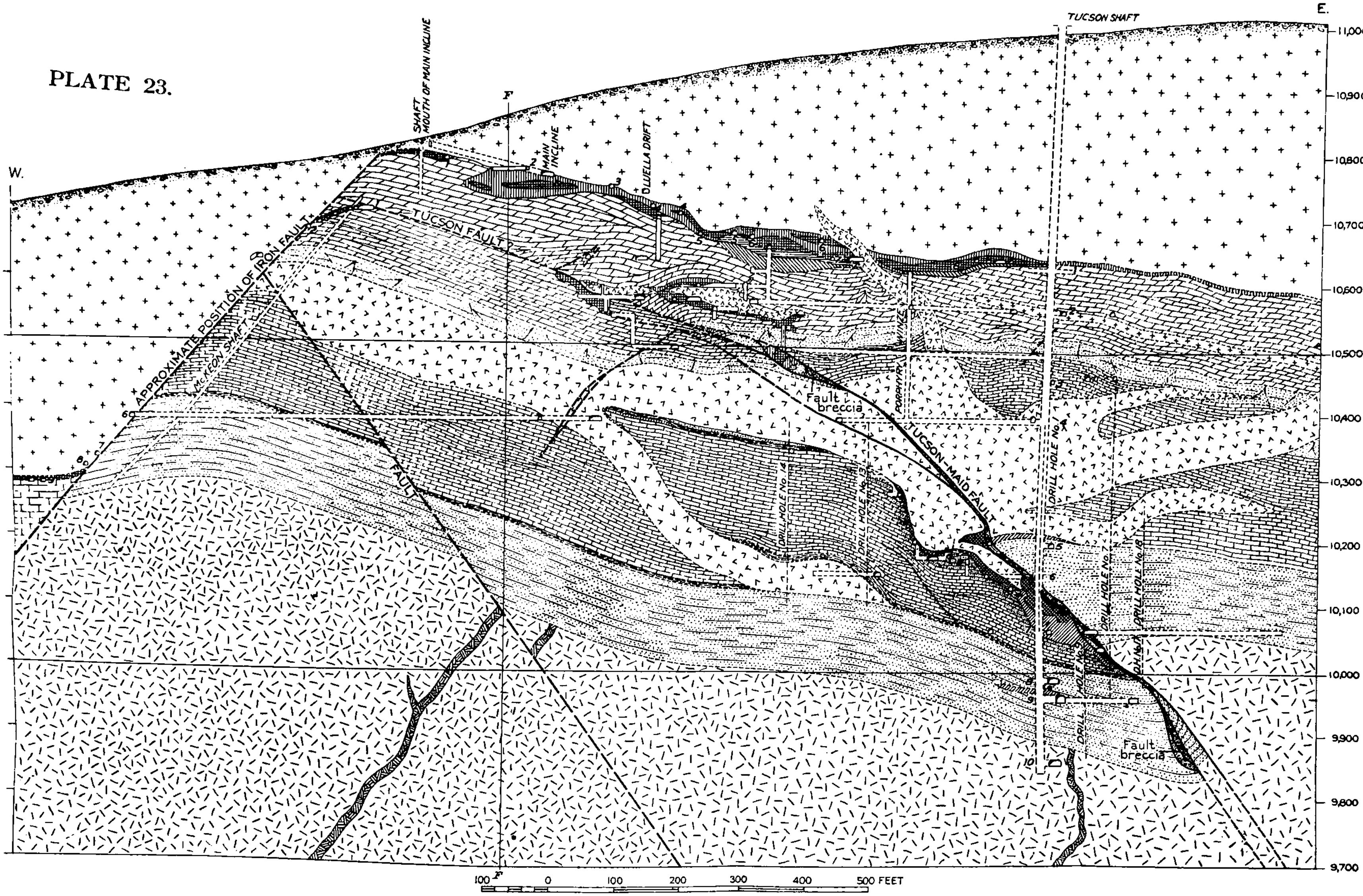
Where the veins of the district cut siliceous rocks they consist mainly of pyrite with a little interstitial chalcopyrite in a gangue of quartz. Where they expand into replacement deposits pyrite and quartz persist for a short distance laterally but grade into a mixture of sphalerite and galena in dense quartz or jasperoid. The veins and the pyritic parts of the replacement deposits, as shown in figures 5 and 6, have been valuable mainly for gold, some of which is primary but much of which has resulted from enrichment in the secondary sulfide zone. The gold is accompanied by some silver and in several veins by copper. Some shoots have yielded considerable lead. Zinc is commonly more abundant than lead, and for many years caused the ore to be penalized. The outer parts of the replacement bodies, which consist mainly of sphalerite and galena, also contain some silver but, because of their small size and the high mining cost, they have not been very important sources of ore. In most respects, except size, the outer parts of the replacement bodies are essentially identical with the large deposits, particularly those associated with siliceous gangue or casings, that are typical of the western part of the district.

3. In the western part of the district veins are relatively scarce, whereas replacement deposits of sulfide ore in dolomite are so large and numerous that the bulk of the district's output has come from them. These replacement bodies or "blankets" lie along fractures or sheeted zones beneath impervious covers. There are several such covers or "contacts" that are favorable for the occurrence of ore. The most favorable, known as the "first contact," is that at the top of the Leadville dolomite and under a thick porphyry sill. Other contacts are numbered consecutively downward. In some places, notably Dome Hill and the outlying areas near the crest of the Mosquito Range, only one or two contacts have been productive, but in the Carbonate Hill and Iron Hill areas as many as eleven contacts have been profitably worked. The largest replacement bodies, at the top of the Leadville dolomite, exceed 2,000 feet in length, 800 feet in width, and 200 feet in thickness.

The relations between these large replacement bodies and the few veins that have been found associated with them are essentially identical with those in the eastern part of the district. To illustrate, the Cord vein, in the Iron Hill area (fig. 6) has been mined from the Leadville dolomite down to the pre-Cambrian granite. Where it extends through the dolomite it expands into replacement deposits. The ore mined from the vein between siliceous walls has been pyritic gold ore, whereas that mined from the replacement bodies in dolomite has been silver-bearing zinc and zinc-lead ore.

The western part of the district furnishes examples of the trunk channels along which ore-forming solutions traveled; and it also illustrates the relations of these channels to the pre-mineral reverse faults described on page 358. The Tucson-Maid fault (pl. 23), which trends northwest and dips northeast, is one of the larger of these reverse faults and is closely associated with large

PLATE 23.



EXPLANATION

IGNEOUS AND SEDIMENTARY ROCKS

QUATERNARY: "Wash"

LATE CRETACEOUS OR EARLY TERTIARY: Gray porphyry; White porphyry

CARBONIFEROUS: Blue limestone

ORDOVICIAN: "Parting" quartzite; White limestone

CAMBRIAN: "Transition shales"; Quartzite

PRE-CAMBRIAN: Pegmatite dike; Granite

ORES

Manganosiderite with patches and beds of magnetite; Low-grade iron-zinc sulphide ore; Zinc-iron-lead sulphide ore; Chalcopyrite enriched by chalcocite; Lead carbonate ore; Siliceous iron and manganese oxide ("black iron"); Zinc carbonate ore; Low-grade zinc carbonate

SECTION N. 63° THROUGH TUCSON FAULT, LOOKING NORTHWEST.

BY F. A. AICHER.

(From fig. 18, U. S. Geol. Survey Prof. Paper 148) ore shoots in the most productive part of the district. It extends through Iron and Carbonate Hills and is offset by a strong zone of postmineral faults between these two hills. Its northwestward continuation in the Downtown area is offset by another zone of postmineral faults along the western slope of Carbonate Hill. The dip of the fault is 45°-50° in the lowest workings but decreases upward and finally coincides with that of the beds at or near the base of the Leadville dolomite. Because of this coincidence with the bedding the fault escaped discovery until 1908, when it was recognized by George O. Argall, manager of the Tucson and adjacent mines.

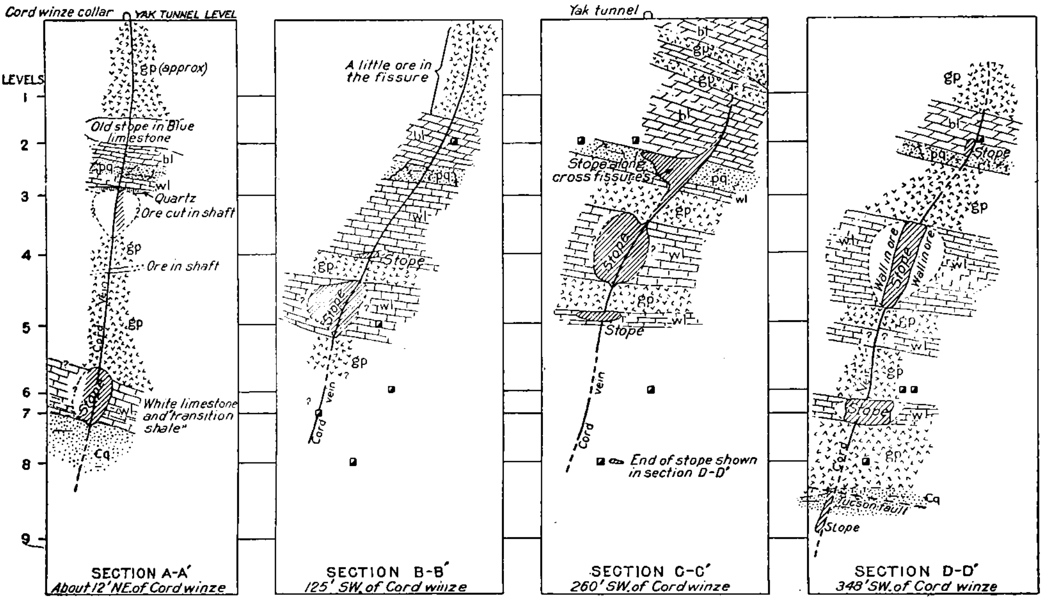


FIGURE 6.—Northwest-southeast section through Cord winze workings, Breece Hill. gp: gray porphyry; bl: blue limestone; pq: parting quartzite; wl: white limestone; Cq: Cambrian quartzite; gr: granite. Blue limestone includes Devonian (Dyer) and Mississippian (Leadville) dolomites; parting quartzite is the lower member of the Chaffee formation; white limestone is equivalent to Manitou dolomite; Cambrian quartzite includes the quartzite and Peerless shale member of the Sawatch quartzite. (From Fig. 22, U. S. Geol. Survey Prof. Paper 148.)

Although the main fault was too full of gouge to permit the free passage of ore-forming solutions, the adjacent auxiliary fissures afforded channels for circulation. Some of these solutions, stopped in their upward progress by the gouge-filled fault, penetrated into the footwall and there replaced the Manitou dolomite. Others rose from the fault or auxiliary fissures into the hanging wall and, gaining access to persistent fracture zones of east-northeast trend, formed large replacement bodies along the top of the Leadville dolomite. (See pl. 23.)

Mineralogy of the primary ore.—The principal primary gangue mineral in and around the ore bodies nearest the Tucson-Maid fault is manganosiderite, which has also been found closely associated with magnetite in the outer parts of the silicate-oxide zone. This mineral preceded the sulfides and quartz, both of which have replaced it to a considerable degree. The replacement deposits farther from the Tucson-Maid fault are encased in dense quartz or jasperoid. A little barite is present in the outermost parts of these ore bodies, and barite with quartz is the most conspicuous gangue mineral in the replacement deposits in the outlying areas.

The most abundant sulfide in the western part of the district is pyrite, which forms some large masses that contain so little silver and gold as to be of no commercial value, except here and there where pyrite has been mined for the manufacture of sulfuric acid. Should a strong and persistent demand for pyrite arise, the Leadville district contains some very substantial though unmeasured reserves.

Nearly pure masses of marmatite (ferriferous sphalerite) have been found occasionally, and the same is true of galena, but for the most part these two minerals occur together, associated with pyrite. This mixed sulfide ore commonly contains a few ounces of silver and .03 to .05 ounce of gold to the ton, but here and there small shoots have been found that are unusually rich in silver and gold and also contain bismuth. Intergrowths of argentite, bismuthinite, and a little galena have been found in this rich ore. These minerals were formed very late in the sequence of ore deposition, and veins containing them have been found cutting large bodies of the ordinary mixed-sulfide ore.[3] Locally tetrahedrite, chalcopyrite, and arsenopyrite also occur, chiefly in replacement deposits.

Secondary (supergene) deposits.—Climatic conditions during late Tertiary time were favorable for the oxidation and enrichment of ores to considerable depths, but Pleistocene glaciation scoured off much of the oxidized material, especially along the larger gulches in the eastern part of the district. Since Pleistocene time oxidation has been insignificant.

Supergene processes have given rise to several different classes of oxidized ore, extensively mined in the past, and minor though locally considerable quantities of enriched sulfide ore. Water seeping downward through the pyritized "Early White porphyry" became charged with sulfuric acid and ferric sulfate, which were very effective in attacking the sulfide deposits in the underlying Leadville dolomite. Galena (lead sulfide) was oxidized through anglesite (the sulfate) to cerussite (the carbonate) without appreciable migration. The cerussite was accompanied by considerable horn silver or cerargyrite (silver chloride), especially close to the surface. Sphalerite (zinc sulfide) was com-

[3] Chapman, E. P., Newly recognized features of mineral paragenesis at Leadville, Colorado: Am. Inst. Min. and Met. Eng., Tech. Pub. 1105, 12 pp., 1939.

pletely dissolved and the zinc was carried downward and redeposited as smithsonite (the carbonate) and hemimorphite or calamine (the hydrous silicate), which replaced dolomite or manganosiderite at favorable places beneath the original sulfide ore body. Where manganosiderite was the only abundant gangue mineral around the primary ore body and graded outward into the dolomite country rock, large bodies of high-grade oxidized zinc ore were formed; where dense quartz or jasperoid was the predominating gangue, or where a sill of porphyry of the Gray porphyry group lay a short distance below the original ore body, the descending zinc solution became scattered in passing through the unreplaceable rocks, and only small bodies of low-grade ore were formed.

Oxidation of large pyrite bodies produced correspondingly large deposits of brown iron (limonite) ore, partly residual after the pyrite and partly replacing the adjacent dolomite or manganosiderite. Oxidation of manganosiderite produced black manganese-iron ore and locally some high-grade manganese oxide. Both the iron and the manganese-iron ore have been shipped for furnace flux, and the manganese-iron ore has been used intermittently in steel manufacture. The value of these ores as fluxes is increased by their small content of silver and lead. Oxidation of the small sulfide shoots containing unusually large quantities of bismuth produced deposits of bismuth oxide and carbonate that have been intermittently productive.

Much of the copper was carried below the oxidized zone and was redeposited as coatings of chalcocite on chalcopyrite and pyrite and of covellite on sphalerite. The chalcocite appreciably increased the copper content of the ore but was probably more valuable as a precipitant of gold and silver from descending solutions. Zinc blende, especially if previously coated with a film of the copper sulfide covellite, was also effective in precipitating the gold. Some mines have yielded very rich bunches or small shoots of ore that contained gold coatings on sphalerite and some of the richest shoots in the present oxidized zone evidently represent ore that had first been enriched in this way. This rich ore was also a source of the coarse gold found in the placers along California Gulch.

Rich silver ore has been mined just below the oxidized zone in some of the large replacement bodies, as in the Penrose mine. The silver is in the form of leaf and wire (native) silver and of the sulfide argentite, which were deposited on the original base-metal sulfides by descending solutions.

Placers.—Placers in the Leadville district are confined to California Gulch and its short branches. This gulch lies between Carbonate, Iron, and Breece Hills on the north and Rock and Printer Boy Hills on the south. It drains on unglaciated area, once overlain, however, by a thin mantle of high-terrace gravels. The short branch gulches along its upper part head in the slopes of Breece and Printer Boy Hills and Ball Mountain, all areas in which siliceous rocks contain gold-bearing veins and related small replacement bodies. The oxidized parts of these deposits are obviously the sources of the placer gold, which was intensively mined from 1859 to 1885. Very little was mined from then until the industrial depression that began in 1929 and led many to try placer mining. Small operations reached a maximum in 1936, then rapidly declined and ended in 1942. The total output of placer gold in Lake County from 1931 to 1942 amounted to 3,916 ounces. The small extent of California Gulch and the thoroughness with which it has been prospected implies that no very appreciable quantity of placer gold remains.

From 1915 to 1925 a total of 692,557 ounces of placer gold was mined in Lake County, mainly if not wholly, through the Derry Ranch dredging operation near Twin Lakes. A thorough study of Pliocene and glacial deposits in Lake County may lead to the discovery of additional placer ground, but until such a study is completed no suggestions for exploration are warranted.

Recent Developments and Future Exploration

Bulletin 779 of the U. S. Geological Survey, entitled "Guides to ore in the Leadville district, Colorado," and published in 1926, concluded with a discussion of ore reserves—not in terms of tonnage but of areas in which the relative chances of finding ore were weighed. This discussion was also included in Professional Paper 148, published in 1927. As the Downtown area had become completely flooded in 1926, conditions there have not changed since the date of the publications. The same was true of the Fryer Hill area until 1945, when the water began to be lowered slowly by drainage through the new drainage tunnel. To the north in the Canterbury Hill and adjoining areas no significant prospecting has been reported since the driving of the Canterbury Hill tunnel ceased in 1927. Exploratory work through this tunnel was disappointing and confirmed the interpretation that this area was outside of the well-mineralized part of the district. A short distance to the south, however, in Little Evans Gulch, siliceous silver ores, reported to have been productive before the collapse of the price of silver in 1893, remain for further consideration.

In the Carbonate Hill-Graham Park area, unwatered in 1925, the mining of large ore bodies continued until 1931, when the industrial depression caused the mines to be flooded again. During that interval some ore was produced from the William Wallace mine and some work was done through the Evelyn shaft, apparently in an effort to find another southwesterly ore zone similar to the very productive zones in the northwestern part of the area, but the work was discontinued. This experience tended to confirm the impression that the southern part of Carbonate Hill was outside of the well-mineralized area.

In the Iron Hill area some mining in well-established ore zones has continued at or above the level of the Yak tunnel but, according to the annual reviews in the Minerals Yearbook of the U. S. Bureau of Mines, most of the district's output has come from dumps and from mines in the eastern part of the district, where drainage through the Yak tunnel has favored the further development of both replacement bodies and cross-cutting veins.

The situation in 1940 was summarized by Henderson as follows:[4]

"Owing to the filling of four fault-blocked basins of ore deposits by water, output fell heavily in 1931 and still more in 1932, revived somewhat in 1933 with the increased price of gold, and improved again in 1934 with the fixation of the gold price at $35 an ounce and Government regulation of the silver price. In 1939 and 1940 the production was mainly in the treatment of gold-bearing dumps, with some shipments of newly mined and dump gold ore and lead-silver ore and of dump zinc-lead ore. The principal new work in the Leadville district was that by the Newmont Mining Corporation (of New York) and the Hecla Mining Company (of Idaho) at the Resurrection mine at the end of Yak tunnel, where water is not a problem. Ore has been developed at the Resurrection mine in sufficient quantity to furnish gold-silver-lead-zinc ore for a 300-ton-a-day concentration mill. Early in 1941 these companies acquired the Yak tunnel with its tracks, right-of-way, and certain mining property contiguous to the Yak drainage-transportation tunnel."

This operation at the Resurrection mine, based largely on an appraisal of local geologic factors controlling ore deposition, has restored the output of lead and zinc to something like its pre-depression status; it has also contributed substantially to the nation's supplies of these metals during World War II. Prospecting through the Yak tunnel of ground near the Mosquito fault east of the Resurrection mine is also worthy of consideration, as the surface along the west side of the fault shows distinct evidence of mineralization.

More recently the American Smelting and Refining Company has been doing exploratory work, chiefly diamond drilling through the Eclipse and Garbutt shafts, on Breece Hill.

The stimulation of gold mining from 1931 to 1941 proved that the eastern part of the district, despite the extensive work done in the Ibex mine, is entitled to further exploration. The large quantity of dump material milled gives a fair idea of the low-grade ground that could not be profitably treated until the technique of milling had advanced to its present status. There are large tonnages of mineralized siliceous rock in the eastern part of the district that deserve thorough sampling to determine their value as milling ore.

Likewise, the recent treatment of low-grade zinc-lead ore from dumps in the Iron Hill and Carbonate Hill areas gives some idea of the grade of ore left unmined. Large tonnages of this grade of ore no doubt remain, together with an unknown quantity of higher-grade ore that awaits further exploration in these areas.

[4]Henderson, C. W., Gold, silver, copper, lead, and zinc in Colorado; U. S. Bur. of Mines Minerals Yearbook, 1940, p. 300, 1941.

The future of these two areas, as well as the Downtown and Fryer Hill areas, is obviously dependent on unwatering. The same is true of the little explored area east and southeast of Breece Hill, all the way from Evans Gulch to Iowa Gulch. Drainage of this area could be brought about by driving a 4,500-foot lateral from the Yak tunnel to the Sunday vein, which is in the same north-trending zone as the Hellena vein in Iowa Gulch. Drifting southward from such a lateral would explore this zone and would probably unwater the Leadville dolomite in the vicinity of the Sunday vein. In the Hellena mine, however, this dolomite would still be below tunnel level, though the pumping lift would be substantially decreased.

The western part of the district, however, is far less favorably situated with respect to drainage. Water now issues from the A. V. shaft, whose altitude is close to 10,000 feet, at the south end of the city of Leadville. Only a long tunnel could lower the water level enough to be an effective aid to mining. Our proposed tunnel, 6 miles long, would have extended northward from the mouth of the Thompson Gulch to the base of the Penrose shaft, and would have been low enough to drain practically all the mineralized ground throughout the district, but efforts to finance its construction were not successful.

During World War II a shorter tunnel, from the East Fork of the Arkansas River to Fryer, Carbonate, and Iron Hills, was proposed and funds for it were appropriated by Congress in 1943. The tunnel (altitude about 9,960 feet) was begun in December of that year, but so many obstacles were encountered that progress was slow. By June, 1945, the breast of the tunnel was about 6,500 feet from the portal, and had reached the border of the Fryer Hill area, but in the meantime the war had ended and further appropriation for completion of the tunnel was not forthcoming. Its ultimate completion would unwater large quantities of ore, but the deepest areas of productive ground in the Carbonate Hill and Downtown areas would still be as much as 600 feet below tunnel level; indeed, all of the ore bodies in the Downtown area would be below its effective drainage level.

As was to be expected, this tunnel has thus far penetrated ground outside of the well-mineralized areas; however, it has already reached the northwest edge of the Fryer Hill area, where the water has begun to subside slowly. Some revival of mining in that area is therefore to be expected. There the geology is complex; the general shallowness of the mine workings, few of which were accessible during any of the geologic surveys of the district, have left much to be learned of the detailed geologic conditions. Moreover, the dolomite formations are split into several slabs, each enclosed in porphyry; the identity of the slabs needs to be confirmed or revised, and the positions of possible channels of mineralization beneath the old ore bodies should be explored. The extension of the tunnel for another 1,000 feet would be likely to cross any deep channels, but it is not certain whether the ore in this area was introduced by upward movement through local channels or through a more roundabout route from the East Fryer Hill or even from the Carbonate Hill area.

If the tunnel should be extended into the Iron Hill area, as originally planned, it would lower the water level there by 300 feet or more below the Yak tunnel and would drain all but the very deepest workings. It might also slowly lower the water level in the Rock Hill area, south of California Gulch, where some rather large ore bodies were mined years ago. These ore bodies are essentially southwestward continuations of the great Moyer and the A. Y. and Minnie ore bodies of the Iron Hill area. They have replaced the upper part of the Leadville dolomite below a sill of porphyry of the Gray porphyry group. Whether other ore bodies lie beneath these is questionable, as the mineral composition and shapes of the bodies are of the type characteristic of the outlying areas, where the deposition of replacement bodies of commercial size was confined to the upper part of the Leadville dolomite. Lowering of the water level, however, would encourage further exploration.

Beneath the eastern part of Rock Hill structural conditions near the Mike fault may have been favorable for ore deposition, but the Leadville dolomite is so deeply buried there that it would remain at least 100 feet below any extension of the new tunnel. This area is not far north of the small porphyry stock in Iowa Gulch where there is evidence of a minor center of mineral deposition. If water in this vicinity were lowered to the level of the new tunnel, its surface would lie about 600 feet below the bottom of Iowa Gulch, and ore bodies there, hitherto only accessible by heavy pumping, might be mined.

Along Iowa Gulch east of the Mike fault the Leadville dolomite lies well above natural drainage level and has been extensively explored, but the only ore bodies of impressive size thus far found, according to available records, are those of the Lillian group, which extend northward through Printer Boy Hill. Mines similarly situated on Long and Derry Hill on the opposite side of Iowa Gulch were worked long ago and practically no record of them is available.

Two miles south of Iowa Gulch, and a mile due south of Mitchell Ranch, the dumps of some old prospects along or close by some reverse faults in the Leadville dolomite have showings that appear to invite further attention. They are, however, more typical of the less extensive ore bodies of the bordering areas of mineralization. These prospects lie at an altitude of about 11,000 feet and can be reached by trail, southward from Empire Gulch or northward from the head of Little Union Gulch.

Far to the east of the main district and close to the crest of the Mosquito Range, three mines of impressive size, the Continental Chief, Hilltop, and Peerless, have been very productive in times past, and a few others, like the Liddia, are credited with appreciable outputs. Their ore bodies have all been in the upper part of the Leadville dolomite. Structural conditions appear favorable for the occurrence of similar ore bodies, particularly beneath the crest of the range where the Leadville dolomite is cut by numerous mineralized fissures and is overlain by a thick sill of Early White porphyry, locally separated from the dolomite by a thin bed of the basal shale of the Weber (?) formation. This extreme altitude of 13,000 feet, more or less, and the relative inaccessibility of the porphyry-dolomite contact along the steep slope are obstacles to exploration, especially as even the largest ore bodies thus far found are small in comparison with those of the main district. The future of the district as a whole, therefore, is dependent on further developments of the areas that have hitherto been the most productive.

KOKOMO (TENMILE) MINING DISTRICT, SUMMIT COUNTY

By A. H. Koschmann

Location and Topography

The Kokomo mining district lies in the southwest corner of Summit County in north-central Colorado. Kokomo, the main settlement within the district, is on State Highway 91, about 5 miles north of Climax and about 22 miles north of Leadville.

The Kokomo district lies immediately north of the Continental Divide near the headwaters of Tenmile Creek, which separates the Tenmile Range (also called Mosquito Range) to the south and the Gore Range to the north. The valley of Tenmile Creek ranges in altitude from about 10,000 feet to 11,000 feet, and the summits of the highest peaks, which are in the Tenmile Range, exceed 14,000 feet. Mines are situated at altitudes up to 11,800 feet.

History and Output

During its early history the Kokomo district was a relatively minor producer of lead, silver, and gold, which were derived from oxidized and secondarily enriched ores, but when methods of recovering zinc became perfected the output of zinc, derived chiefly from the primary ores, equalled or exceeded that of lead and the precious metals. Although the first lodes were discovered in the pre-Cambrian rocks in the sixties, the district did not become active until the discovery of bonanza ore in the sedimentary rocks during the summer of 1878.[1] Output reached its peak in the period of 1880-82. The blanket of oxidized and enriched ore was rapidly mined out, bringing the bonanza period of the camp to an early close. Thereafter mining activity fluctuated, and from 1923 to World War II mining had practically ceased; however, the recent demand for base metals needed for war purposes again aroused interest in these deposits and the district again became an important source of zinc and lead.

[1]Henderson, C. W., Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, p. 11, 1926.

Few figures are available on the output of the Kokomo district, as neither governmental nor private agencies kept any systematic record of the metal mined during the years prior to 1902, which include the period of greatest activity. Henderson[2] places the value of the metal output from Summit County during the period 1880 to 1902 at $19,619,000. What part of this value came from the Kokomo district is not recorded, but $10,000,000 can safely be assumed as the approximate value of output during that period. From 1902 to 1944, inclusive, the district's output comprised 20,968 fine ounces of gold, 1,228,098 fine ounces of silver, 11,337,800 pounds of lead, 15,565,300 pounds of zinc, and 213,200 pounds of copper.

Geology of the Bedrock

The rocks exposed in the area mapped, shown on plates 24 and 25, include formations of pre-Cambrian, Cambrian (?), Pennsylvanian, and Permian (?) age, invaded by porphyries of late Cretaceous or early Tertiary age.

Pre-Cambrian Rocks.—The pre-Cambrian rocks occupy only a small area in the northern part of the district on Copper Mountain, but much larger masses extend northward along the Gore Range and southward along the Tenmile Range. The pre-Cambrian rocks on Copper Mountain consist chiefly of gneiss and schist, but small masses of medium-grained pink granite, probably Silver Plume granite, and pegmatite dikes are also present.

Paleozoic Rocks—CAMBRIAN (?) QUARTZITE.—The oldest exposed Paleozoic rock in the area mapped is a fine-grained, glassy quartzite, about 10 feet thick, that intermittently crops out on the south slope of Copper Mountain between the pre-Cambrian and Pennsylvanian rocks. The trend of its outcrop is discordant with the strike and dip of the adjacent Pennsylvanian rocks. Its discordant structural relation and its glassy character imply that it is not part of the Pennsylvanian strata and, like similar quartzite in the Climax district,[3] it is tentatively correlated with the Sawatch quartzite of Cambrian age.

PENNSYLVANIAN AND PERMIAN (?) ROCKS.—The Pennsylvanian and Permian (?) rocks are the most extensive in the district. They consist of a folded and faulted series of sedimentary rocks which were deposited on an erosion surface of lower Paleozoic rocks, with a northward overlap onto the pre-Cambrian rocks. They consist predominantly of interbedded coarse- and fine-grained clastic rocks—conglomerate, grits, sandstone, siltstone, and mudstone—in which relatively thin beds of fossiliferous limestone are intercalated at widely spaced stratigraphic intervals. These limestone beds mark the chief ore horizons of the district. Of interest in the Kokomo district are a few local lenses of volcanic tuffs and breccias and subangular fragments of white rhyolite found stratigraphically in the lower beds exposed on Tucker, Union, and Copper Mountains.[4]

[2]Henderson, C. W., op. cit., p. 245, 1926.
[3]Butler, B. S., and Vanderwilt, J. W., The Climax molybdenum deposit, Colo.: U. S. Geol. Survey Bull. 846-C, p. 210, 1933.
[4]Koschmann, A. H., and Wells, F. G., Preliminary report on Kokomo mining district, Colo.: Colo. Sci. Soc. Proc., vol. 15, no. 2, pp. 48-112, 1946.

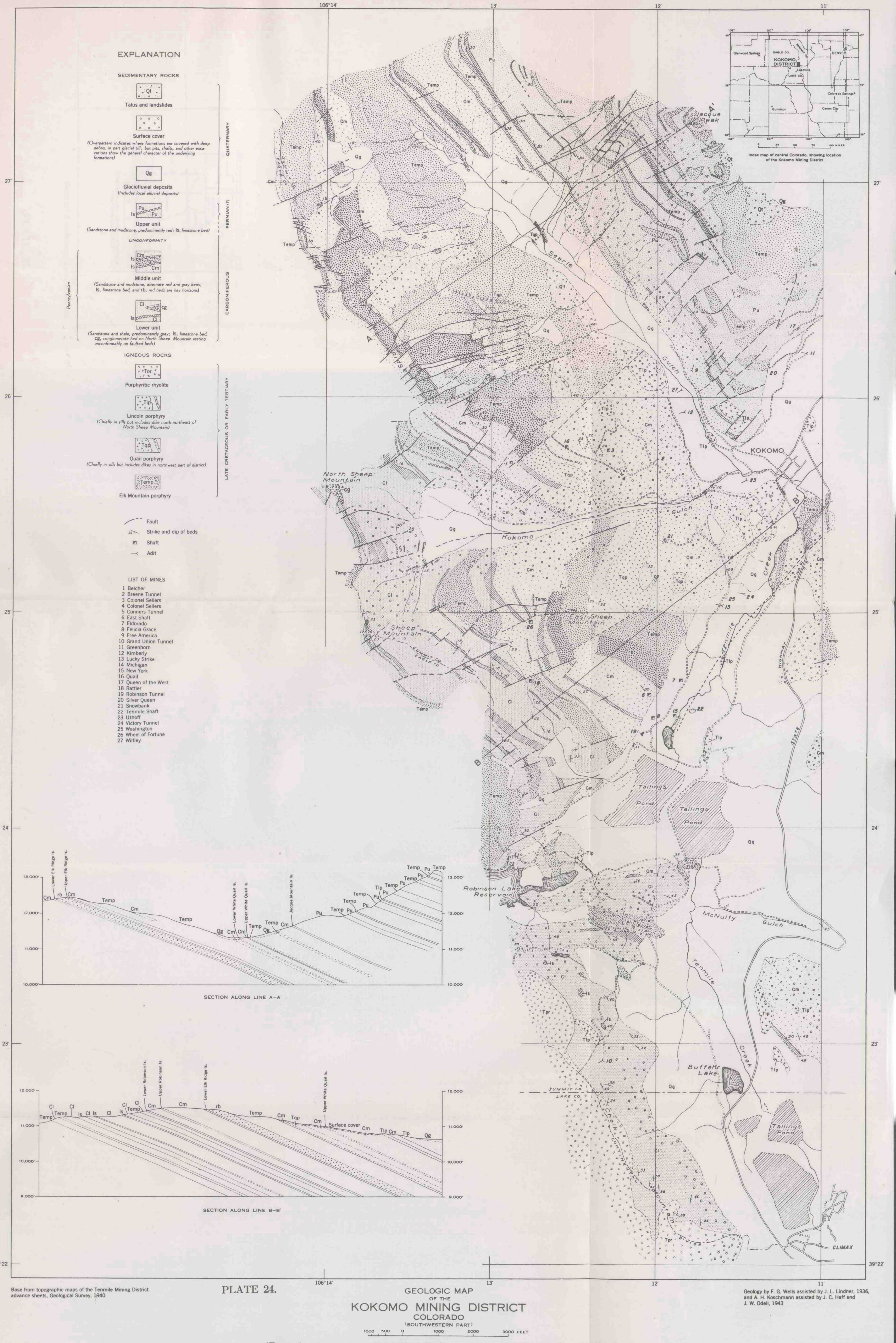
TABLE 6

Table showing general stratigraphic section of the Pennsylvanian and Permian (?) rocks of the Kokomo district, Colorado

Age	Major lithologic divisions	Lithologic subdivisions	Thickness (feet)	Character
Permain (?)	Upper unit (sandstone and mudstone)		2,000±	Predominantly thin-bedded sandstone and mudstone of brick-red color, with a few conglomerate beds 1 to 2 feet thick.
Carboniferous (Pennsylvanian)	Middle unit (mainly sandstone, mudstone, and limestone)	Jacque Mountain limestone of local usage.	15-25	Bluish-gray to dark-gray oolitic limestone. Most exposures show a single bed, but near south end of Searle Gulch there are several closely spaced thin beds with shale partings.
		Sandstone	800-900	Thin-bedded red to maroon sandstone and mudstone, with a little conglomerate.
		White Quail limestone of local usage.	175±	Locally includes three limestone beds, but in most places the uppermost is absent. Upper limestone, gray and argillaceous and 5 to 15 feet thick, is separated from middle limestone by 25 to 50 feet of white to pinkish grit and red mudstone. Middle limestone bed, 20 to 30 feet thick and blackish-gray, is immediately overlain by seam of black carbonaceous shale; is separated from lower limestone by 100 to 150 feet of thin-bedded red sandstone with some beds of pinkish conglomerate. Lower limestone bed, 15 to 20 feet thick, is dark bluish-gray.
		Sandstone	250-400	Chiefly white to cream-colored micaceous sandstone.
		Elk Ridge limestone of local usage.	250±	Includes two limestone beds, separated by 200 to 225 feet of thin-bedded red sandstone and conglomerate; shown as key horizon on map. Upper limestone bed is 5 to 7 feet thick, dark bluish-gray, and overlain by 10 to 12 feet of black micaceous shale; lower bed is 12 to 15 feet thick; upper 7 to 8 feet crystalline and light gray, lower 6 to 7 feet mottled dark bluish gray.
		Sandstone and shale.	300-500	Cream-colored to gray micaceous sandstone interbedded with black carbonaceous shale.
		Robinson limestone of local usage.	200-250	Generally includes three beds of limestone but locally only two. Upper bed, about 15 feet thick, is separated from midddle or main Robinson bed, about 35 feet thick, by 100 to 200 feet of sandstone.
	Lower unit (sandstone and shale)		1,200±	Interbedded whitish to gray sandstone grit, arkose, and conglomerate, all micaceous, black carbonaceous shale, and a few beds of dolomitic and cherty limestone.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH COLORADO STATE
GEOLOGICAL SURVEY BOARD AND COLORADO METAL MINING FUND



Base from topographic maps of the Tenmile Mining District advance sheets, Geological Survey, 1940

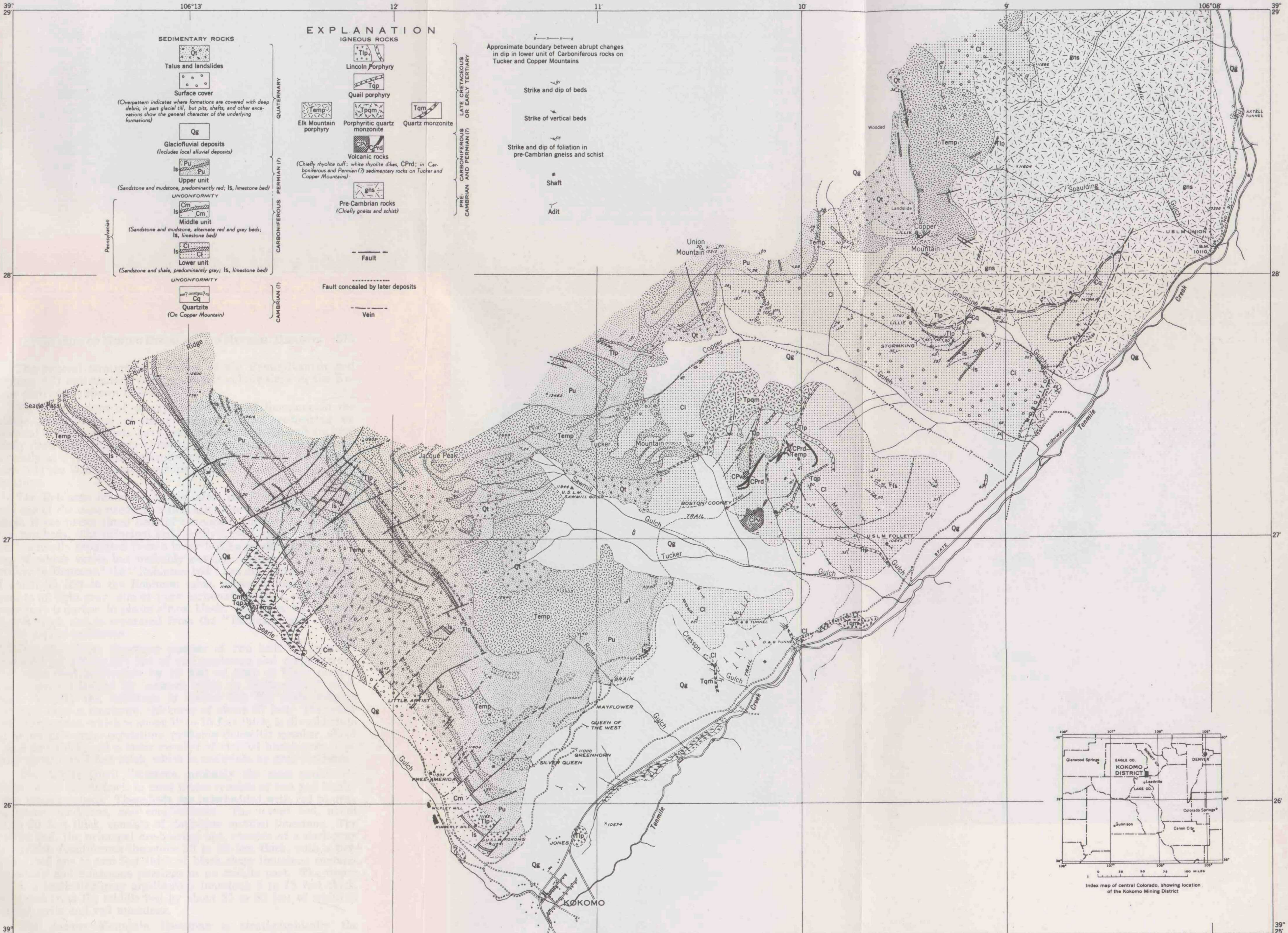
PLATE 24.

GEOLOGIC MAP
OF THE
KOKOMO MINING DISTRICT
COLORADO
(SOUTHWESTERN PART)

1000 500 0 1000 2000 3000 FEET

Geology by F. G. Wells assisted by J. L. Lindner, 1936, and A. H. Koschmann assisted by J. C. Haff and J. W. Odell, 1943

(From plate 1, preliminary map, U. S. Geol. Survey Strategic Minerals Investigations)



Base from topographic maps of the Tenmile Mining District advance sheets, Geological Survey, 1942

Geology by A. H. Koschmann assisted by J. W. Odell, 1944

GEOLOGIC MAP
OF THE
KOKOMO MINING DISTRICT
COLORADO
(NORTHEASTERN PART)

1000 500 0 1000 2000 3000 FEET

(From plate 2, preliminary map, U. S. Geol. Survey Strategic Minerals Investigations)

The general stratigraphic section of the Pennsylvanian and Permian (?) sedimentary rocks and their subdivisions in the Kokomo district are shown in Table 6.

The four groups of closely spaced beds of limestone in the middle unit, because of their importance as ore-bearing or potential ore-bearing beds, have been mapped in detail and are here briefly described. From the oldest to the youngest they are referred to locally as : (1) the Robinson limestone, (2) the Elk Ridge limestone, (3) the White Quail limestone, and (4) the Jacque Mountain limestone.

The Robinson limestone, named after the Robinson mine, has been one of the most productive formations in the district. In most places it comprises three beds of limestone, but locally there are only two beds. The principal bed, locally known as the "Robinson bed" is locally separated from a lower bed by sandstone, the thickness of which varies but probably nowhere exceeds 18 feet. According to Emmons,[5] the "Robinson bed" has an average thickness of about 35 feet in the Robinson mine, where its upper 20 feet consists of light-gray, almost pure carbonate of lime, whereas the lower part is darker, in places almost black. The upper bed is about 15 feet thick and is separated from the "Robinson bed" by 100 to 200 feet of sandstone.

The Elk Ridge limestone consists of two beds of limestone separated by 175 to 225 feet of red sandstone and conglomerate. The upper bed is overlain by 10 feet or more of black carbonaceous shale followed by massive white to cream-colored sandstone. Locally the limestone is absent but the shale persists and may have a maximum thickness of about 40 feet. The lower bed of limestone, which is about 12 to 15 feet thick, is divisible into an upper pale-gray, crystalline, probably dolomitic member, about 7 to 8 feet thick, and a lower member of mottled bluish-gray limestone about 6 to 7 feet thick, which is underlain by gray sandstone.

The White Quail limestone, probably the most productive formation in the district, in most places consists of two and locally three limestone beds. These beds are interbedded with red to gray sandstone, mudstone, and conglomerate. The lowest bed, about 15 to 20 feet thick, consists of dark-blue mottled limestone. The middle bed, the principal ore-bearing one, consists of a dark-gray to blackish fossiliferous limestone 20 to 30 feet thick, with a persistent bed one to two feet thick of black shaly limestone containing sandy and micaceous partings in its middle part. The upper bed is a lenticular gray argillaceous limestone 5 to 15 feet thick, separated from the middle bed by about 25 to 50 feet of white to pinkish grits and red mudstone.

The Jacque Mountain limestone is stratigraphically the highest persistent limestone in the area. Its massive beds of bluish-gray to dark-gray limestone are characterized by a pronounced oolitic texture. At most places it consists of a single bed of lime-

[5]Emmons, S. F., U. S. Geol. Survey Geol. Atlas, Tenmile district, special folio 43, p. 4, 1898.

stone about 20 to 30 feet thick. Locally, however, it consists of several closely spaced thin beds of limestone with alternate beds of fissile chocolate-colored shale three feet or more thick.

Igneous rocks.—Igneous rocks of late Cretaceous or early Tertiary age form numerous and extensive sills, irregular intrusive bodies that include small stocks and a chonolith, and a few dikes. Six types of igneous rocks have been recognized, all but the last of monzonitic composition:[6] (1) the Elk Mountain porphyry, (2) porphyritic quartz monzonite, (3) quartz monzonite, (4) the Quail porphyry, (5) the Lincoln porphyry, and (6) porphyritic rhyolite.

The Elk Mountain porphyry is by far the most widely distributed and most abundant igneous rock in the district. It is typically pale gray and is characterized by phenocrysts of quartz and plagioclase. The porphyritic quartz monzonite is identical in mineral composition with the Elk Mountain porphyry into which locally it grades imperceptibly in places, but its groundmass is distinctly granular and the phenocrysts are less distinctly set off from the groundmass. The phenocrysts consist of plagioclase, quartz, biotite, and locally hornblende; the groundmass consists of orthoclase and quartz. The quartz monzonite in the area mapped crops out along the highway on the north side of Tenmile Creek just west of Tucker Gulch, but a large mass crops out on the southeast side of Tenmile Creek on Bald Mountain.[7] In mineral composition the quartz monzonite is similar to the porphyritic quartz monzonite and the Elk Mountain porphyry, but is granitic in texture. The typical quartz-monzonite is whitish gray, generally medium-grained, and somewhat porphyritic. It consists essentially of plagioclase, orthoclase, quartz, and biotite.

The Quail porphyry is a dark to greenish-gray fine-grained rock with distinct phenocrysts of hornblende and poorly developed phenocrysts of whitish plagioclase. It is the least abundant of the igneous rocks and occurs in widely scattered dikes and sills.

The Lincoln porphyry is somewhat similar in appearance and mineral composition to the Elk Mountain porphyry, but is distinguished by its large, well-formed phenocrysts of gray to pink orthoclase, which attain a maximum length of about two inches. Present also are much smaller but distinct phenocrysts of quartz, plagioclase, and biotite.

The porphyritic rhyolite is characterized by phenocrysts of feldspar and slightly smoky quartz, which stand out in a white felsitic groundmass. Chalk Mountain, a prominent ridge on the Continental Divide on the southwest edge of the Kokomo district, derives its name from the dazzling white exposures of this rhyolite on its upper south and west sides.

Structure

The rocks of the Kokomo district are both folded and faulted. Their structures are products of recurrent deformation probably

[6] Koschmann, A. H., and Wells, F. G., op. cit., 1946.

[7] Crawford, R. D., A contribution to the igneous geology of central Colorado: Am. Jour. Sci., 5th series, vol. 7, p. 372, 1924.

dating back to early Paleozoic or even to pre-Cambrian time. Three periods of deformation are clearly represented, but because of large gaps in the pre-Pennsylvanian stratigraphic record and lack of knowledge of the precise age of some of the Pennsylvanian and Permian (?) rocks, neither the number nor the dates of some periods can be satisfactorily determined. The three major periods of deformation that have been recognized[8] have been assigned to (1) pre-Pennsylvanian time, (2) the Pennsylvanian epoch, and (3) the Laramide revolution.

Pre-Pennsylvanian.—Deformation in pre-Pennsylvanian or possibly early in Pennsylvanian time is indicated by the unconformity at the base of the Pennsylvanian rocks. West of the area mapped along the Eagle River[9] and just east of that mapped in Mayflower Gulch[10] the Pennsylvanian rocks lie on pre-Pennsylvanian sedimentary rocks, but on Copper Mountain they rest unconformably on pre-Cambrian rocks, thus showing a northward overlap. From this overlap it is evident that the site of Copper Mountain and the area immediately surrounding it, where the Pennsylvanian rocks rest on pre-Cambrian rocks, was elevated to form a landmass in pre-Pennsylvanian time. Later movement of this landmass during Pennsylvanian time produced some of the Pennsylvanian structures, and still later, during the Laramide revolution in late Cretaceous and early Tertiary time, these earlier structures influenced the igneous intrusions which took advantage of the zone of weakness along the margin of the landmass.

Pennsylvanian.—Deformation during Pennsylvanian time produced folds, faults, and unconformities within the Pennsylvanian rocks. Strikes and dips, shown on plate 25, reveal discordant structural relations within the strata assigned to the lower unit of the Pennsylvanian sequence on Copper and Tucker Mountains. These discordant structures are too obscure to form a reliable basis for their interpretation, but they show that the Copper Mountain area falls within a zone of crustal unrest, already alluded to above, along which the rocks were intermittently deformed in different ways. Related structures are not found in the overlying rocks, assigned to the upper unit of the Pennsylvanian and Permian (?) sequence, and hence the structures in the lower unit are clearly of Pennsylvanian age. Local discordances in strike and dip at different stratigraphic horizons south of Searle Gulch also indicate deformation during Pennsylvanian time though this deformation was less intense than that of the Copper Mountain area.

A shallow eastward trending synclinal flexure at the site of the old town of Robinson is likewise probably of Pennsylvanian age. Exposures are not continuous enough to determine the details of this structure, but its general synclinal form is obvious from local strikes and dips, and Emmons[11] called it the Robinson syn-

[8]Koschmann, A. H., and Wells, F. G., Preliminary report on Kokomo mining district, Colo.: Report in press, Colorado Sci. Soc., 1946.

[9]Emmons, S. F., op. cit., p. 1, 1898.

[10]Unpublished data obtained during field work in 1945.

[11]Emmons, S. F., op. cit., p. 5, 1898.

cline. Involved in this structure are the lowest strata assigned to the middle unit of the sedimentary rocks. The syncline is tentatively regarded as a product of Pennsylvanian deformation because (1) a major unconformity is between its component strata and those assigned to the upper unit, and local minor unconformities at different stratigraphic horizons within it are implied by discordant strikes and dips; and (2) the easterly strike is at right angles to the larger Kokomo syncline, the dominant fold, described below, which was formed during the Laramide revolution. In the northeastern part of the area mapped (see pl. 25), most if not all of the middle unit of sedimentary rocks is absent and there the upper unit rests unconformably on strata of the lower unit. The general absence of definite horizon markers in the northeastern part of the area prevents a final statement regarding the extent of the hiatus represented there. If the limestone beds on Copper Mountain prove to be the equivalent of the Robinson limestone, as indicated by fossils, the hiatus is approximately equal to that part of the middle unit above the Robinson limestone.

Laramide and Tertiary.—The structural features which were formed during the Laramide revolution and later in the Tertiary are the most conspicuous in the district. Chief among them are the shallow northward-plunging syncline, described by Emmons,[12] and the Mosquito fault, which has a throw of several thousand feet and has cut off a large part of the east limb of the syncline. The rocks within the syncline have been much faulted. Though all the faults except the Mosquito are characterized by small displacement, they apparently have been an important factor in the localization of ore shoots, as is indicated by the accordance in trends of faults and ore shoots.

Ore Deposits

The productive ore deposits of the Kokomo district, composed chiefly of zinc-lead sulfides, occur in a relatively narrow zone of northeasterly trend on the northwest side of Tenmile Creek. Altho the mineralized area is more extensive and includes high-temperature silicate-oxide deposits in the outlying areas, chiefly on Tucker and Copper Mountains,[13] output from other parts of the area has been relatively small. The ore deposits are of two types, sulfide replacement deposits in limestone and sulfide veins in siliceous rocks, but output has come chiefly from the replacement deposits. The veins have been exploited in places, but output from them has been small.

The most productive deposits have been found in the Robinson limestone and the middle bed of the White Quail limestone, but small deposits have also been found in the Jacque Mountain limestone; all of these are in the middle unit of the Pennsylvanian and Permian (?) sequence. The Robinson limestone has been the chief ore-bearing rock in the Robinson, Felicia Grace, New York, Champion, and Wheel of Fortune mines, and probably in the Eldorado

[12]Emmons, S. F., op. cit., p. 3, 1898.
[13]Koschmann, A. H., and Wells, F. G., op. cit., 1946.

and East mines. The White Quail limestone is the chief productive rock in the White Quail, Colonel Sellers, Wilfley, Kimberly, Breene, Delaware, Snowbank, Lucky Strike, Washington, Michigan, and Uthoff mines. Ore deposits in the Jacque Mountain limestone have been exploited in the Wintergreen, Free America, and Selma mines. Some of the underground workings near the head of Kokomo Gulch may have penetrated limestone beds in the lower unit of the Pennsylvanian rocks, but these workings are inaccessible, and not much is known as to their extent and production.

Replacement Ore Bodies.—In mineral composition the replacement bodies are aggregates of sulfides, being composed of pyrite, pyrrhotite, marcasite, sphalerite, galena, and chalcopyrite, with a small proportion of gangue. Locally there are barren bodies of jasperoid which may be impregnated along the margins with sulfides. The replacement deposits are generally composite in character; the relative abundance of their minerals varies widely, both in the same deposit and from one deposit to another. On the basis of composition they can be divided into three groups: (1) pyrite deposits, (2) pyrrhotite deposits, and (3) mixed-sulfide deposits, which are the only ones of present commercial interest. As the pyrite and pyrrhotite deposits, although large, are of no present value, they will not be further described here.

The bulk of the district's output has come from the mixed-sulfide shoots. They consist of pyrite, sphalerite (marmatite), and galena, all more or less argentiferous, accompanied by accessory pyrrhotite and a little gangue. In most of the ore the sulfides are mingled irregularly, but in some shoots the ore is banded, and locally galena is concentrated in pockets or lenses. Quartz and carbonates, chiefly siderite, are the most common gangue minerals; Emmons[14] reported a little barite in the White Quail mine, and barite, rhodochrosite, and rhodonite in the Robinson mine.

The ore shoots are irregular in size and shape, though in general they occur as fingerlike shoots trending N. 50° to 60° E. As the regional trend of faults and fissures is also N. 50° to 60° E., the ore shoots were presumably controlled by dominant fissures. Recent work suggests that the ore-forming solutions migrated along the bedding from their deep-seated source and were guided by fissures or other structures, and thence migrated laterally replacing the limestone. The ore shoots range from a few feet to 300 feet in width, and some, as in the Robinson mine, have been mined down the dip for more than 2,000 feet. Although the thickness of the ore is locally as much as 30 feet, it rarely exceeds 10 feet. The roof of the ore bodies is clearly defined at the top of the limestone beds but the base is irregular.

Veins.—The veins of the district comprise two types: (1) metalliferous veins, and (2) carbonate veins. The carbonate veins are of no economic importance. The only commercially important veins are those in the closely spaced group exploited in the Queen of the West and adjoining mines on Jacque Mountain. According

[14]Emmons, S. F., op. cit., pp. 4-5, 1898.

to Emmons,[15] the veins occupy a series of parallel, closely spaced faults of slight displacement, which cross alternating layers of sandstone and porphyry at right angles. Their strike is N. 60° to 70° E.—about the same as the prevailing regional trend of the larger faults. In mineral composition the veins are similar to the replacement deposits. The unaltered ore that was mined consisted mostly of galena, sphalerite, and pyrite, but also contained sulfides of silver; the gangue was chiefly calcite and altered country rock. The most productive parts of these veins contained oxidized ore which extended 300 feet or more below the surface.

Future of the District

Reserves of known ore in the district are fairly large; furthermore, geologic conditions are favorable for the extension of known ore bodies to great depths and for the discovery of new ore bodies in unexplored or inadequately explored ground. As ore has been mined in the Robinson mine down the dip for 2,000 feet with no indication of restriction of mineralization in depth, deep exploration of other known ore bodies is warranted. The most productive ore bodies in the district are the replacement deposits in the limestone beds and future prospecting should be chiefly concentrated on these beds wherever there is evidence of mineralization. Vein deposits have been relatively unimportant; they offer opportunities to the small lessee, but are too small to justify a plan of extensive development.

[15]Emmons, S. F., op. cit., pp. 5-6, 1898.

THE GILMAN DISTRICT, EAGLE COUNTY

By Ogden Tweto and T. S. Lovering

The following discussion is condensed from a preliminary report on the Minturn Quadrangle. This report is on open file for public inspection in the office of the United States Geological Survey, Washington, D. C., and in the office of the Economics and Statistics Branch of the United States Bureau of Mines, Denver. A survey of the Minturn quadrangle and the Gilman district, begun in 1940 and interrupted by the war, was completed in 1946, and a report covering the area is in preparation.

Introduction

The Gilman district, also known as the Red Cliff or Battle Mountain district, is on the northeast flank of the Sawatch Range, in southeastern Eagle County, about 20 miles north-northwest of Leadville, Colorado. It covers an area of three or four square miles between the towns of Gilman and Red Cliff. Gilman, the present-day mining center, is at an altitude of 9,000 feet at the top of the cliff wall of Eagle Canyon. Eagle River and the track of the Denver and Rio Grande Western Railroad are 600 feet almost vertically below Gilman. Early mining was concentrated in the walls of the canyon, but in later years the center of mining has been east and southeast of Gilman, under Battle Mountain.

Rich oxidized silver-lead ore was discovered in blanket veins in the limestones in 1879, and in 1884 gold was discovered in the underlying quartzites. By 1900 about $8,000,000 in silver, gold, and lead had been produced, but by that time the oxidized ores in the limestones had been mostly worked out down to the sulfide zone, which was found to consist mainly of zinc ore. Zinc production began in 1905 and has continued to the present except for the interval from 1931 to 1941 when no zinc ore was mined. The district was the largest source of zinc in Colorado during the war years. The Empire Zinc Company, a subsidiary of New Jersey Zinc Company, entered the district in 1912, and over a period of years consolidated most of the larger mines in limestone into the Eagle mine. Exploitation of the lower parts of zinc sulfide ore bodies led to the discovery of chimneys of pyritic silver-copper smelting ore which was mined intensively from 1931 to 1941. During this period the Eagle mine had a consistent output amounting to about 85 percent of the copper and 65 percent of the silver output of Colorado. For several years the district has ranked first among the base- and precious-metal mining districts of Colorado in value of annual output.

The total output of Eagle County from 1880 through 1944, as reported by the Bureau of Mines in the 1946 Mining Yearbook of the Colorado Mining Association, is given below. More than 99 percent of the output credited to Eagle County came from the Gilman district.

		Value
Gold	310,257 oz.	$ 8,455,135
Silver	50,732,986 oz.	34,644,125
Copper	177,075,773 lbs.	18,382,786
Lead	140,205,492 lbs.	7,054,503
Zinc	440,274,529 lbs.	37,462,565
		$105,999,114

Geology

Rocks.—The bottom of Eagle Canyon is in pre-Cambrian rocks which include granite, schist, and minor gneissic diorite. The pre-Cambrian rocks are overlain by Paleozoic sedimentary rocks ranging from Cambrian to Pennsylvanian and Permian (?) in age. The stratigraphy of the sedimentary formations is summarized in the chart on page 380. The lower formations up through the Leadville limestone are well exposed in the northeast wall of the canyon, but from this locality northeastward for 10 miles, to the Gore fault, they are covered by the thick series of Pennsylvanian and Permian (?) rocks. The mines are all in the lower formations, and no ore deposits are known in the great mass of Pennsylvanian and Permian (?) rocks in the vicinity of Gilman. The only igneous rock of late Cretaceous or early Tertiary age in the Gilman district is a persistent sill of quartz latite porphyry which lies a few feet above the Leadville limestone.

Geologic Formations in the Gilman District

Age	Formation	Thickness feet	Character
Pennsylvanian and Permian (?)	Maroon formation	4,500 to 6,000	100-300 ft. black shale, quartzite, and thin limestone at base, followed by 3,000-4,000 ft. gray shale, conglomerate, and arkosic grit, with some dolomite and limestone beds; at top, 1,000-2,000 ft. predominantly reddish shale, grit, and conglomerate, with a few limestone beds.
Mississippian	Leadville limestone	136	Massive gray to black limestone, all dolomitized in vicinity of Gilman. Abundant chert in middle part. Karst erosion surface at top.
	Gilman sand stone member	20-50	Gray sandstone, black cherty dolomite, and breccia containing much black clay. Breccia related both to Paleozoic weathering and to mineralization during the Laramide revolution.
Devonian	Chaffee formation		
	Dyer dolomite member	80	Gray to black, thin-bedded dolomite. Some chert in lower part; persistent 1-5 inch bed sandy dolomite 35 feet below top.
	Parting quartzite member	35-40	Light tan to white, fine- to coarse-grained, massive quartzite; conglomeratic at base; locally shaly.
Ordovician	Harding sandstone	15-80	6-25 ft. massive white quartzite overlain by thin-bedded green quartzite, conglomerate, and shale.
Cambrian	Sawatch quartzite		
	Peerless shale member	65	Red, green, and buff, thin-bedded dolomitic shale, sandy dolomite, and clay shale. Locally ferruginous and glauconitic.
	Quartzite member	195	Lower 75 ft. white quartzite with fine conglomerate at base, thin bed containing many brachiopods at top; next 85 ft. lenticular white quartzite, dolomitic quartzite, and sandy dolomite; top 35 ft. vitreous white quartzite.
Pre-Cambrian			Granite and schist.

Structure.—The sedimentary rocks of the Gilman district dip about 12° northeastward from the flank of the Sawatch Range. This dip continues northeastward from Gilman for about 8 miles to a synclinal axis that parallels the Gore fault and lies 1 to 2 miles from it. The dips on the northeast flank of the syncline increase toward the fault, where the beds become vertical or overturned.

The rocks near the ore deposits appear only very slightly deformed. The chief structural features are bedding faults which are probably related in origin to the regional Sawatch and Gore uplifts. The bedding faults include several strong and persistent zones of reverse-fault movement and a great number of minor slips showing normal-fault and horizontal movement. The beds in the Eagle mine are gently corrugated by folds with slopes of 5° or less. A few steep faults are found in the mine and in the canyon walls, but the displacement is less than 10 feet along most of them, and the greatest displacement is 50 feet. Many of the steep faults in the mine end abruptly against bedding faults above and below, and they thus constitute the side-walls of blocks that moved differentially in a place essentially parallel to the bedding.

A relatively weak but persistent fault zone that strikes north-northwest lies about a mile east of Gilman, and a similar zone striking about east lies a mile to the north. The displacements along these faults are only about 50 feet, but the faults are of interest and possible importance because they are weakly mineralized. Chalcopyrite, siderite, and fluorite found along the faults high in the section of otherwise barren Pennsylvanian and Permian (?) shales and grits suggest a possibility of leakage from ore bodies or channels in the limestones at depth.

Ore Deposits

The ore bodies include several different types as regards form, stratigraphic occurrence, and mineral content. Fissure veins in the pre-Cambrian rocks contain pyritic gold and complex sulfide ores, and small veins in the Sawatch quartzite contain gold-silver telluride ore. Replacement deposits include pyritic gold and auriferous sideritic sulfide bodies or mantos along bedding veins in the quartzites, chimneys of pyritic silver-copper ore in the limestones, and zinc-sulfide mantos in the limestones. By far the greatest output has come from the replacement bodies in the limestone.

The ore bodies in the limestones are arranged roughly in the shape of a three-pronged spear or trident pointing southwest or up dip. The tines of the trident are three long, slender zinc mantos which turn downward into steeply pitching pyritic copper-silver chimneys at their lower or northeast ends. The chimneys are connected by zinc mantos that are nearly parallel to the strike of the limestone. The tines are each about 4,000 feet long, and the outer ones are about 4,000 feet apart at the upper end. The chief gold deposits in the Sawatch quartzite are under the trident and approximately in line with the upper ends of the zinc mantos. Some of the more important gold fissure veins in the pre-Cambrian rocks correspond in a general way to downward extensions of the "tine" ore bodies, but the positions of few of them suggest any direct present connection, and several lie between the tines or outside the trident.

Fissure Veins.—The fissure veins contain auriferous sulfides and their oxidation products, and occur chiefly in the pre-Cambrian rocks; many of them end or weaken greatly at the base of the quartzite, and only a few, mostly small, have been mined in the quartzite. The output from the fissure veins has been much smaller than from the replacement deposits, but some of them have supplied several hundred thousand dollars worth of ore.

The sulfide veins are relatively narrow bodies in wide shear zones of altered rock. Some are almost entirely pyritic and contain a little gold, but most of them contain marmatite, chalcopyrite, and galena in addition to pyrite and are of value both for silver and gold. Gibson[2] reports that ore in streaks 1 to 10 inches wide in the Mabel mine contained 2 to 4 ounces of gold and 5 to 15 ounces of silver to the ton, 8 to 10 percent of lead, and up to 3 percent of copper. The Bleakhouse vein contained an average width of 4 inches of argentiferous galena that contained 50 to 700 ounces silver per ton.[3] The Bleakhouse is one of the few veins in the granite that persisted upward into the quartzite and remained productive.[4] Its ore bodies are related to structural controls common in fissure veins, such as intersections and changes in course and dip. Another type of occurrence, more or less peculiar to the district, is at the upper ends of veins that terminate at the base of the quartzite. At such places, the quartzite is separated from the granite by a heavy seam of gouge or gougy breccia along which considerable movement has occurred. Some of the veins abut sharply against this gouge, but others turn into it and are accompanied by considerable shattering and brecciation on the inside of the turn. The shattered rock may be filled with ore, as in the Ben Butler mine.

Small veins in the quartzite contain pockets of rich telluride ore. This ore is usually called petzite. but some hessite has been identified, and other gold-silver tellurides may be present as well. Pure petzite forms thin veinlets occupying small fissures and connecting joints.

Replacement Deposits in the Quartzite.—Most of the output from the quartzites has come from manto or bedding vein deposits in the Rocky Point breccia zone, which is about 180 feet above the base of the quartzite member and 10 to 20 feet below the base of the Peerless shale member of the Sawatch quartzite. In some places a single bed 2 to 4 feet thick is mineralized. and in others the ore zone consists of two beds, each 2 to 4 feet thick, separated by 3 to 8 feet of barren quartzite.

Two distinct ages and types of mineralization are recognized. The first was almost entirely pyritic and was preceded or accom-

[2]Crawford, R. D., and Gibson, Russell. Geology and ore deposits of the Red Cliff district, Colorado: Colorado Geol. Survey Bull. 30, pp. 67-70, 1925.

[3]Hoskin, A. J., Revival of mining at Red Cliff: Mines and Minerals, vol. 33, pp. 147-151, 1912.

[4]Means, A. H., Geology and ore deposits of Red Cliff, Colorado: Econ. Geology, vol. 10, pp. 1-27, 1915.

panied by extensive solution of the quartzite. Openings in breccia and along joints, sheeted zones, minor fissures, and bedding planes were enlarged by solution, forming open channels in the massive quartzite. Pyrite was deposited as a filling in breccia, joints, and small fissures, and as disseminated grains in the glassy quartzite. A very little chalcopyrite and an inconsequential amount of gold and silver accompanied the pyrite.

The younger mineralization was guided by the earlier channels and by younger breccia zones and minor fissures. Manganosiderite, pyrite, chalcopyrite, galena, marmatite, and barite were deposited. Gold and silver were chiefly associated with the chalcopyrite, which was erratically distributed. The manganosiderite and sulfides partly filled openings and also replaced pyritized quartzite adjacent to these openings.

The early pyritic mineralization permeated relatively large areas that have irregular and hazy boundaries. The later manganosiderite-sulfide mineralization was restricted to well-marked channelways within the pyritized quartzite. At the bottom of the Rocky Point mine the younger mineralization was restricted to two adjacent channels 10 to 40 feet wide that transect the bedding at a low angle. As these channels are followed up-dip toward the outcrop, 1,500 to 2,000 feet to the southwest, they become thinner, flare out on the bedding, and split and anastamose in the plane of the bedding. In the upper Rocky Point workings there are several channels in a zone extending for 1,500 feet along the strike of the quartzite.

Practically the entire output from the quartzite mantos has come from the oxidized zone. The oxidized material consists largely of clinkery iron and manganese oxides, iron sulfates, and pasty iron ocher. Much of it is barren, and mining has been directed toward a light-colored gougy bedding seam a few inches thick between the iron oxides and the quartzite floor. Gold and silver may have been concentrated in this seam by base exchange. Guiterman[5] reports that gougy oxidized ore from the Ground Hog mine contained seven ounces of gold and 50 ounces of silver to the ton. So-called nuggets rich in silver and gold and consisting of lumps of mixed iron oxides, silver-and gold-bearing "clay," horn silver, and "telluride" are reported from most of the mines in quartzite.[6789]

A large part of the early-day output from the Gilman district came from the mines in the quartzites, which probably contributed several million dollars worth of gold and silver. Little work has been done in the quartzite in recent years.

Replacement Deposits in the Limestones.—Almost the entire output during the last 25 years, the district's most productive era,

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[5]Guiterman, F., Gold Deposits in the quartzite formation of Battle Mountain, Colorado: Colorado Sci. Soc. Proc., vol. 3, pp. 264-268, 1890.

[6]Guiterman, F., op. cit.

[7]Olcott, E. E., Battle Mountain mining district, Eagle County, Colorado: Eng. and Min. Jour., vol. 43, pp. 418-419, 436-437, 1887.

[8]Von Rosenberg, Leo, The mines on Battle Mountain, Eagle County, Colorado: Eng. and Min. Jour., vol. 53, pp. 544-545, 1892.

[9]Tilden, G. C., Mining notes from Eagle County: Colorado School of Mines Bienn. Rept. 1886, pp. 129-133, 1887.

has come from replacement deposits in the Leadville limestone and the Dyer dolomite member of the Chaffee formation. These deposits have been worked largely through the Eagle mine, but the upper parts were worked earlier through several mines spaced along the outcrop of the Leadville limestone. The ramifying workings of the older mines constitute the first 13 levels of the Eagle mine. The main workings of the Eagle mine are on levels 14 to 20. Workings on these levels had a total length of 65 miles in 1941. Level 16 is the main haulageway and is connected with the

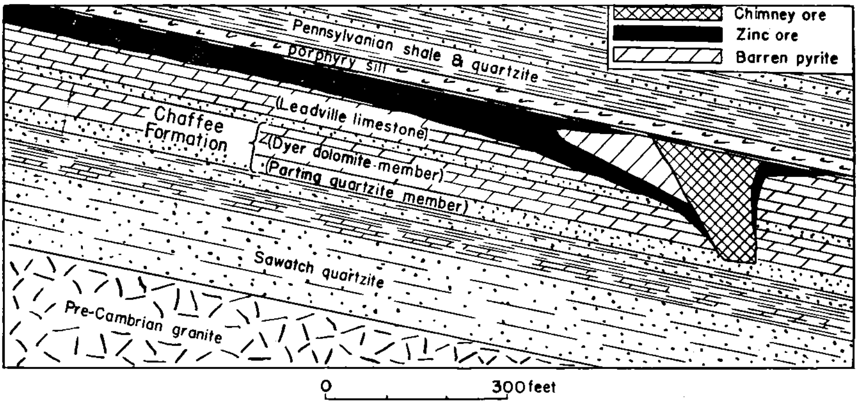


FIGURE 7.—Diagrammatic section showing relationship between chimney and manto ore bodies at Gilman.

surface by a vertical shaft and the Newhouse tunnel, which opens to the railroad in the canyon below Gilman and also connects with the head of the 600-ton underground mill. The lower levels, which are 85 feet apart vertically, are connected with the level 16 by two inclines that have 15-degree slopes.

The relationship between the copper-silver chimneys and the zinc mantos is illustrated in figure 7. The chimneys are the thickened, downward-tapering lower ends of the manto ore bodies. There is no physical break between the two types of ore body, but there is a pronounced mineralogic difference. The chimneys consist essentially of a core of pyrite which is surrounded by a discontinuous shell of sphalerite and a more or less continuous outer shell of manganosiderite. The pyritic cores contain minor quantities of other minerals which make them valuable for silver, copper, and gold in the order named. These metals are eratically distributed, and the ratios between them vary widely. The chief copper mineral is chalcopyrite, which replaces pyrite and fills openings in it. Silver and gold are associated with chalcopyrite, minor interstitial galena, and with a group of late copper and silver minerals that line vugs. The galena contains small inclusions of hessite, the silver telluride; a little petzite (gold-silver telluride) is associated with the hessite and contains minute blebs and veinlets of free gold. Among the late copper and silver minerals are tetrahedrite, freibergite, polybasite, stromeyerite, bournonite, and schapbachite. Late accessory minerals include manganosiderite, dolomite, barite, apatite, and quartz.

The manto ore bodies consist of sphalerite, pyrite, manganosiderite, minor galena, and accessory chalcopyrite, barite, dolomite, and quartz. The sphalerite is the black, iron-bearing variety, marmatite, and contains about 10 percent iron and 53 percent zinc. Pyrite is abundant in most of the manto ore. Some of the mantos contain cores of barren pyrite near their lower ends, but these cores are parts of the pyritic chimneys that were not enriched by the later copper-silver mineralization. (See fig. 7.) Manganosiderite is mostly concentrated in a shell a few feet thick around the manto bodies, but it is also common within the ore. The manganosiderite shell thickens as the mantos are followed up-dip. Galena is erratically distributed, but an almost continuous ribbon of relatively high-grade lead ore twists along the sides, tops, or bottoms of the mantos. The average ratio of lead to zinc is low but on the whole increases up-dip. The galena and accessory chalcopyrite of the manto ores contain little silver and almost no gold, whereas the oxidized ore was of value chiefly for lead, silver, and gold. Olcott[10] reported in 1887 that the oxidized ore contained 4 to 25 ounces of silver and a trace to 0.5 ounces of gold to the ton and about 13 percent lead.

The chimneys are roughly circular or elliptical in cross section and have major diameters of as much as 300 feet at the top. They extend from the top of the Leadville limestone down to or into the Parting quartzite member of the Chaffee formation, and taper downward, especially below the bottom of the Leadville limestone. In the quartzite below them only pyrite-coated joint surfaces are found.

The mantos are long and relatively slender. They have a generally subcircular or elliptical cross section but are irregular in detail. They are 50 to 300 feet wide, 5 to 150 feet thick, and up to 4,000 feet long. In general they tend to flatten and widen up-dip. They are all in Leadville limestone and, except for one whose lower end occupies the full thickness of the Leadville, all lie in the upper part of the formation, where both the early barren and the ore-forming solutions were restricted by the overlying impervious shale.

The ore bodies are intimately related to channels and caves eaten out of the limestone or dolomite by early barren solutions, and the immediate ore control was thus the early wall-rock alteration. An obscure but important structural control of the channels was afforded by the joints, which opened and closed at various times as the beds, moving on bedding faults, moved over gentle structural domes and corrugations.

The Leadville limestone is believed to have been dolomitized hydrothermally during the earliest stage of mineralization. Later, as a result of alternating solution and deposition, zebra structure developed in the upper part of the formation. Zebra rock consists

[10] Olcott, E. E., op. cit.

of alternating bands of dark, fine-grained dolomite and white, coarsely crystalline, vuggy dolomite. At a later stage, extensive solution of dolomite occurred. Solution began with "sanding," a process whereby the individual grains of dolomite were loosened by solvent attack along the intergranular faces. The disintegration ranges in degree from slightly friable dolomite to free-running sand. Sanding began along joints and any other pre-existing openings, such as the small vugs in the zebra rock. As the solvent attack continued, enough dolomite was eventually removed along trunk

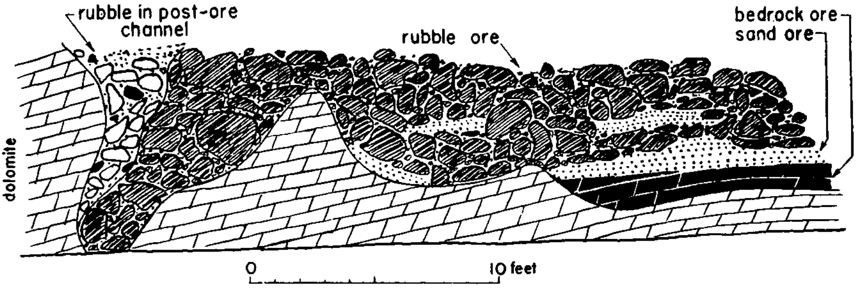


FIGURE 8.—Sketch showing replacement of rubble, sand, and bedrock in ore channel at Gilman. Mineralogic zoning is parallel to contact of ore body and independent of textural types.

channelways to cause open channels to develop. Such channels are common at Gilman, and many are enlarged locally to caves. Once open channels were formed, water circulated actively, dolomite sand was transported, and deposits of stratified dolomite sand were laid down at places on the floors of the channels and caves. Blocks fell from the walls and backs of the growing channels and collected as open rubble. Some channels reopened pre-Pennsylvanian karst water courses. Caves extending along the top of the Leadville limestone exposed the weak cap rocks, and fragments of shale, quartzite, and porphyry that fell into the cave and channel system and are now found as much as 150 feet below the top of the Leadville limestone.

The ore-forming solutions naturally followed the system of openings developed by the early barren solutions. All of the ore bodies follow well-defined channels. As shown in figure 8, the ore replaced rubble and stratified sand within the channels as well as adjacent bedrock. It is thus conveniently classified as "sand ore," "rubble ore," and "bedrock ore." There can be no doubt that the textures were inherited from deposits of pre-ore sand and rubble such as are found in unmineralized channels in the mine. The manganosiderite shell crosses bedrock, rubble, and sand bodies indiscriminately, as do contacts between pyrite and sphalerite ore. The sand ore preserves stratification, cross-bedding, ripple marks, crenulate folding, subsidence faults, and vertical sand "runs" that are identical to similar features in unmineralized dolomite sand. Pockets of delicately stratified sand ore suspended in rubble ore preclude the possibility that the rubble ore is a post-ore breccia. The bedrock ore preserves bedding, joints, brecciation, zebra structure, and faults.

The chimneys consist largely of sand ore, as if they were formerly holes filled with sand that had slid in from the manto channelways. Bedrock ore is present along the sides and bottoms of the chimneys, and there is some rubble ore near the tops. Much of the bedrock ore is brecciated (pre-ore breccia), and the chimneys evidently occupy zones that were originally strongly shattered.

The mantos follow open pre-ore channels and contain much rubble ore; sand ore is abundant only near their lower ends. In general they consist of a channel of rubble ore on one side or at the top, and a body of bedrock ore along the other side or at the bottom. Parts of some mantos consist of two channels of rubble ore with bedrock ore between them. Rubble ore in the mantos is usually overlain by unmineralized cap-rock rubble which consists of fragments of quartzite and porphyry in a matrix of black shale. The presence of such material stratigraphically lower than the top of the Leadville limestone is a favorable sign, because it indicates the presence of a channel in the dolomite lower down, and thus the possibility of finding ore.

THE CRIPPLE CREEK DISTRICT, TELLER COUNTY

By A. H. Koschmann

Location and Topography

The Cripple Creek gold mining district lies in Teller County in central Colorado, about 45 miles by highway southwest of Colorado Springs. Within the producing area are the towns of Cripple Creek and Victor, which are about 3 miles apart in its northwestern and southwestern parts, respectively. The district is served by the Midland Terminal Railroad, which connetcs it with Colorado Springs, the site of the Golden Cycle mill, where practically all of the ore is treated.

The Cripple Creek district is situated on a gently undulating plateau near the southwest end of the Front Range, and 9 miles southwest of Pikes Peak. The altitude of the area mapped ranges from about 10,700 feet down to 9,500 feet. It is drained by Beaver Creek and its tributaries on the east and by Oil Creek and its tributaries on the west; both creeks belong to the Arkansas drainage basin.

History and Output

Gold deposits were discovered in the Cripple Creek district in 1891. To the end of 1944 the district had a total recovered output of 18,496,735 fine ounces of gold and 2,084,535 fine ounces of silver. Output reached its peak in 1900 when 878,067 ounces of gold were mined, but fluctuated thereafter. In general, the district's output declined until 1932, when only 109,346 ounces of gold were produced. Interest in the district was revived by the depression of 1930-33, especially late in 1933 and early in 1934, when the price of gold was increased from $20.67 to $35.00 an ounce. Many mines that had been inaccessible for years were then reopened. In 1941 interest in the camp was further stimulated by the driving of the Carlton deep-level drainage tunnel (altitude of portal 6,893 feet) at a depth of about 1,100 feet below the Roosevelt drainage tunnel (altitude of portal 8,020 feet) to make available reserves that, because of pumping costs, could not be economically prospected and mined. Early in 1942 government regulations,[1] labor and material shortages, and economic factors related to World War II, forced many mines to close, and output declined markedly during the war years. The known and probable ore reserves, however, are large and the output of the camp will undoubtedly increase when business conditions again become favorable. There are unexplored portions of the district where further prospecting is worthy of consideration.

The Cripple Creek Basin

General Features.—The ore deposits of the Cripple Creek district are located within or at the margin of an irregular mass of Miocene fragmental rocks, locally called breccia, of non-volcanic as well as volcanic origin. These rocks occupy a steep-walled basin or caldera about 4 miles long and 2 miles wide in pre-Cambrian rock, which comprises granite, gneiss, and schist. Locally the surrounding pre-Cambrian rocks are capped by sandstone grits, and volcanic rocks, older than the fragmental rocks that fill the basin and probably of Eocene and Oligocene age.

The origin and development of the Cripple Creek basin are discussed below. Its development took place in several stages, the earliest pre-dating the igneous activity that furnished the fragmental material of the breccia and ended with the formation of the gold deposits.

The fragmental rocks in the basin are cut by dikes and irregular masses of alkaline rock, including latite-phonolite, syenite, phonolite, and alkaline basaltic rocks (lamprophyres).[2] Dikes of phonolite cut the surrounding pre-Cambrian granite throughout a large area (see Prof. Paper 54), and those of basaltic rock are found along mineralized zones in granite close by the breccia mass. In its south-central part the mass of fragmental rocks includes a small pipe of basaltic breccia, known as the "Cresson blowout."[3] It has been exposed to a depth of more than 2,000 feet, its lower part splitting into two roots or pipes.

[1]Needham, C. E., Gold and silver: Minerals Yearbook, 1942, pp. 80-84, 1943.

[2]For a detailed description of these and the pre-Cambrian rocks in the district the reader is referred to chapter 3 (by L. C. Graton) of Professional Paper 54.

[3]Loughlin, G. F., Ore at deep levels in the Cripple Creek district, Colo.: Am. Inst. Min. Met. Eng. Tech. Paper 13, pp. 5-7, 1927.

Loughlin, G. F., and Koschmann, A. H., Geology and ore deposits of the Cripple Creek district, Colo.: Colorado Sci. Soc. Proc., vol. 13, No. 6, pp. 252-261, 1935.

Origin.—CONCLUSIONS.—The early detailed geologic investigations made of the Cripple Creek district, first by Cross and Penrose[4] in 1894, and later by Lindgren and Ransome,[5] yielded the classic picture of a crater in pre-Cambrian rocks which was formed by explosive eruptions. Later work by Loughlin and Koschmann modified this picture to that of a composite crater that separated at depth into roots or sub-craters which had been formed at favorable places at intersecting fissure systems in the pre-Cambrian rocks.[6] A continuation of this work in 1934 and 1935, particularly in the newer mine workings in the eastern part of the district, revealed the presence of much well-bedded sandstone, shale, and conglomerate, derived mostly if not wholly from the pre-Cambrian rocks. As these beds were found as much as 1,000 feet below the surface and not far from the pre-Cambrian wall rocks the suggestion was made[7] that the floor of the basin may have subsided after the earliest stage of explosive activity, and that sedimentary material accumulated on the floor to be covered later by breccia and tuffs produced by renewed volcanic activity.

Field work since 1935 has shown that well-bedded and sorted rocks of non-volcanic as well as volcanic origin, were of very appreciable vertical and horizontal extent, and as a result of this evidence it has been concluded[8] that (1) the main mass of "breccia" occupies a pit or basin which owes its origin to intermittent subsidence along vertical or steeply dipping faults and is not a direct product of violent volcanic eruptions; (2) as the basin intermittently subsided it was gradually filled first with non-volcanic sediment and later with a thick accumulation of volcanic breccia; (3) the basin was a locus of intense igneous activity. Volcanic vents or necks from which phonolitic agglomerate could have been violently ejected have not been found, and it therefore seems likely that fissure eruptions accounted for the volcanic material, which was subsequently eroded and redistributed by running water.

Recent studies also suggest that the floor and walls of the basin consist of a number of fault blocks, differential and repeated movements of which produced some of the irregularities in the configuration of the basin described below, and also produced shear zones in the fragmental and adjacent pre-Cambrian rocks, which were filled with dikes and later with veins.

CONFIGURATION.—In general outline the Cripple Creek basin is rudely elliptical but in detail it is very irregular. (See pl. 26.) Its longer axis strikes northwest and long stretches of the basin wall are approximately parallel to this northwesterly axis, as is well

[4]Cross, Whitman, and Penrose, R. A. F., Jr., The geology and mining industry of the Cripple Creek district, Colo.: U. S. Geol. Survey 16th Ann. Rept., pt. 2, pp. 1-209, 1895.

[5]Lindgren, Waldemar, and Ransome, F. L., Geology and gold deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper 54, 1906.

[6]Loughlin, G. F., and Koschmann, A. H., Geology and ore deposits of the Cripple Creek district, Colo.: Colo. Sci. Soc. Proc., vol. 13, 1935.

[7]Loughlin, G. F., and Koschmann, A. H., Idem. p. 247.

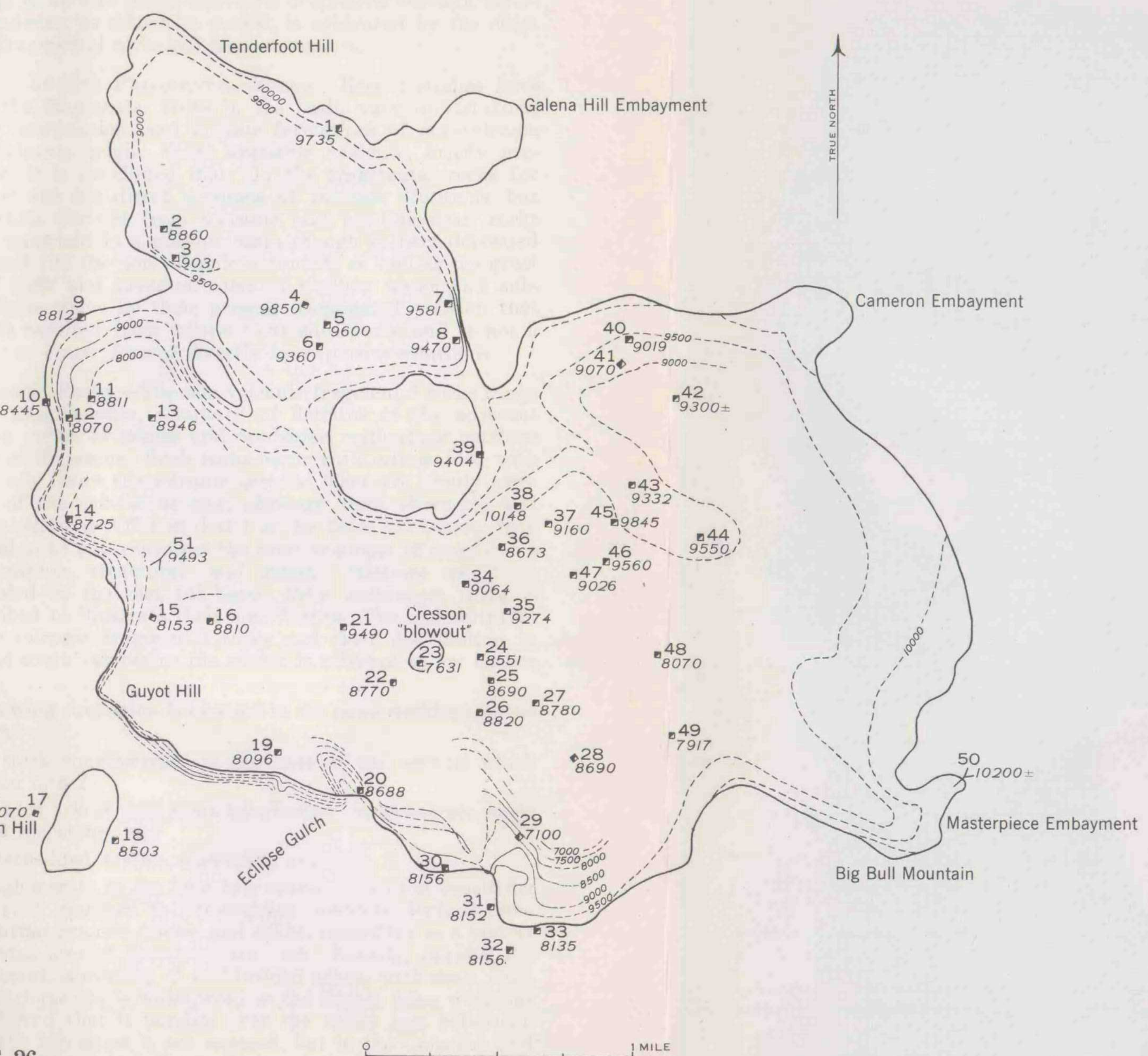
[8]Koschmann, A. H., New light on the geology of the Cripple Creek district, Colorado, and its practical significance: Colorado Mining Assoc., Denver, Colo., January 1941.

shown northwest of the Forest Queen mine and southeast of the Cameron mine. Shorter parallel stretches are also present southeast of the Theresa mine, between the Ajax and Queen mines, and northeast of Beacon Hill. Irregularities in its outline are produced by short though significant stretches of the wall of northerly and easterly trend, the intersections of which form several sharp bends and right-angle turns, notably along the south side of the basin. Three conspicuous embayments are also present along the basin wall—the Galena Hill and Cameron embayments on its northeastern side and the Masterpiece embayment on its southeastern side. The prevailing trends of the basin wall imply that the outline of the basin is locally governed by the strike and dip of the dominant fissures of the region.

The sub-surface structure and configuration of the basin can be deciphered only in a general way. Available data show that it is composite in structure and comprises 3 minor basins or sub-basins separated by buried granite ridges and spurs. The "island" of granite and farther west a smaller "island" of schist which crop out in the central part of the basin, are revealed by underground workings to grade downward into a granite ridge. Mine workings reveal that the schist "island" connects underground with the pre-Cambrian rocks that form the west wall of the basin. It probably connects also with the granite "island" to the east, although this connection has not been exposed underground. This ridge thus separates the basin north of the "island," hereafter referred to as the north sub-basin, from the larger one to the south, which will be referred to as the south sub-basin. The granite "island" also connects on the east with a buried spur of pre-Cambrian rock which is exposed in the Empire-Lee and Victor workings. Its southern extension, however, is not known. This spur in places rises at least 400 feet above the floor of the minor basin to the northeast, hereafter referred to as the east sub-basin, which it separates, at least in part, from the larger south sub-basin. It is significant that both the ridge marked by the schist "island" and the spur extending southeast from the granite "island" strike northwest and are in general parallel to the main axis of the composite basin.

There are also two buried spurs of pre-Cambrian rocks along the south side of the composite basin; one is exposed in the Portland and the other in the Queen workings, shown on plate 26. Besides the ridges and spurs the basin wall, where followed underground, has minor salients and reentrants and is irregular in detail.

The basin walls, as determined from underground exposures, are irregular but in general steep. In most places their average slopes range from 46° to 80° toward the center of the corresponding sub-basin. In places, however, notably along the southwest wall, they overhang, and in other places, as in the Cameron mine, they slope as little as 23°; in still other places they consist of gently sloping benches with steep walls above and below, as in the Ajax and Portland mines.



EXPLANATION

Actual and inferred slope of walls

9403 ◪ 50 Shaft

(Upper number refers to name in accompanying list; lower number to altitude of shaft bottom or of lowest level)

LIST OF SHAFTS REPRESENTED

1. Hoosier
2. Gold King
3. C. O. D.
4. Plymouth Rock No. 2
5. Deerhorn
6. Plymouth Rock No. 1
7. Forest Queen
8. Jerry Johnson
9. Abe Lincoln
10. Conundrum
11. Moon Anchor
12. Midget
13. Anchoria Leland
14. Index
15. Mary McKinney
16. Jackpot
17. El Paso
18. Mable M.
19. Elkton
20. Queen (Eclipse)
21. Joe Dandy
22. Moose
23. Cresson
24. Blue Bird
25. Dexter
26. Rose Nicol
27. Last Dollar
28. Clyde
29. Portland
30. Ajax } Granite
31. Dillon } mine
32. Strong
33. Independence
34. John A. Logan
35. Orpha May
36. Eagles
37. South Burns
38. Zenobia
39. Wild Horse
40. Cameron
41. Pinnacle
42. School Section (Block B)
43. Empire-Lee (Isabella)
44. Victor
45. Deadwood No. 1
46. Deadwood No. 2
47. Findley
48. Vindicator No. 1
49. Golden Cycle
50. Masterpiece tunnel
51. Anaconda tunnel

PLATE 26.

OUTLINE OF COMPOSITE CRIPPLE CREEK BASIN SHOWING:

(1) slopes of its walls by contour lines, and
(2) the positions of the deeper shafts with altitudes of their bottom or deepest workings.
(Modified after Fig. 8, Colo. Sci. Soc. Proc., vol. 13, no. 6, 1935)

That the composite basin described originated through intermittent subsidence, as stated on p. 389, is evidenced by the character of the fragmental rocks and local structures.

EVIDENCE OF THE FRAGMENTAL ROCKS.—Recent studies have shown that the fragmental rocks in the basin vary in structure, texture, and composition, and include formations of non-volcanic as well as volcanic origin. From available evidence, briefly presented below, it is concluded that (1) the fragmental rocks for the most part are not direct products of volcanic eruptions, but represent debris derived from volcanic and pre-Cambrian rocks and largely waterlaid in a shallow basin though in part deposited subaerially and (2) the non-volcanic sediments as well as the great thickness of tuffs and breccias, some of shallow water and subaerial deposition, show by their present deep-seated position that the basin has resulted from intermittent subsidence and is not a volcanic vent or crater formed directly by explosive eruptions.

Non-volcanic Rocks.—The non-volcanic fragmental rocks range from coarse conglomerate, composed of detritus of the adjacent pre-Cambrian rocks, to arkose and mudstone, with shale partings and laminae of limestone. Such rocks occur both interbedded with and strategically below the volcanic breccia. They are locally present in each of the sub-basins and, although their character and stratigraphic relations differ in detail in the three sub-basins, they are in general alike and represent the same sequence of events. As their stratigraphic, structural, and genetic relations are most clearly revealed in the east sub-basin, their occurrence there is briefly described to illustrate their significance. For a description of these non-volcanic fragmental rocks and their distribution in the north and south sub-basins the reader is referred to my earlier report.[9]

The following succession is exposed in the mine workings in the east sub-basin:

(1) A thick conglomerate at the base of the section which grades upward into 2;

(2) Bedded arkose with some interbedded conglomerate, shale and clay, and limestone; and

(3) Interbedded arkose, mudstone, and tuff.

The conglomerate at the base is a coarse formation consisting of poorly sorted, rounded to sub-angular boulders derived from the pre-Cambrian granite, gneiss, and schist, embedded in a matrix of finer detritus also of pre-Cambrian rock. Locally, channel deposits are present, consisting of well-bedded arkose with shale partings. The conglomerate is widespread in the deeper mine workings and it is inferred that it persists over the entire east sub-basin. The base of the formation is not exposed, but in the Cameron and Pinnacle mines it has a minimum thickness of about 400 feet. Its character, its total lack of volcanic detritus, and its relation to the

[9]Koschmann, A. H., op. cit., pp. 6-13, 1941.

pre-Cambrian rock surface imply that the conglomerate lies stratigraphically below and is older than the volcanic fragmental rocks.

The bedded arkose, into which the conglomerate grades upward, is at least 200 feet thick in the Cameron mine, and consists predominantly of feldspar, quartz, and mica fragments derived from the pre-Cambrian rocks. Interbedded with the arkose are shale partings, in which fossil leaves were found in the Cameron mine,[10] some lenses of conglomerate and laminae of limestone.

The upper part of the arkose contains increasing amounts of volcanic debris and thus grades into the overlying series of bedded volcanic fragmental rocks interbedded with which are layers of non-volcanic rocks—chiefly arkose and mudstone. In the School Section mine this interbedded series of rocks has been intricately folded and faulted on a small scale and is unconformably overlain by a coarse phonolite breccia, which contains boulders 6 feet or more in diameter.

Although the floor of the basin has not been exposed in mine workings, the total absence of admixed volcanic detritus in the exposed section of the basal non-volcanic rocks is significant in showing that the basin could not have been blown out, to be filled later with detritus washed back in. If the basin had been blown out by violent eruption, agglomerate would have partly filled the basin, forming its floor, and would also have blanketed the surrounding pre-Cambrian country rocks.

The widespread distribution of the basal non-volcanic rocks across the sub-basin, together with the occurrence of channel deposits and interbedded coarse and fine sediment shows that they were not deposited in a deep body of standing water, such as a crater lake, but rather in shallow water, possibly on an alluvial plain which intermittently subsided. The somewhat greater thickness of conglomerate near the margin of the mass of detritus suggests deposition in a basin bounded by fault scarps. The basin wall exposed in the Cameron mine has an average slope of 46° from the surface to level 8 and is clearly a scarp. In most places at which the contact has been seen, however, it is clearly one of deposition and indicates one or more periods of quiescence during which weathering and erosion locally reduced the slope of the basin wall and, where not interrupted by later movement, concealed the position of the fault itself.

Volcanic Rocks.—The prevailing fragmental rock in the basin is a volcanic tuff and breccia. It ranges from a fine-grained tuff in which the fragments are less than ¼ inch in diameter to a breccia in which the fragments range from ¼ inch to 2 inches in diameter. The prevailing breccia is decidedly unlike a true agglomerate which normally consists of unsorted volcanic debris in which boulders are mingled with fine-grained debris. Such coarse debris is found locally, but it pinches out in short distances. It forms only a small part of the volcanic fragmental rock, probably less than 5 percent.

[10] Loughlin, G. F., and Koschmann, A. H., op. cit., p. 246.

Most of the breccia is well-sorted and much of it is well-bedded. It is clearly volcanic detritus that has been reworked and laid down mainly under water. Some of the breccia now found at great depth also shows features characteristic of shallow water and subaerial deposition, including mudcracks, raindrop impressions, crossbedding, fossil footprints of birds, and structural unconformities. Such sorted and well-bedded breccia, showing features of shallow water and subaerial deposition, has a wide vertical as well as horizontal range,[11] and shows that the basin subsided intermittently. Subsidence apparently kept pace with accumulation, and deposits thus recognizable as having formed at the surface became buried to the greatest depths reached by mining—at least 3,350 feet in the Portland mine.

Source of Volcanic Breccia.—From the foregoing conclusion that the composite basin is not essentially a volcanic vent but is instead a product of subsidence, it is not to be inferred that the latite-phonolite and phonolite breccias were not primarily erupted locally. Such rocks are not found in adjacent parts of the region, from which they might have been brought into the basin. The breccia is cut by numerous dikes of latite-phonolite and phonolite whose presence clearly shows that the Cripple Creek basin was an area of volcanic activity and implies that early eruptions of latite-phonolite and phonolite supplied the great volume of breccia; however, no vents of agglomerate have been found that can be pointed to as actual sources of these volcanic products.

The only known pipe of agglomerate that has been found is the Cresson "blowout,"[12] but it consists of basaltic breccia and is later than the latite-phonolite and phonolite breccia and the dikes that cut it. It may be that the few irregular intrusive masses, such as irregular stocks of syenite exposed in the Vindicator and Rittenhouse workings may have occupied and thus obliterated vents. There may have been other early vents, but if they existed they have been covered by reworked breccia and lie below the deepest mine workings. Dikes, and solid masses of latite-phonolite and phonolite interpreted to be chiefly flows,[13] are by far the most abundant and widespread igneous bodies in the district, and from this fact together with the absence of any proved vents and of extensive agglomerate deposits, it is inferred that both flows and breccia are the products of local fissure eruptions.

STRUCTURAL EVIDENCE.—The accumulation of so great a thickness of bedded and stratified rocks, some with characteristics of shallow-water and subaerial deposition, at so great depth below the surface, and the bounding of these rocks by steep walls of pre-Cambrian rocks indicate that their present position is due to subsidence through faulting. Direct evidence of faulting along the contact is furnished by fault breccia, gouge, and slickensides found at many places along the contact. These features are well exposed

[11]Koschmann, A. H., op. cit., pp. 5-13, 1941.
[12]Loughlin, G. F., and Koschmann, A. H., op. cit., pp. 252-261, 1935.
[13]Koschmann, A. H., op. cit., p. 8, 1941.

in the southeastern part of level 8 of the Theresa mine, level 6 of the Portland No. 1 mine about 300 feet east of the shaft,[14] the northwestern part of level 15 of the American Eagle mine, the Cripple Creek and Gold Hill tunnel, the Forest Queen mine, the north end of level 2 of the Patti Rosa mine, the east end of level 5 of the Cameron mine, and the Masterpiece tunnel.

Although the emplacement of the breccia mass was brought about essentially by intermittent subsidence along faults, in places the contact with the pre-Cambrian rocks is clearly one of deposition, indicating periods of quiescence during which fault scarps were subjected to weathering and erosion, which locally reduced the angle of dip of the basin wall and produced many irregularities along it. Such contacts are well exposed in the Cameron and Patti Rosa mines. On levels 5, 6, and 7 of the Cameron mine a coarse breccia, in places bedded, with boulders as much as 6 feet in diameter, rests on solid granite, the contact dipping from 23° to 73° toward the breccia. At the south end of level 2 in the Patti Rosa mine well-bedded fine breccia rests on solid granite, and the contact dips 37° toward the breccia. In still other places, as in the Ajax, Independence, and Portland mines,[15] although the contact is in general steep, the breccia in places near the contact contains such an abundance of granite detritus resting against an irregular though firm wall of granite that it is also clearly a contact of deposition. The original boundaries of the sub-basins were essentially straight faults but through erosion of the exposed parts the basin was locally modified in outline. The walls thus receded from the fault along which subsidence took place, and the fault in such places became obscured or buried.

Vein Systems

Distribution and Relation to Structure.—One of the outstanding features of the vein system in the Cripple Creek district is the occurrence of relatively short individual veins in long narrow zones. Many of these vein zones lie close to the margin of the breccia mass, others persist for rather long distances into the breccia, and some cross the contact into the pre-Cambrian rocks for 2,000 feet and more. A structural analysis of the known vein zones shows that most of them approximately accord in distribution and strike with the abrupt bends or recessions along the contact or to such known internal structures of the basin as the buried spurs or ridges.[16] Vein zones in accordance with abrupt bends or recessions along the contact are notably illustrated by the Vindicator, Portland, Ajax, Queen, Elkton, and El Paso-Mary McKinney vein zones. Those more closely related to the internal structures of the basin include the Empire-Lee-Victor and some of the Portland-Ajax vein zones.

[14] Lindgren, Waldemar, and Ransome, F. L., op. cit., p. 28, 1906.

[15] Lindgren, Waldemar, and Ransome, F. L., op. cit., pp. 26-29.

[16] For a more complete description of the vein zones and their relation to the structure of the basin the reader is referred to the writer's earlier report: "New light on the geology of the Cripple Creek district, Colorado, and its practical significance."

The extent of the fissure or vein zones is in general indicated by the relative amount of recession of the contact. The Independence-Portland-Ajax vein zones, and the Mary McKinney-El Paso vein zones coincide with those places along the contact where the amount of recession is relatively large, and the conditions for late shearing action apparently most favorable. The Vindicator zone is approximately in line with the long recessional contact southeast of it. By contrast, the Queen and Elkton zones, which also lie along the south wall of the basin and are of relatively small extent, are related to relatively minor bends or recessions along the contact; but even these have been very productive. The fact that many of the known vein zones correspond in distribution and strike with the major bends and recessions along the contact or to internal structures should serve as guides in future prospecting.

Suggested Places for Prospecting

On the basis of the relation between the structure of the basin and the known vein zones the following places, which either have not been prospected or are inadequately explored, have been recommended for further study and prospecting:[17]

1. The south end of the Vindicator vein system, south of the Theresa mine.

2. The area to the south of the Queen mine, especially along the extension of the southerly-trending contact.

3. The northeast extension of the Gold Dollar-Mabel M. zone.

4. The northwest-trending contact west of the Anaconda tunnel and along its extension both in the breccia and granite.

5. The northwest-trending contact between the Index shaft and the Goodwill tunnel and its extension in the granite and breccia.

6. The west wall of the North basin which is marked by a series of step-like recessions of the contact.

7. Both walls of the Galena Hill embayment especially along their projected course in the breccia.

8. The contact east of the Patti Rosa mine and northwest of the Cameron mine.

9. Both walls of the Cameron embayment, especially along their projected course in the breccia.

10. The irregular contact north of the Masterpiece tunnel where stretches of contact of northerly trend alternate with stretches of northeasterly trend.

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[17]Koschmann, A. H., op. cit., pp. 26-28, 1941.

THE SAN JUAN REGION

By W. S. Burbank, E. B. Eckel, and D. J. Varnes

GENERAL FEATURES

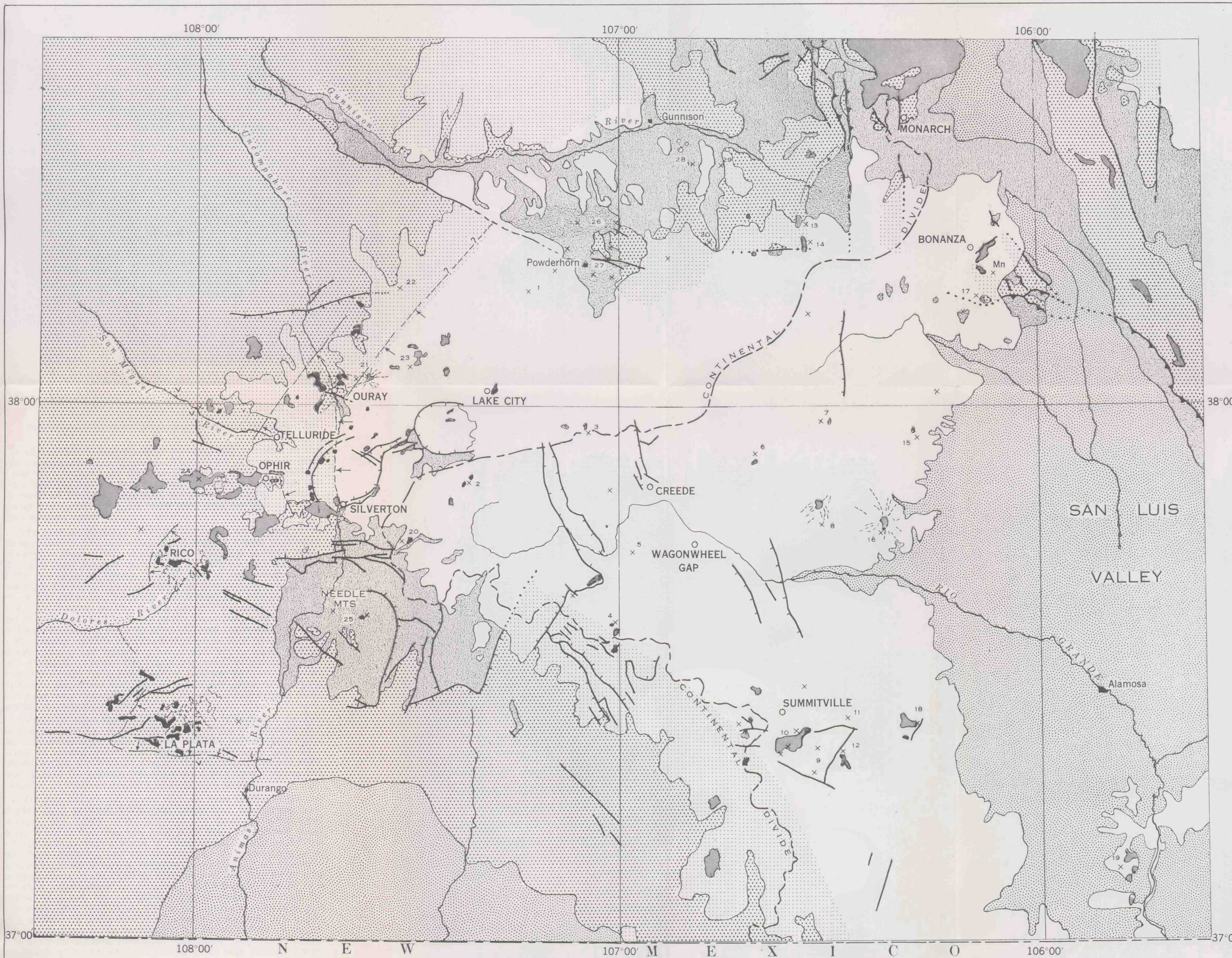
By W. S. Burbank

Geography and Economic Importance

The San Juan region as broadly defined covers an area of about 12,000 square miles in southwestern Colorado between longitudes 106° and 108° 15′ and latitudes 37° and 38° 30′ (pls. 4 and 27). Much of the country is composed of rugged mountains, and altitudes in the area range from 6,000 to over 14,000 feet. The continental divide enters the area from the northeast, loops westward to the vicinity of Silverton in the western part of the region, swings back east and passes southeast into New Mexico. The entire area east of the divide drains either into the Rio Grande, or into the San Luis Valley north of the river, and thence into the Gulf of Mexico. West of the divide the principal drainage basins are tributaries of the Colorado River, which flows into the Gulf of California. They are the Gunnison River, forming the north boundary of the region, the Uncompahgre, San Miguel, and Dolores Rivers on the west, and the Animas and other tributaries of the San Juan River on the south. The average altitude of the region is high, as fourteen peaks within the San Juan region rise above 14,000 feet and hundreds more above 13,000 feet. The broad mountain mass tends to precipitate moisture, and as a consequence the rainfall is especially heavy along the western and southern borders of the mountains. The annual precipitation in the mountains exceeds 40 inches and locally is more than 50 inches. Snowfalls of 20 to 40 feet have been recorded, and avalanches are not uncommon in some mountain areas in the western part of the region. Although temperatures are not subject to great extremes, winters in the more rugged parts of the mountains are long and relatively severe. Snow and transportation difficulties have retarded mining development and steady production from some areas.

The catchment basins at the headwaters of most of the streams are in areas of high rainfall, and consequently there are many large streams with steep gradients. Very little water power has been developed except for local plants in the western part of the mountains that have served to increase power available to the mining industry. The first industrial line in the United States using high voltage alternating current for transmitting power over a considerable distance was constructed near Telluride in the western San Juan in 1890-91. During the long cold winters the flow of all streams is greatly reduced. On streams of steep gradient small reservoirs may become quickly filled with debris from spring freshets and summer cloudbursts. Many reservoirs have been con-

PLATE 27.



GENERALIZED GEOLOGIC MAP SHOWING PRINCIPAL STRUCTURAL AREAS IN THE SAN JUAN REGION, COLORADO.

0 10 20 30 40 50 60 Miles

EXPLANATION

Tertiary and Quaternary sedimentary rocks and alluvium
(Only larger areas shown)

Tertiary volcanic rocks
(Dotted pattern indicates underlying sedimentary rocks)

Early and late Tertiary intrusive rocks
(Pre-volcanic and post-volcanic intrusive rocks not differentiated by symbols, smaller areas solid black)

Paleozoic and Mesozoic sedimentary rocks

Pre-Cambrian rocks

Principal high-angle faults
(Hachures on downthrown side where known)

Low-angle overthrust fault
(Triangles on upthrown side)

Monoclinal fold
(Arrows point to downfolded side)

o RICO
Principal town or large mining district

× 3
Other mining districts and mineralized areas

LIST OF MINING DISTRICTS AND AREAS OF MINERALIZATION

(Age designations of intrusive rocks refer to classification in Bulletin 843, U. S. Geological Survey)

1. Indian and Trout Creek. *(Center of Lake Fork volcano)*
2. Carson Camp. *(Intrusive center of Sheep Mtn. age)*
3. Mineral and Rough Creeks. *(Covered center of Fisher age)*
4. Near Piedra Peak. *(Stocks of Fisher age)*
5. Spar City. *(Covered center of Fisher age)*
6. Wanamaker Creek. *(Stocks of Conejos age)*
7. Royal Park. *(Intrusive rocks of Conejos age)*
8. Embargo district. *(Volcanic neck and center of Conejos age)*
9. Platoro and Lake Fork districts.
10. Stunner–Gilmore districts. *(Stocks of Conejos age)*
11. Jasper district.
12. Axel. *(Stock of Conejos age)*
13. Needle and Lakespur Creeks. *(Stock of granite porphyry)*
14. Razor Creek. *(Stock of Conejos age)*
15. Crystal Hill district. *(Center of Beidell intrusive rocks)*
16. Summer Coon district. *(Intrusive center of Conejos age)*
17. Columbia Gulch.
18. Gato Creek. *(Stock of Conejos age)*
19. San Luis Hills. *(Stocks of Conejos age)*
20. Bear Creek district.
21. Cow Creek.
22. Cimarron Creek.
23. Porphyry Basin.
24. Mt. Wilson district.
25. Needle Mountains district.
26. Cebolla district.
27. Iron Hill.
28. Chance, Iris, districts.
29. Cochetopa district.
30. Cochetopa Creek. *(Tungsten and mercury mineralization)*

PLATE 27.

structed to conserve water mainly for irrigation purposes in the valleys surrounding the mountains. The number of partial failures of reservoirs indicates the need for further study of this problem. It has been pointed out that many of the more suitable sites are the result of landslide or glacial moraine topography. Leakage through the coarse valley fill below such sites has been a serious factor in some instances.

The chief industries of the San Juan region are mining, stock-raising, farming, and lumbering, which support a total population estimated at about 50,000. A single standard-gauge railroad enters the region from Alamosa on the east and extends into the center of the mountains at Creede. On the west several narrow gauge lines enter the mountains short distances to important mining centers, such as Silverton, Telluride, and Ouray, and standard gauge lines serve Durango on the Animas River at the south and Montrose 30 miles northwest of Ouray on the Uncompahgre River. Many good auto roads cross the mountains, but local transportation within the mining districts is often hampered by lack of all-weather secondary roads and by the expense of maintaining roads, particularly during the winter. The region has many recreational attractions, but except for a few localities facilities have not been developed to the extent that they have in other parts of the State nearer the main lines of travel. This industry should become of increasing importance.

Somewhat more than half of the region is underlain by Tertiary volcanic rocks, which rest on a basement of Paleozoic and Mesozoic sedimentary rocks and pre-Cambrian metamorphic rocks. About 22 mining districts of appreciable magnitude have been defined within the volcanic area of the mountains. In the older rocks around the volcanic area there are 5 or 6 main districts and a number of other mineralized areas of some interest.

The San Juan metal mining districts have yielded to the end of 1945 about $446,000,000 in gold, silver, lead, copper, and zinc, or nearly one-quarter of the total value of these metals recovered in the State of Colorado (see table 8, p. 404). In addition, from 8 to 10 million dollars worth of other metals, chiefly vanadium, have been produced, but also included are tungsten, manganese, iron, and arsenic. Bismuth, cadmium, and antimony are recovered as by-products of the smelting operations on the base metal ores, but their value cannot be estimated. Molybdenum is found in a number of places, but not in quantities or grades that would insure commercial production. Pyrite in substantial quantities, possibly suitable for production of sulphuric acid and iron, is found in the western part of the mountains, but its utilization up to this time has generally been considered uneconomic. Deposits of alunite are known at 5 or 6 localities but have not been developed commercially. The total output of coal from the southern border of the mountains near Durango was more than 5,400,000 short tons ($11,000,000) to the end of 1944. The total value of fluorspar output from the San Juan is estimated to be of the order of magnitude of 2 million dollars, chiefly from one area, but 4 or 5 other localities have also produced or are potentially productive. Other non-metallic and construction materials produced, the values of which are not known, include bentonite or fuller's earth, sulphur, vermiculite, sand and gravel, granite, volcanic tuff, limestone, and brick and fire clay. Twelve large hot spring areas are known in the mountains and along their borders, and many of these have been developed for commercial purposes.

Metallogenetic Provinces of the San Juan

The San Juan region is superficially a high volcanic plateau which was formed in the Tertiary, and since that time has been deeply carved by erosion into the present mountains. The entire geologic history is complex, however, and at least six provinces of the region must be taken into consideration in defining the various metallogenetic epochs and environments under which mineral deposits were formed. Exclusive of construction materials, somewhat over 85 percent of the total value of metallic and non-metallic mineral output of the San Juan has come from the Tertiary volcanic rocks or from deposits directly related to them, about 10 percent was derived from metallic deposits around older intrusive centers within the Paleozoic and Mesozoic sedimentary formations, about 2 percent from metallic mineral deposits, chiefly vanadium ore, formed in sedimentary rocks which were not associated with igneous activity, 2 percent from coal deposits in the sedimentary rocks, about one-quarter of 1 percent from miscellaneous mineral deposits in the pre-Cambrian rocks, and about one-tenth of 1 percent from deposits of placer gold.

The various geologic formations are in part shown by the geologic patterns on plate 27 and are listed in more detail in table 7; their role in the formation and localization of the mineral deposits is briefly outlined in the following paragraphs:

1. The pre-Cambrian rocks consist of schist, gneiss, granite, and folded and faulted sedimentary rocks, chiefly quartzite, conglomerate, and slate. Faults and folds are commonly of northwest or east-west trend. These are the oldest recognized structural trends of the region, but they have been reactivated in later geologic times and have thus influenced the localization of igneous activity responsible for mineralization and the localization of individual deposits even in much younger rocks. Scattered ore deposits of probable and possible pre-Cambrian age are found on both the northern and southern flanks of the mountains, where the largest areas of such rocks are exposed. Production has been comparatively small.

2. The Paleozic and Mesozoic formations include chiefly marine and continental sedimentary rocks. They are the source of the coal deposits of the region. The total thickness of the sedimentary rocks is very great as shown in table 7. Locally they underlie the volcanic rocks of the mountains, as indicated roughly on plate 27, but have been largely removed from beneath the central part of the San Juan uplift. Folds and faults in these rocks along the

southern border of the mountains generally paralleled the folds and faults in the pre-Cambrian rocks. Along the west border, however, deformation at the close of both the Paleozoic and the Mesozoic eras formed northerly and northeasterly trending folds and faults. The intersection of these structures with the westerly and northwesterly trending pre-Cambrian structures probably influenced the localization of igneous activity in the formation of the ancestral San Juan Mountains described in paragraph 3. In the Mesozoic rocks concentrations of vanadium ore with a little chromium took place around the west and southwest borders of the mountains during or shortly after the period of sedimentation. This constitutes the second metallogenetic epoch. The Paleozoic and Mesozoic rocks are also important host rocks of silver-lead-zinc ore deposits of the third metallogenetic epoch which follows.

3. The third major event in the geologic development of the San Juan region was the formation of what may be called the ancestral San Juan Mountains. These mountains closely defined the outlines and formed the basement on which the volcanic accumulations rest. At the close of the period of sedimentation during the Mesozoic era the San Juan region was uplifted high above sea level, and the bordering sedimentary rocks were sharply folded and faulted at the edges of the main uplifted block. The uplift of the Needle Mountains area and the deepening of the San Juan basin to the south were accentuated, the folds and faults again following the older pre-Cambrian trends. The western border of the San Juan uplift underwent its most severe deformation at this time, and a series of intrusive rocks penetrated upward through the pre-Cambrian basement into the thick sedimentary cover. The conditions favored the formation of laccolithic domes above the centers of intrusion, and centers of mineralization at Ouray, Rico, and in the La Plata Mountains are all believed to have formed at this time along the hinge-line of northeast trend. This prominent zone of weakness would be favorable for igneous activity, and its intersections with certain strong northwest and west-trending pre-Cambrian and Paleozoic lines may very well have been responsible for the positions of the three known laccolithic centers. Except at Ouray, however, much of the direct evidence of structural control is concealed. At Ouray base and precious metal ore deposits were formed in blanket bodies and veins in both Paleozoic and Mesozoic rocks. These ores are definitely older than the volcanic rocks and were partly eroded before the volcanic eruptions of Tertiary time began. At Rico and in the La Plata Mountains the evidence for the age of the ores is furnished by analogy, and especially by the position of the two latter centers along the same hinge-line of late Mesozoic deformation that was responsible for the Ouray center. As mentioned above, this period of metallization has contributed approximately 10 percent of the total mineral output of the San Juan region, chiefly in silver, lead, and zinc. The chances that there exist undiscovered centers of this age still concealed by the younger volcanic cover will be mentioned in later discussions.

4. The fourth event was mainly one of destruction rather than formation of mineral wealth. The ancestral San Juan Mountains were eroded deeply and reduced for the most part to a sloping plain, which in the west spread out from the great center of uplift in the Needle Mountains. The resistant rocks of the Ouray, Rico, and La Plata centers of eruption remained as low hills or monadnocks rising from a few hundred to a thousand feet above this plain. The Needle Mountain core of highly resistant pre-Cambrian rocks remained as a central range several thousand feet above the level of the erosion surface at the borders of the present mountains. In the eastern San Juan Mountains the erosion surface remains concealed by later volcanic rocks so that its configuration is conjectural. It was probably a rolling plain, perhaps indented with broad valleys corresponding roughly to the present major drainage lines.

No mineral concentration of appreciable magnitude is known for this event in the history, but placer concentrations of gold could conceivably have formed in some of the gravels covering the plain about the sites of mineralization. Some oxidation and enrichment of ore deposits exposed on the erosion surface probably occurred. The erosion surface that was formed is, nevertheless, of considerable economic consequence in regard to future development of San Juan mineral resources. In the west it is commonly called the Telluride erosion surface, on which rests a covering of gravel, sand, and silt, known as the Telluride conglomerate. This surface, together with the conglomerate beds where present, marks the base of the Tertiary volcanic series. For some mineral deposits in the volcanic rocks, particularly where these rocks are underlain by softer sedimentary rocks, the Telluride erosion surface marks an approach to the lower economic level of development. To deposits of the earlier epochs it marks the absolute top of ore, wherever the deposits are still preserved beneath and up to the level of the surface. Beneath this surface where it is overlain by younger volcanic rocks there remain chances that older unexposed mineral deposits of the third epoch or even of pre-Cambrian age may be found. The favorable places for such concealed deposits, however, may be of small extent because of the necessary coincidence of structural and other environmental conditions that would be favorable to the formation of ore. In addition, at certain places the mineralization of late Tertiary age has been of more value in rocks beneath the erosion surface than in the younger volcanic rocks above. Particularly favorable combinations of circumstances are required, however, for relative enrichment of the late Tertiary veins in the basement rocks.

5. The fifth metallogenetic province is that of the Tertiary volcanic formations and their function in the formation of ore deposits. The period of volcanism extended over a large part of middle Tertiary time, and five main periods of eruption have been recognized, each separated by an erosion interval. These accumulations were more than a mile thick and formed a great irregular dome or series of plateaus over 100 miles across. Large numbers of

separate eruptive epochs yielded the flows, breccias, and other volcanic products. At least four or five of these were attended by some mineralization or alteration of the rocks about centers where stock-like bodies penetrated the basement and overlying volcanic rocks.

Near the close of volcanism in late Tertiary time the San Juan region as a whole was deformed relative to its surroundings. In most parts of the San Juan a collapse of the crust which had begun during the earlier volcanic epochs culminated in faulting and fissuring that localized many of the larger intrusive bodies and associated ore deposits. In the western part of the region the local sinking of crustal blocks and the consequent fissuring permitted the penetration of large intrusive bodies into the shallower formations. Further fracturing of the rocks during the final crustal adjustments about these centers provided fissures in which mineralizing solutions deposited the ores. In the eastern part of the San Juan region the flows were faulted and tilted eastward slightly; beneath the San Luis valley they are now covered by younger sedimentary deposits.

The structural lines and centers of eruption of the volcanic epoch perhaps do not bear as direct relation to inherited trend lines as did the structures of previous stages of mountain development, but the larger intrusive centers between Silverton, Telluride, and Lake City in the western San Juan region lie not far inside the earlier line of laccolithic intrusions. Also the series of northerly to northwesterly faults near Creede and farther southwest may reflect older zones of weakness related to the pre-Cambrian trends along the southwest border of the San Juan. A study of plate 27 will show other relations between older fault lines in the basement rocks and the locations of productive districts and prospected areas. For example, the Bonanza district and several small districts south of the Gunnison River lie near prominent lines of faulting and folding of westerly to northwesterly direction. Some of these relations may be significant, but they cannot be adequately appraised until more critical information has been accumulated by field studies.

From the areas immediately adjacent to the larger late Tertiary intrusive centers in the western San Juan region there has been derived about 80 percent of the total value of base and precious metals. Most of this mineral production has come from deposits in the volcanic rocks themselves. A small part of the late Tertiary ores mined, however, were formed in the underlying basement rocks beneath the Telluride erosion surface or its equivalent elsewhere in the region. Some of the ores in the pre-Cambrian rocks in Gunnison County and in the Needle Mountains area are believed to be of late Tertiary age. In San Miguel County ore has been mined from fissure veins in Paleozoic and Mesozoic sedimentary rocks, where the composition or texture of the rock favored open fissuring or replacement of the wall rocks.

Probably not over 1 percent of the total worth of late Tertiary ores has come from older rocks beneath the lavas, but this low ratio may not be representative of the potential value to be found in these deeper rocks; exploration has not in general been carried to this depth except where erosion has revealed the underlying deposits. It is not to be expected, however, that conditions in the sedimentary basement rocks during late Tertiary time have favored the blanket type of ore bodies formed in sedimentary rocks about the early Tertiary laccolithic centers. The late Tertiary fissuring in general produced through channels for the mineralizing solutions that extended to the surface of the volcanic plateau. The blanketing effects of the shale beds that were most effective at the time of formation of the early Tertiary ore deposits became greatly reduced in later Tertiary time because of partial destruction of the late Mesozoic rocks by erosion and also because such rocks became indurated and more readily susceptible to open fracturing.

6. Pleistocene and recent glaciation and erosion began after volcanism declined and have produced the present mountainous topography as well as some mineral concentrations of appreciable importance. Five major cycles of erosion and glaciation are recognized, but possibly the most important of these economically is that of the Florida cycle of erosion, which just preceded Pleistocene glaciation. This cycle probably began by a relatively gradual uplift of the country as a whole rather than by appreciable doming of the San Juan region itself. The rejuvenated streams began by cutting canyons which were gradually broadened into wide valleys as much as 2,000 feet below the surface in the central part of the original volcanic plateau. Near the margins of the volcanic plateau the cutting was much less deep, amounting to only a few hundred feet, and the streams deposited their loads to form gravel-covered benches that still remain around the mountains and now identify this cycle of erosion. At the end of this erosion period the circulation of ground waters was fairly deep in the central parts of the mountains, but erosion was not rapid enough to remove all the products of weathering. Consequently veins now cropping out on or near remnants of the Florida surface show stronger and deeper effects of oxidation and enrichment than veins that became subject to later cycles of glacial erosion and canyon cutting.

Thus in the Creede district, where broad remnants of the early Florida surface remain, the ores that had formed in the great silver-bearing lodes along faults were greatly enriched during this period. Possibly as much as three-fourths of the silver value of the ore may be apportioned to this enrichment, or from 15 to 20 percent of the total silver production of the San Juan region. Not many veins in other districts were as favorably situated with respect to this surface, so that the bulk of the remainder of San Juan metal production comes from primary unenriched ores.

The later cycles of glaciation and canyon cutting that followed the Florida cycle of erosion were produced likewise by additional stages of uplift and renewed erosion, but none advanced to the mature stage of the Florida cycle. Glacial and lower bench gravels formed during these later stages and modern stream gravels contain concentrations of placer gold from which a small output, probably not exceeding $300,000 to $400,000 in value has been made.

Manganese ore produced in the San Juan is the result of oxidation of primary manganese-bearing minerals in veins or came from spring deposits and warm waters circulating in volcanic and sedimentary formations just after the close of active volcanism. Locally the manganese has been deposited directly from warm spring waters in the oxide form, either in cavernous limestone and travertine or in certain bedding deposits in lavas and tuffs. Recent deposits of relatively high-grade bog manganese are known, but little or no production has been made from them. The total yield of manganese ore is about one or two hundred thousand dollars in value, chiefly from Saguache, San Juan, Gunnison, Ouray, and Hinsdale counties. Bog iron deposits were mined locally in the early history of the region but are not now of economic importance. In at least one instance, however, sufficient detrital gold was concentrated with bog iron derived from iron pyrites to justify working the deposit in a small way to recover the gold.

Metal Mining

Introduction.—The metal mining industry in what was called the San Juan country began in the early seventies, although there are some records of earlier prospecting activity in eastern counties and in Gunnison County to the north. The country developed rapidly and, except for the first gold placer discoveries, the early history of the region shows that the miners had a primary interest in silver ores. By 1874 nearly four-fifths of the locations made were silver lodes. In the late seventies smelters did not pay for ore carrying less than one ounce of gold, and so the famous Camp Bird gold vein though filed on in 1877 was not recognized for its real worth until nearly 20 years later. In 1890 treatment of low-grade ores by concentration and amalgamation at the Sunnyside and Silver Lake mines near Silverton started a new period in mine development. From 1894 into the early nineteen hundreds gold recoveries increased, and in most of the western camps its values exceeded those of silver. Lead output remained throughout of substantial value. Copper was only partly recovered and was subject to appreciable loss also in the smelting operations. Zinc was first recovered as a marketable product at the Silver Ledge mine north of Silverton in 1904. Until comparatively recently the complex mineralogy of the San Juan primary ores offered problems that defied common milling practice. The first large-scale selective flotation mill successfully separating lead and zinc came into operation in 1917-1918 on ores of the Sunnyside vein. The ultimate three-way separation into lead, copper, and zinc concentrates has been accomplished only since the beginning of 1945 on ores of the Black Bear vein milled at Red Mountain.

Table 8. Production of gold, silver, copper, lead, and zinc in the San Juan inclusive, in terms of recovered or recoverable metals. allocated or apportioned to geologic

PROVINCE, COUNTY, AND PRINCIPAL DISTRICTS	ORE (Short tons) (Partial record only)[1]	GOLD		SILVER	
		Ounces	Value	Ounces	Value
Early Tertiary (Laccolithic)					
Dolores (Rico, Dunton)..	525,961	103,104	$ 2,196,108	13,804,680	$ 10,562,143
La Plata................	100,920	211,506	4,692,197	2,039,893	1,303,545
Ouray (Uncompahgre)[2]..	450,000[3]	187,790	4,033,300	7,442,500	5,708,600
Total, Early Tertiary......		502,400	$ 10,821,605	23,287,073	$ 17,574,288
Late Teritary (Volcanic)					
Eastern and Central San Juan					
Archuleta		110	$ 2,819	552	$ 338
Conejos (Platoro, Gilmore, Stunner)......		1,884	39,306	57,026	34,074
Mineral (Creede)......	1,399,132	136,639	2,889,006	54,409,621	35,795,255
Rio Grande (Summitville, Embargo).....	249,077	253,214	6,853,869	424,270	343,971
Saguache (Bonanza)[4]..	597,778	19,207	428,689	5,610,048	3,717,060
Western San Juan (Silverton and Lake City volcanic center)					
Ouray (Sneffels, Red Mountain, Upper Uncompahgre)	2,018,110	1,693,037	36,401,286	37,169,392	28,495,053
San Juan (Eureka, Animas)	8,266,419	1,557,203	35,809,050	40,412,952	27,421,031
San Miguel (Telluride, Ophir)	13,177,392	3,395,081	73,362,157	51,329,809	37,255,226
Hinsdale (Galena, Lake Fork)	83,780	71,140	1,477,026	5,778,266	4,674,615
Total Silverton center....		6,716,461	$147,049,519	134,690,419	$ 97,845,925
Gunnison and Montrose (Cebolla, Cochetopa, etc.)[5]		....	....	....	....
Total Late Tertiary........		7,127,515	$157,263,208	195,191,936	$137,736,623
Grand Totals..............		7,629,915	$168,084,813	218,479,009	$155,310,911
Percentage of State Total..		20		27.5	

[1]Records of tonnage mainly from 1904-1944.
[2]Total county production divided between early and late Tertiary deposits on the basis of partial records, and hence figures are not significant to the values shown in the table.
[3]Figure includes about 120,000 tons recorded prior to 1904, but not a complete record.
[4]Figures for county include probably less than ½ of 1 per cent from districts outside of the San Juan region.
[5]Includes an unknown output from deposits of probable pre-Cambrian age.

region by counties and geologic provinces from earliest production to 1945, (Compiled from figures of the U. S. Bureau of Mines, and provinces by W. S. Burbank)

COPPER		LEAD		ZINC		
Pounds	Value	Pounds	Value	Pounds	Value	Total Value
9,986,939	$ 1,642,852	104,057,085	$ 6,128,998	89,930,916	$ 7,215,691	$ 27,894,227
288,576	46,087	726,183	38,708	....	....	6,080,537
5,045,300	699,500	33,179,300	1,500,500	525,340	50,100	11,992,000
15,320,815	$ 2,388,439	137,963,568	$ 7,668,196	90,456,256	$ 7,265,791	$ 45,966,764
....	....	800	$ 47	2,000	$ 130	$ 3,334
4,815	$ 797	3,400	149	....	....	74,326
639,688	91,076	207,791,549	9,379,797	27,699,407	1,522,154	49,677,288
554,797	67,393	112,747	6,321	....	....	7,271,554
15,728,254	2,263,553	38,882,356	2,377,273	6,012,148	532,103	9,318,678
22,401,461	3,105,207	144,332,550	6,607,107	5,298,910	539,300	74,147,953
76,852,718	10,909,472	502,629,595	27,606,170	228,278,684	15,664,885	117,423,819
20,371,466	3,208,113	253,106,390	14,310,099	27,231,182	2,261,111	130,396,706
2,956,840	415,275	99,474,899	4,150,617	1,354,634	76,821	10,794,354
122,582,485	$17,638,067	999,543,434	$52,673,993	262,163,410	$18,542,117	$332,762,832
....	....	....	....	....	....	750,000
139,510,039	$20,060,886	1,246,334,286	$64,437,580	295,876,965	$20,596,504	$399,858,012
154,830,854	$22,449,325	1,384,297,854	$72,105,776	386,333,221	$27,862,295	$445,824,776
	34.5		30.6		14.3	23.0

As the complexity of the ores imposed restrictions upon mining, the records of production of many San Juan districts fail to reveal the overall metal content of the veins that were worked. Much ore was left in the ground through selective mining operations to avoid costs of handling and penalties for zinc, and much labor was also expended in sorting ore brought to the surface. Considerable zinc in ore shipped to smelters was not recovered. In recent years treatment of old dumps has recovered a little of these losses, but they remain substantial. The mining and metallurgical history thus tended to foster an impression that San Juan mineralization was predominantly a gold and silver type of relatively shallow depth. Many small operations for recovery of these metals stopped when the massive sulphide ores were reached. Deeper developments and output in later years have counteracted this impression. Nevertheless, the costs of handling and treating low-grade complex ores remain comparatively high so that many large veins are of marginal or submarginal value.

With a few exceptions the mining industry of the San Juan has had neither spectacular booms nor prolonged periods of depression, but has shown a gradual shift of emphasis in keeping with the economic trend. More recently there has been greater attention to deeper mining and consolidation of properties in many districts, giving reason to believe that a new era of more efficient exploration and development is under way. With forseeable improvements in mining and milling practices, increased demands for the base metals, and with better knowledge of the geologic factors controlling localization of the various kinds of ore, the future of the region should easily equal the steady 70-year record of the past.

Production.—The summaries of total production of the San Juan region by counties up to and including close estimates for 1945 have been reassembled in table 8 on page 404. Reassembling of the common tabulations has been made in order first to bring together districts representing the two most productive metallogenetic epochs, early Tertiary and late Tertiary, and secondarily to make certain geographic and geologic groupings. In separating early and late Tertiary mineralization, it has been necessary to apportion the production of Ouray County between the Uncompahgre district and other districts in the county based upon ratios of metals produced in the principal mines and upon the total production of the larger mines in the Uncompahgre district. The splitting of the total figures for Ouray County into two geologic provinces consequently gives results that are not significant to the numbers shown in the two parts. Records of individual mine production prior to 1905 are not available in most instances, particularly for many smaller operations that amounted to an appreciable output in the aggregate. Separation of ores of possible or probable pre-Cambrian age is not attempted, but most of the output came from the southern part of Gunnison County. The estimate for this part of the county is based upon a prior one by Larsen and indicates that the total output, partly representing ores of pre-Cambrian age, is approximately $500,000 to $1,000,000.

Yearly production of the San Juan region has been fairly steady. It exceeded $1,000,000 in value in 1881, and has in general fluctuated between $5,000,000 and a maximum of over $12,500,000, attained in 1907. Since 1938 the value of the yearly output has ranged between 5 and 6 million dollars.

Descriptions of the major districts are given in two groups based on age of mineralization, early and late Tertiary, and within these groups where possible by geologic affinities, thus providing the best background for their comparison. Many small districts and areas in which prospecting has been done cannot be considered individually in this review. Locations of most of these are shown on plate 28, and further information may be found for some under the bibliographic references listed by counties in part I of this bulletin.

The totals and sub-totals of production for various geologic units of the San Juan region afford a partial comparison of the distribution of metal values, but in making these comparisons account should be taken of the factors of actual metal recoveries and of the mining history as noted above. The effects of zoning may be noted in several instances. The early Tertiary laccolithic deposits perhaps show this most strongly. The ratios of gold to silver and of total precious metal to base metal are highest in the La Plata district, which is the least denuded of the laccolithic centers. Most of the production has come from deposits relatively high in the geologic section, notably in the Jurassic and Cretaceous sedimentary rocks. Some production has come from parts of the Carboniferous rocks, and near some of the intrusive bodies copper ore has been mined. The Uncompahgre center at Ouray is next in these ratios, where notable production of precious metals has come from the Cretaceous and Jurassic rocks, but including some from the Leadville limestone of Mississippian age. The Dolores (Rico) district, which of this group has yielded the greatest proportion of lead and zinc, yielded ore mainly from the lower Hermosa formation (Pennsylvanian), but some ore including copper, lead, and zinc has come from the Leadville (Mississippian) and Ouray (Devonian) limestones. The recovery of zinc, however, has been practiced more consistently in this district than in either of the other two.

In the late Tertiary group of districts, the counties covering the Silverton caldera illustrate some lateral zoning outward from the center of volcanic activity and intrusions. Vertical zoning is apparent also in these areas although scarcely expressed by the county figures. San Juan and Ouray counties near the center have the highest ratio of copper to other base metals. San Miguel County, averaging farthest from the center, has the highest ratio of precious metals to base metals. In the eastern San Juan country, Saguache and Rio Grande counties have the highest relative copper recoveries, both producing from districts closely related to intrusive centers. Mineral County has a high precious metal to base metal ratio, chiefly because of silver values. This is partly accounted for by lack of close relation to a large intrusive center and partly by secondary enrichment of the silver ores near the Florida erosion surface.

Hinsdale County, representing chiefly the Lake City area, is to some extent an eastern prong of the Silverton center and partly a separate center of later age. As in San Juan County, base and precious metal values are nearly equal. This equality would be more pronounced in the figures for both counties if recoveries of zinc and copper had compared favorably with those of other metals.

The output from Gunnison County in the northern part of the San Juan is chiefly gold and copper, coming from veins and lenses in pre-Cambrian rocks. They seem related to a moderately high temperature mineralization, in part pre-Cambrian, as the tourmaline-bearing gold-quartz veins* and in part Tertiary, which includes the veins that are related to local small intrusive bodies. The age of the copper mineralization is not established, but some of it is conceivably older than the late Tertiary.

*Hill, J. M., Notes on the economic geology of southeastern Gunnison County, Colorado: U. S. Geol. Survey Bull. 380, pp. 21-40, 1909.

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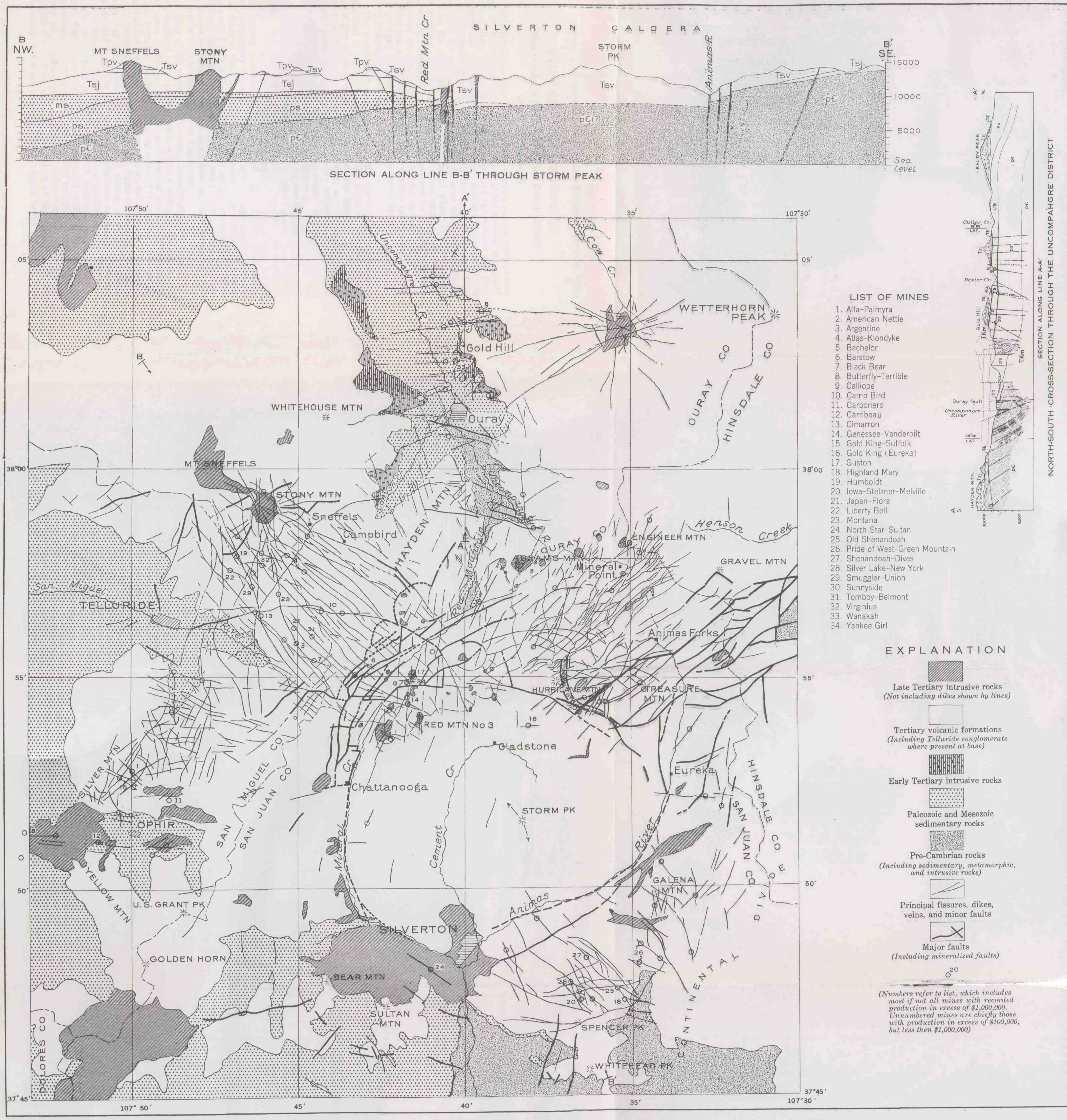


PLATE 28. GEOLOGIC MAP SHOWING STRUCTURE OF THE SILVERTON VOLCANIC CENTER AND NEARBY AREAS, OURAY, SAN JUAN, SAN MIGUEL, AND HINSDALE COUNTIES, COLORADO.

1 0 1 2 3 4 6 MILES

Section along line A-A'	Section along line B-B' through Storm Peak	
		Late Tertiary intrusive rocks are shown in same pattern as map.
		Tertiary volcanic formations
	Tpv	Potosi volcanic series
	Tsv	Silverton volcanic series
Tsj	Tsj	San Juan tuff
TE		Telluride erosion surface
TKm		Early Tertiary intrusive rocks, chiefly quartz monzonite porphyry
	ms	Mesozoic sedimentary rocks
Ku		Upper and Lower Cretaceous sedimentary rocks
JR		Triassic and Jurassic sedimentary rocks
ps	ps	Paleozoic sedimentary rocks
pЄ	pЄ	pre-Cambrian rocks

EARLY TERTIARY ORE DEPOSITS

Uncompahgre (Ouray) District, Ouray County

By W. S. Burbank

Introduction.—The Uncompahgre district covers considerable parts of three townships in Ouray County at the western margin of the San Juan Mountains. The main part of the district and particularly the part containing the early Tertiary deposits covers about 15 square miles in the vicinity of the town of Ouray. This district is the only one in the San Juan area where the relations between the older and younger epochs of mineralization during the Tertiary may be determined by direct geologic observation. Parts of the Telluride erosion surface covered by volcanic rocks are preserved throughout the area, and in the canyons the upward terminations of the older veins at this surface are clearly exposed. The younger veins cut both the older rocks beneath the surface and the overlying volcanic formations.

The commercial development of the mining district has been controlled to a very large extent by the physical features of Uncompahgre canyon, which cuts through the heart of the mineralized area. This canyon and its tributaries are carved through the volcanic rocks deeply into the ore-bearing sedimentary formations, thus exposing the ores and their associated structural features which would otherwise have been effectively concealed. As the rocks through a vertical range of nearly 6,000 feet are thus exposed within an area only a few miles across, many structural features of San Juan geology spanning the period from the pre-Cambrian to late Tertiary are strikingly revealed. At the canyon bottom crosscutting intrusive bodies and dikes penetrate the Carboniferous sedimentary rocks and 2,000 feet above spread out in laccoliths and sheets at the base of the Mancos shale. The mineralizing solutions rose beneath the laccolithic dome along the crosscutting dikes or along fissures and then spread laterally along favorable open or porous sedimentary beds or along fissures where these cut rocks that were readily susceptible to fracturing.

Most of the mining of the older, more productive deposits has been confined to the canyon walls within a radius of 3½ miles from the town of Ouray. In 1875 gold-bearing lodes were discovered in the Permian and Pennsylvanian rocks of the canyon walls within sight of the town, and a little later silver-lead deposits in the Leadville limestone just south of the town. Some deposits of high-grade silver-lead ores were discovered and mined in following years, among which may be mentioned the Calliope ore body in the Dakota quartzite. This was brought into production in 1887 and yielded ore valued at several hundred thousand dollars prior to 1890. The discovery of phenomenally rich gold ore in the Dakota quartzite at the American Nettie in 1889 resulted in rapid development of adjoining gold properties, which together subsequently yielded the bulk of the gold production of this camp. Although the silver-lead lodes extending to the main valley sides had been known for many years the principal silver ore body in the Dakota quartzite in the Bachelor was not discovered until 1892. During the height of its production about 1895 this property shipped about 30 cars of crude ore monthly, and the production and profit sustained for a period of about 2 years exceeds that of any other mine in the district. Since that time developments in the district have followed the pattern of other San Juan districts in attempts to treat lower-grade ores by milling and in search for additional shoots of high-grade gold and silver ores. Since 1931, the Banner American 100-ton custom mill, later operated as the General Ore Reduction Co., permitted continued small production of lead-silver-zinc ore, coming partly from the older veins, to be made through the World War II period.

The early Tertiary vein deposits of the district in comparison with those of the later Tertiary in other districts offer complications adverse to most efficient mining. As the better ore shoots tend to follow certain favorable horizons in the bedded sedimentary rocks, which dip northward or eastward and away from the Uncompahgre canyon, lateral developments to deeper levels require either long transportation tunnels or inclines to service them. Even with this handicap, however, the district may be expected to remain a small contributor of low-grade ores already within reach of mine workings and to yield additional bodies of high-grade gold and silver ores. The possibility of future developments at much deeper levels below the valley floor in the Leadville and Ouray limestones and farther east or northeast beneath the Telluride erosion surface involve risks and expenditures that are not likely to be undertaken without the incentive of very much higher metal prices or through subsidizing of exploratory operations.

Geology.—The sedimentary rocks of the Uncompahgre district include most of the formations shown in table 7, page 398, from the pre-Cambrian to the Upper Cretaceous Mancos shale, and total about 4,000 feet in thickness exclusive of the pre-Cambrian quartzites and slates. The Cambrian quartzite is missing at Ouray and the equivalent of the Rico formation is not recognizable there. The Dolores formation of Jurassic (?) and Triassic age is commonly less than 100 feet thick in this district, and the overlying Entrada sandstone is also thin.

The structure of the district is that of a laccolithic dome formed chiefly by spread of laccolithic tongues either near the base of the Morrison formation (Jurassic) or at the base of the Mancos shale (Upper Cretaceous). A few thin sills were intruded in the Hermosa and Cutler formations but not to the extent found in the Rico and La Plata laccoliths. The intrusive bodies were mostly porphyritic quartz monzonites or related rocks and dikes of similar texture. A few small bodies of non-porphyritic rock of similar composition are intruded near the central zone of eruptive activity that crosses the Uncompahgre canyon northeasterly.

The zone of eruptive activity is situated near a sharp turn in the strong monoclinal folds of late Paleozoic age. A faulted nose of the late Paleozoic San Juan uplift made by this sharp turn pitches northwesterly (fig. 9 and pl. 27) and forms a cross-axis of folding, which is repeated in the late Mesozoic or early Tertiary structures as indicated by the "Uncompahgre axis" of folding in figure 9. These cross-axes may very likely have localized the intrusive and mineralizing activity where they intersect the northeast-trending hinge-line of the early Tertiary San Juan uplift.

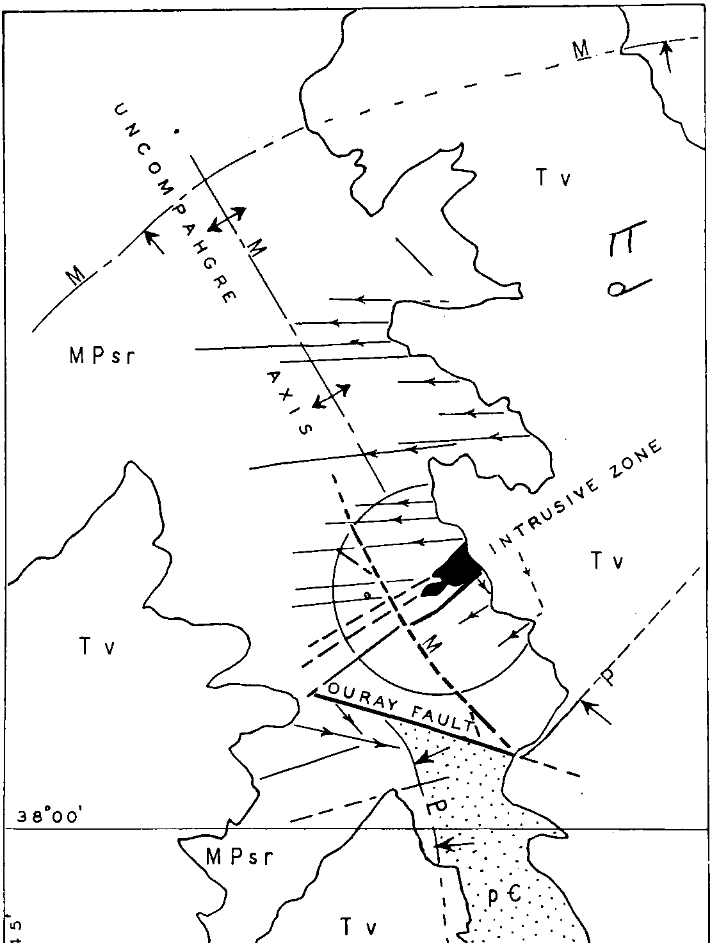


FIGURE 9.—Structural map of the Uncompahgre district, Ouray County, Colorado.

(pC, pre-Cambrian rocks; MPsr, Paleozoic and Mesozoic sedimentary rocks; Tv, Tertiary volcanic rocks; large single arrows with lines marked P represent late Paleozoic monoclinal folds—with lines marked M, late Mesozoic monoclinal folds; the Uncompahgre axis represents a broad anticlinal fold of Mesozoic age; the early Tertiary intrusive stock is shown in black within a circle including the central area of gold mineralization; small arrows along lines of fissuring indicate the general directions of movement of mineralizing solutions.

Most of the dikes terminate upward beneath the level at which the laccolithic bodies spread out, but a few cut through these bodies and up to the Telluride erosion surface. The crosscutting bodies near the intrusive center, locally known as the Blowout, are the site of much alteration of the sedimentary rocks, and the porphyritic rocks themselves are likewise altered.

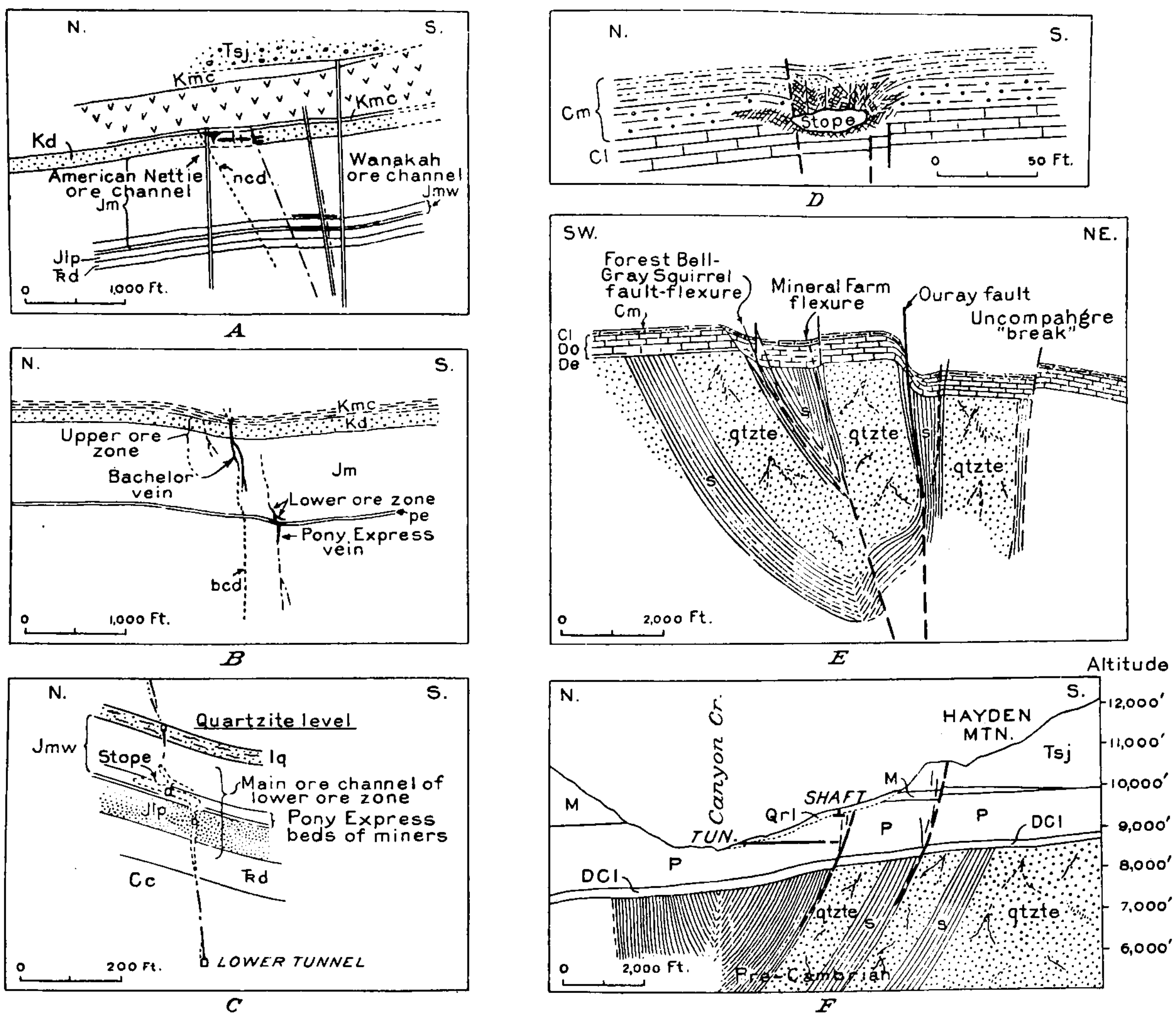
Mineralization is younger than the porphyritic rocks as it locally follows the walls of dikes and spreads beneath some of the overlying sills and laccolithic bodies. Injections of clastic material forced upward by explosive eruptions of gases and vapors preceded and accompanied the mineralization and carried upward fragments of rocks from great depths. The presence of pre-Cambrian granitic rocks in some clastic dikes indicate that such rocks, in addition to the exposed pre-Cambrian quartzite and slate, underlie the area. All dikes and veins terminate upward at the base of the Telluride erosion surface, except a few veins and a few dikes clearly related to younger volcanic centers near this area. In most instances the older veins failed to penetrate much above the base of the Mancos shale, as this formation was not favorable to open fissuring.

Erosion that produced the Telluride surface reduced the Uncompahgre dome to remnants of a few resistant laccolithic tongues and harder mineralized rocks, which now form low monadnocks rising a few hundred feet above the general level of this surface. It appears doubtful if this erosion destroyed many ore deposits close to the Uncompahgre valley, since over much of the strongly mineralized area the Mancos shale was the oldest formation stripped by erosive activity at this time.

Ore Deposits.—The ore deposits have great diversity of form, ranging from typical fissure veins to flat-lying bedding-plane replacement deposits. As shown in plate 29 intermediate deposits having characteristics of both types are found. The veins not uncommonly flatten and offset horizontally at certain favorable horizons in the gently dipping sedimentary rocks forming rolls along which high-grade ore may be localized. At some distance above and also below such rolls a vein may contain comparatively little ore, and this condition coupled with the evidence showing lateral injection of the clastic dikes indicates that the ore solutions locally tended in some veins to follow up the bedding of the rocks along these favorable rolls. Thus in the most productive part of the district north of the main intrusive zone, the solutions moved up along the beds and along fissures from east to west (fig. 9). The source of the solutions responsible for the greater part of the productive ore bodies was therefore east of the valley and deep beneath the Telluride erosion surface, which is now covered here by as much as several thousand feet of Tertiary volcanic rocks. Along the intrusive zone the lower Paleozoic limestones lie two thousand feet or more beneath the valley bottom, so that prospecting at depth or laterally for additional ore shoots is blind and much more hazardous than is the case with the younger Tertiary veins.

PLATE 29.

PLATE 29.



A, Generalized section through the American Nettie-Wanakah flexure and ore channels.
B, Generalized section through the Pony Express and Bachelor veins and flexure.
C, Section through the Pony Express vein and bedding channel.
D, Section through the Mineral Farm ore channel, at contact of Molas formation and Leadville limestone.
E, Idealized section in southern part of district, with restoration of eroded parts of the lower Paleozoic limestone: shows relations of the main faults and folds in the pre-Cambrian basement to faults and flexures in the immediately overlying Paleozoic limestones.
F, Section approximately through the New Mineral Farm mine on the north slope of Hayden Mountain; approximate position of concealed syncline in slate beds of Uncompahgre formation is indicated; tunnel on north-south vein is nearly parallel to plane of section.

Qrl, Quaternary and Recent landslide and morainal debris
Tsj, San Juan tuff
Kmc, Mancos shale
Kd, Dakota (?) sandstone locally altered to quartzite
Jm, Morrison formatian, which includes the Pony Express limestone breccia of miners (pe) and the lower quartzite of miners (lq)
Jmw, Wanakah member of Morrison formation
Jlp, lower La Plata sandstone of miners
d, Dolores formation
M, Mesozoic formations undifferentiated
Cc, Cutler formation
Cm, Molas formation
Cl, Leadville limestone
DCl, Devonian and early Carboniferous limestones
Do, Ouray limestone
De, Elbert formation
P, Paleozoic formations, Molas, Hermosa, and Cutler, undifferentiated
s, slate of Uncompahgre formation
qtzte, quartzite of Uncompahgre formation
ncd, Nettie No. 2 clastic dike of miners
bcd, Bachelor clastic dike

(From plate 54, U. S. Geol. Survey Bull. 906-E)

TYPES OF STRUCTURAL CONTROL OF ORE DEPOSITION IN THE UNCOMPAHGRE DISTRICT.

It is quite conceivable that ore deposits may have formed in the older Paleozoic limestones beneath the Tertiary volcanic cover along the northeastward extension of the monoclinal fold exposed in the southeastern part of the district, more especially where east-west fissures and dikes intersect this fold. If the fissures persist in this direction, such an intersection might lie as much as 3 miles east of the canyon and beneath a thick covering of volcanic rocks. All evidence that might aid in determining the presence or absence of favorable structural conditions on the limb of this uplift is effectively concealed by the volcanic rocks.

There is considerable diversity in the composition of the mineral deposits, which may be roughly divided into four groups: (1) magnetite-pyrite ores containing a little copper and gold; (2) pyritic ores containing copper and gold; (3) pyritic base metal ores containing native gold, with gold and silver tellurides; and (4) siliceous and baritic ores containing silver, lead, and zinc, but commonly little gold. This grouping represents mainly the zoning outward from the intrusive center. Silver-rich minerals of the gray-copper group are present in many ores and form the most widely distributed of the valuable minerals. The silver-lead-zinc veins have had the highest gross productivity, but the gold and silver ore of group (3) have yielded high returns on a few fortunate but smaller operations.

The contact metamorphic deposits formed chiefly in the thin limy beds of the Dolores formation and the Pony Express limestone member of the Wanakah formation and were locally enriched in gold along small fissures later than the pyrite and magnetite. Much of the pyrite and magnetite that replaced these limy beds is very low-grade or barren. The major gold production was yielded by pyritic deposits in the Dakota quartzite, the beds of which originally were sandstone and have been altered to quartzite for several miles about the center. These deposits, with or without tellurides of gold and silver, are in the form both of veins along dike walls and fissures and of replacement deposits and open channel fillings that follow certain zones along the bedding of the quartzite. Some pyritic ore of this kind also was formed in fissures along dike walls and in sandstone beds in the lower part of the Mesozoic strata and in the Cutler and Hermosa formations.

The silver-lead production has come chiefly from veins and bedding deposits in rocks ranging from the base of the Dolores formation to the top of the Dakota quartzite. Bedding deposits or deposits in rolls along the veins occur at a large number of horizons in the Jurassic strata and in the Dakota quartzite, chiefly at places where the rocks change from sandstone to shale. One of the principal zones is the limestone and shale beds (Pony Express) in the sandstones at the base of the Jurassic formations. The Dakota quartzite, however, has been the source of the highest grade silver-lead ores. Some silver-lead ore has been produced from narrow bedding or manto deposits at the top of the Leadville limestone and in the overlying Molas formation in the southern part of the district south of the Ouray fault where these formations are upturned along the ancestral San Juan uplift.

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Rico Mining District, Dolores County

By D. J. Varnes

The Rico mining district is in a small group of mountains which are isolated from the main San Juan Mountains to the east and northeast. The town of Rico is in the valley of the Dolores River at an altitude of about 8,700 feet. The mountains rise to an altitude of about 12,500 feet. The slopes are steep but not rugged, and below 11,000 feet they are covered by dense growths of aspen and spruce.

The mountains are carved from a low structural dome which is roughly circular in shape and 12 to 15 miles across. Rocks ranging in age from pre-Cambrian to Jurassic were involved in the doming. The schist, quartzite, and diorite of pre-Cambrian age are overlain successively by the Ignacio quartzite of Cambrian age; the Ouray and Leadville limestones of Devonian and Mississippian ages, respectively, and shales, sandstones, and thin limestones belonging to the Hermosa formation of Pennsylvanian age; sandstone and sandy shale belonging to the Rico formation of Permian (?) age; and red shale, sandstone, and conglomerate of Triassic and Jurassic age on the flanks of the dome. All of these rock units have been intruded by numerous sills of hornblende-monzonite porphyry and by a stock of quartz monzonite of Tertiary (?) age. The igneous activity and doming were followed by faulting which produced a complex structure in the central part of the dome.

Those faults near the center of the dome having greatest displacement trend westward. Long blocks and wedge-shaped slices between these main faults have been dropped step-like away from the central and structurally highest block in the heart of the dome. The dip of the strata progressively decreases away from the center of the dome.

The main production of the district has come from the northeast, east, and southeast sides of the central igneous core. Mining exploration first began in 1869 with the discovery of ore deposits in the Leadville and Ouray limestones near the present Atlantic Cable Shaft. Ten years later rich silver ores were found in the

"Enterprise blanket" deposit in the Hermosa formation on what is now called Newman hill, and the town of Rico was founded. Although the rich silver ores of Newman Hill southeast of the town were soon exhausted, other deposits were discovered and the district has continued to produce until the present time. Two lead smelters and numerous mills have been built in the district. From 1924-1929 the St. Louis Smelting and Refining Co. had a large production, chiefly from mines in CHC Hill northeast of the town, but this activity was brought to a close by the collapse of the metal market at the beginning of the depression. Lately the Rico Argentine Mining Co. has produced steadily from several areas, but chiefly from the country above Silver Creek, a mile east of town. This mine is now one of the major zinc, lead, and silver producers in Colorado. Records of the Bureau of Mines give the total value of gold, silver, copper, lead, and zinc produced in Dolores County from 1879 to 1944 as $26,279,454. The Rico district has accounted for almost all of this amount, of which about 40 percent is represented by silver, 24 percent by zinc, 22 percent by lead, 8 percent by gold, and 6 percent by copper.

Some of the veins occupy faults, some occupy fissures parallel to and close by faults, and some trend at various angles to the main faults. Most of the veins are too small to be mined profitably by themselves, but many widen and form large irregular bodies of ore where they intersect limestone beds, gypsum beds, or brecciated zones within shales of the Hermosa formation.

No general rules can be laid down as to which system of veins is likely to contain ore because the direction of ore-bearing veins is relatively constant only for small areas within the district. Furthermore, the directions of ore-bearing veins, which coincide with or are closely parallel to faults throughout the district as a whole, do not appear to follow any pattern so far as the geology is now known.

At the Nora Lilley mine, half a mile north of town, production has come from the main westerly vein system. The faults and veins which cut replacement deposits in the Argentine, Iron and Blackhawk mines to the east of Rico along Silver Creek trend about N. 15° W., and the veins at the Yellowjacket mine on Nigger Baby Hill north of Silver Creek trend northwestward and westward.

A large part of the production of the district has come from blanket deposits in the lower part of the Hermosa formation on Newman Hill southeast of the town. At this place a bed of sedimentary gypsum, originally 15 to 30 feet thick, in a series of shales, sandstones, and limestones, had previously been dissolved out, probably by the ore solutions, to leave a brecciated zone ideally fitted as a site for the deposition of ores. The ore solutions were admitted through a series of northeastward and northwestward trending fissures that traverse the rocks below the blanket. The northeasterly fissures were themselves productive, as lode deposits, to depths of 150 feet below the blanket, below which they contained little in addition to the worthless quartz and pyrite gangue.

The silver-bearing minerals of the richer ores are argentite, prousite, polybasite and argentiferous tetrahedrite, but the more abundant ore minerals are galena, sphalerite, chalcopyrite, and pyrite. The dominant gangue minerals are quartz and rhodochrosite.

Considerable prospecting has been carried on in the Leadville and Ouray limestones, and replacement ore bodies in it have been developed at several times. In the vicinity of the Atlantic Cable mine and Van Winkle shaft irregular bodies of massive lead, zinc, copper, and iron sulfides are mined from marbleized and serpentinized phases of the limestone. Hematite and chlorite are abundant gangue minerals in this type of deposit.

The limestone unit is normally 150-200 feet thick but recent geologic studies have proved this unit and the underlying quartzite to be much thinner or totally absent in some parts of the mining district. Apparently part or all of the unit was removed locally by post-Mississippian pre-Pennsylvanian faulting and erosion, and recurrent movement along these old faults is expressed in some of the younger faults now observed.

Tracing of the ore-bearing beds in the Hermosa and Rico formations across faults which bound the main blocks within the dome calls for careful interpretation of all available geologic data. Unfortunately, the geologic information is too often very meager because landslides and timber cover much of the ground surface. However, with further study, the prospects of discovering additional ore, now hidden by surface cover or lying in limestone beds not yet explored, are reasonably good in several parts of the district.

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La Plata District, La Plata and Montezuma Counties

By E. B. Eckel

The La Plata mining district lies within the La Plata Mountains, a rugged mountain group between the main San Juan Mountains and the Colorado Plateau. The climate is rigorous, but the mountains are well watered, and much of the area of 120 square miles that includes the mines is covered by moderately heavy vegetation. An excellent example of the complex laccolithic type of mountain group, the La Plata Mountains were carved from a domal uplift of sedimentary rocks that were invaded by numerous stocks, dikes and sills of igneous rock. (See pl. 30.)

The sedimentary formations that are exposed within the district are shown in the following table.

SEDIMENTARY ROCKS OF THE LA PLATA DISTRICT

Age	Formation	Member	Thickness (feet)
Cretaceous	Mancos shale		1200
	Dakota sandstone		100-150
Upper Jurassic	Morrison formation		400-625
	Junction Creek sandstone		160-500
	Wanakah formation	Marl member Bilk Creek sandstone member Pony Express limestone member	25-150
	Entrada sandstone		100-265
Jurassic (?) and Upper Triassic	Dolores formation		500-750
Permian	Cutler formation		1500-2200
Permian (?)	Rico formation		100-300
Pennsylvanian	Hermosa formation		2750

These formations are underlain by several hundred feet of Cambrian, Devonian, and Mississippian rocks, and they were at one time overlain by a great thickness of Upper Cretaceous and Tertiary rocks that were involved in the formation of the dome but have since been removed by erosion.

All the igneous rocks are of Tertiary age and all are intrusive. They vary widely in composition and in form, but two general types are recognized—porphyritic and nonporphyritic. The porphyry, most of which is intermediate between diorite and monzonite in composition, is more abundant than any other igneous rock type and forms more or less contemporaneous stocks, sills, and dikes. The nonporphyritic rocks, which are in general somewhat younger than the porphyries, form irregular stocks and associated dikes. They consist of syenite, monzonite, and diorite. The porphyry bodies were intruded forcibly between the layers of sedimentary rock and were thus a major factor in the formation of the La Plata dome, but the later nonporphyritic rocks replaced or assimilated the country rocks during invasion. The intrusion of the porphyries was unaccompanied by metamorphism, whereas the nonporphyritic stocks are surrounded by an aureole of more or less intensely altered sedimentary rock.

The most pronounced structural feature of the La Plata Mountains is a domal uplift of the sedimentary beds, about 15 miles in diameter, which blends somewhat into the southwestern flank of the much broader San Juan uplift. This dome is marked by a steep, horseshoe-shaped fold, open at the south, which nearly encircles the central part of the mountains. Within this fold the rocks are rather thoroughly silicified, but outside it they are relatively unaltered except very locally. On the south side of the horseshoe fold and along the northern and northwestern margin of the dome, several strong faults took part in the uplift of the dome. The formation of these major structural features was contemporaneous with and resulted from the porphyry intrusions but preceded the emplacement of the stocks of nonporphyritic rocks and the regional metamorphism. Numerous short, discontinuous faults of small displacement were formed during the doming process. Many of them trend east-west, but a few radiate from the center of the dome. After the emplacement of the stocks of nonporphyritic rocks, some of these faults were reopened and new ones were formed, and these then became the loci of many ore deposits.

Ore in the district was first discovered in 1873 and from then until 1900 numerous mines were opened, although the annual output remained comparatively small. At intervals from 1900 to the mid-thirties, however, several highly productive deposits were discovered. Together with the continued discovery and mining of smaller deposits, these had by the end of 1937 yielded a total of nearly six million dollars worth of ore. More than half this total came from 2 mines, the May Day and Idaho, and 4 others yielded a total of more than $1,000,000. Gold has always been the most valuable product of most of the mines, but over 2,000,000 ounces of silver and several hundred thousand pounds of lead and copper have also been recovered. The district has been relatively dormant since 1938, particularly during the war years, when gold mining was discouraged.

Over 60 mineral species are known or have been reliably reported to occur in the district. Native gold and the various telluride minerals, particularly those of gold and silver, are by far the most important.

The district is best known for its veins and replacement deposits of gold and silver-bearing telluride ores, from which the greater part of the output has come. In addition to these, however, it includes a surprising variety of types of deposits within a small area. These include disseminated deposits of platinum-bearing chalcopyrite, gold-bearing contact-metamorphic bodies, veins, replacement and breccia bodies of pyritic gold ore, veins of mixed base-metal sulphides with silver or native gold, chalcocite veins, and veins of ruby-silver ore. The gold-bearing placers have not been very productive.

Relations between the different types of deposit are far from clear, but it seems certain that they were formed through a wide range of temperature and possibly of pressure. Some evidence of zoning is to be found, and several lines of evidence point to the conclusion that all the deposits were formed during one general period of hydrothermal activity that followed closely on the emplacement of the nonporphyritic rocks.

GEOLOGIC MAP AND STRUCTURE SECTION OF THE LA PLATA MINING DISTRICT, COLORADO

PLATE 30.

The favorability of both structural features and rocks toward formation of ore shoots depends almost entirely on the extent to which they were able to produce or maintain open spaces along fractures. Ore shoots can only be expected in places where one or more favorable structural features combine with rocks that were either originally favorable to ore deposition or were made so by areal or local (wall-rock) alteration. It is believed that new deposits will yet be found, and output in the future may well equal, if not exceed, that of the past.

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LATE TERTIARY ORE DEPOSITS

Districts of the Silverton Volcanic Center

By W. S. Burbank

General Geology.—The country embraced by the headwaters of the Uncompahgre, San Miguel, and Animas rivers just west of the Continental divide is the most highly mineralized area of the western San Juan Mountains. The area covers about 250 square miles, mainly in Ouray, San Miguel, and San Juan counties, but also includes a small part of western Hinsdale County. The ore deposits are chiefly veins in strongly fissured and slightly tilted volcanic rocks which form a blanket 4 to 6 thousand feet thick on the Telluride erosion surface. As shown in plate 27, the volcanic rocks are underlain along their west border by Paleozoic and Mesozoic sedimentary rocks and to the east by pre-Cambrian metamorphic rocks. The entire section of rocks was intruded in late Tertiary time by volcanic dikes and larger intrusive bodies. Radial and concentric fissuring occurred about a center of disturbance now marked by a down-faulted block or caldera about 8 miles in diameter. At least ten mining districts are commonly designated in the area, and they are separated by interstream divides or county lines and by other arbitrary and in places indefinite boundaries. The mining districts belong to one geologic unit, which may be divided into several sectors based upon geographic and geologic relations (pl. 28). About 70 to 75 percent of total San Juan production comes from mines in this area tributary to the towns of Ouray, Silverton, Telluride and Ophir.

The volcanic rocks at their base are separated from the older basement rocks by a layer of the Telluride conglomerate. In the eastern part of the area where the volcanic rocks rest mainly on the pre-Cambrian basement, this layer of conglomerate is patchy and thin, but it thickens northwestward and in the Telluride quadrangle comprises a maximum thickness of 1,000 feet of sandstone, fine conglomerate and shale. The lower part of the volcanic series consists of 3,000 feet or more of San Juan tuff, which is the host rock of a large number of the more highly productive vein deposits. This is a tuff-breccia of surprisingly uniform texture and composition, and owing to its generally massive and highly indurated nature it has reacted as a unit to fissuring forces. The continuity and uniformity of fissuring in this formation is an important factor in the productivity of many veins. The Smuggler-Union vein system in the Telluride district has been stoped nearly continuously in this rock for about 9,000 feet along the strike and through a vertical range of about 2,500 feet. Overlying the San Juan tuff is the Silverton volcanic series, a complex of latite, rhyolite and andesite flows, tuffs, and breccias, presumably erupted from large concealed vents in the general vicinity of the Silverton quadrangle. These rocks likewise have been highly productive, but with the exception of the stronger fissures and faults there is less continuity and regularity to the fissuring than in the San Juan tuff. Local erosion surfaces which are present throughout and at the base of the Silverton rocks are chiefly of local prominence. The San Juan tuff and Silverton volcanic series, which are confined as units to the western San Juan, are overlain by the Potosi volcanic series, one of the most widespread volcanic series of the San Juan region. The Potosi rocks here are chiefly quartz latite and rhyolite flows and breccias, and they are separated from the underlying volcanic formations by an erosion surface. The Potosi rocks have not been very productive in the western part of the San Juan Mountains, and many of the vein fissures feather out or become unproductive in this series.

Soon after the beginning of the eruptions which formed the Silverton volcanic series, a broad crater-like depression was produced in the center of this series, probably in part bounded by faults and related to the eruptive centers below. Later eruptions worked their way up around the borders and finally, probably after the flows of the Potosi volcanic series, strong curved faults formed around the margins, and a great central block about 8 miles in diameter subsided several thousand feet. During this subsidence large intrusive bodies penetrated the volcanic rocks, possibly even doming them temporarily, and produced a complex system of concentric and radial dikes and fissures. As the intrusive bodies cooled and subsidence continued, further slight fissuring occurred either along dikes of the earlier intrusive epoch or by further division of rock bodies. The ore-forming solutions rose into these fissures in several stages that were separated by renewed slight reopenings of the fissures and produced the ore-bearing veins. Along the borders of the subsided area the ore solutions followed

Table 7. Geologic formations of the western and central San Juan Mountains

ERA	SYSTEM	SERIES	FORMATION	CHARACTER	THICKNESS (Feet)
CENOZOIC	Quaternary	Recent		River gravels, etc., landslide deposits	
		Pleistocene	Wisconsin till and outwash. Durango till and outwash. Cerro till and outwash	Morainal deposits, outwash gravel and sand	
		Unconformity			
	Tertiary	Pliocene (?)	Hinsdale formation	Flows of andesite-basalt, rhyolite, and a local volcanic pile of flows and clastic beds of latite-andesite at the base in the southeastern San Juan region which grades southward into sand and gravel	0–2,500
		Erosion surface			
		Miocene (?)	Fisher latite-andesite	Local accumulations of flows and tuff beds of coarsely porphyritic rock	0–2,000
		Erosion surface			
		Miocene	Creede formation	Sand, gravel, and shaly tuff, containing plant remains. Found locally near the Creede district	0–2,000
		Erosion surface			
		Miocene	Potosi volcanic series	An alternation of rhyolite and quartz latite flows and tuffs, flows predominating near the base	3,000+
		Erosion surface			
		Miocene	Sunshine Peak rhyolite	Great flows of rhyolite with quartz phenocrysts; some intrusive rocks included. Found locally near Lake City district	0–2,000
		Erosion surface			
		Miocene	Silverton volcanic series	A succession of pyroxene andesite, latite, and rhyolite flows, tuffs, and breccias. Includes some dikes and other intrusive rocks	3,000+
		Erosion surface			
		Miocene (?)	San Juan tuff	Bedded tuff-conglomerate and breccia made up of andesitic and latitic material; locally a few flows	100–3,000
		Erosion surface			
		Oligocene (?)	Telluride conglomerate	Chiefly a coarse conglomerate, containing pebbles and boulders of granite, schist, quartzite, porphyry, and the harder sediments of the Paleozoic and Mesozoic formations. In western part of San Juan Mountains (Mount Wilson) are sandstones, shales, and thin fresh-water limestones	0–1,000
		Erosion surface			
		Eocene	Ridgway till	Deposits of boulder till and pebble till composed of material from formations ranging from pre-Cambrian to Upper Cretaceous, and also some porphyries and volcanic rocks derived from the late Cretaceous volcanic formations (destroyed by erosion in San Juan Mountains)	0–200
		Unconformity			
MESOZOIC	Cretaceous	Upper Cretaceous	Mesaverde formation	Gray or yellowish quartzose sandstones and sandy shales, with coal beds in upper part. Invertebrate fossils	300+
			Mancos shale	Dark-gray or carbonaceous clay shale with thin lenses of limestone. Equivalent to Colorado group and part of Pierre shale of the Montana group. Marine invertebrate fossils	1,200±
		Unconformity			
		Upper and Lower Cretaceous	Dakota sandstone	Gray or rusty-brown quartzose sandstone with a conglomerate containing small chert pebbles at or near the base. Carbonaceous shale and coal of poor quality locally present	100–300
		Unconformity			
	Jurassic	Upper Jurassic	Morrison formation	Upper part a complex of alternating yellowish or gray sandstones and variegated shales, chiefly green but also red or brown. Lower part white or gray sandstone, thin limestones, and brown or green shales	650–750
			Junction Creek sandstone	Massive white cross-bedded sandstone. Absent in the Ouray and Telluride areas	160–500
			Wanakah formation	Marl member at top; marly beds with thin limestone and dolomitic limestone, 50-100 feet thick Bilk Creek sandstone member; soft, horizontally bedded, fine grained sandstone, about 20 feet thick Pony Express limestone member; dark gray to black bituminous limestone, locally with limestone breccia and gypsum at top, 0-50 feet thick	70–150
			Entrada sandstone	Very massive friable white to yellow sandstone, distinctly cross-bedded, cliff-forming. Generally even grained and fine textured	45–250
		Unconformity			
	Jurassic (?) and Triassic	Jurassic (?) and Upper Triassic	Dolores formation	Fine-grained bright-red sandstones, sandy marls, and shales. Limestone conglomerates and grits near base containing teeth of Triassic reptiles, carbonized and silicified wood, and leaves	40–600
		Unconformity			
PALEOZOIC	Permian		Cutler formation	A series of bright-red sandstones and pinkish grits and conglomerates alternating with reddish sandy shales and earthy limestones. Commonly unfossiliferous	1,000–2,000
	Permian (?)		Rico formation	Dark reddish-brown sandstone and pinkish grit with intercalated greenish or reddish shale and sandy fossiliferous limestone	0–300
	Carboniferous	Pennsylvanian	Hermosa formation	A series of grits, sandstones, shales, and limestones of variable distribution and development. Some gypsiferous beds locally. Colors generally gray or green. Numerous marine invertebrate fossils in shales and limestones	1,400–2,000
			Molas formation	Red calcareous shale and sandstone with pebbles of quartzite, chert, and limestone containing Mississippian fossils. Thin limestone lenses carry Pennsylvanian fossils	0–75
		Unconformity			
		Mississippian	Leadville limestone	Upper part massive gray and crystalline limestone, in places grading upward into alternations of limestone and red shales or breccia beds. Fossiliferous. Lower part predominantly dark blue-gray or brownish-gray limestone with sandy layers	70–230
	Devonian	Upper Devonian	Ouray limestone	Predominantly gray, buff, white, or pinkish limestones, generally well bedded; lower part shaly with thin quartzites in places. Locally contains Upper Devonian invertebrates	70–120
			Elbert formation	Thin-bedded limestone, sandstone, and calcareous shales. Contains fish remains of Devonian types	0–80
		Unconformity			
	Cambrian	Upper Cambrian	Ignacio quartzite	Quartzite, massive and conglomeratic in lower part, thin bedded with shaly or sandy partings in medial zone, succeeded by more massive quartzite *Obolus* sp.? only fossil found	0–200
		Unconformity			
PROTEROZOIC	Pre-Cambrian		Uncompahgre formation	Massive and some thin-bedded quartzite and bands of shale or slate; quartzites white, pink, and brown to black; shales rusty brown or black	5,000–8,000
			Vallecito conglomerate	Coarse conglomerate consisting of pebbles and boulders of quartzite and greenstone, with some jasper	1,000±
		Unconformity			
			Irving greenstone	Greenstone, greenstone porphyry, and greenstone schist, with subordinate quartz-mica schist and granite gneiss	10,000
			Schist, gneiss, and granite	Quartz-mica and amphibole schists and some granite gneiss, much crumpled and contorted Some of the granite of the area is intrusive into the pre-Cambrian metamorphic rocks	

up along or near volcanic pipes and breccias or along intersecting fractures and produced some ore bodies in the form of chimneys or pipes. Such areas were generally subjected to strong fumarolic alteration by hot waters and gases of volcanic origin. Only in one area, at Red Mountain along the west margin of the caldera, however, have the chimney ore bodies proved to be very productive.

The general features of the geology and pattern of the fissuring are shown on plate 28. The relatively small number of fissures shown in many of the areas on the map is not truly representative of the actual conditions, as only districts on the north and northwest and a small area southeast of Silverton have been mapped in comparable detail. In the following descriptions of the Silverton caldera, those districts that have the same or similar geologic environment are grouped together, even though the groupings may neglect county and topographic boundaries.

TELLURIDE AND SNEFFELS DISTRICTS, SAN MIGUEL AND OURAY COUNTIES

The Telluride district is part of the Upper San Miguel mining area and the principal source of past production from San Miguel County. The Sneffels district adjoins it across the divide separating the upper San Miguel and Uncompahgre drainages. For convenience in description because it makes a better geologic unit the Telluride district as discussed here will be confined to its northern division north of the San Miguel River. The districts together cover about 30 square miles and comprise the northwest swarm of veins and dikes between the margin of the Silverton caldera northwest of Red Mountain Creek and the intrusive stocks of the Mt. Sneffels and Stony Mountain center. The mines are developed from portals in the volcanic rocks within the high glacial basins of several creeks tributary to the main valleys and are interconnected by tunnels that penetrate the mountain divide between the two counties.

In the valley of the San Miguel River at Telluride the Paleozoic and Mesozoic sedimentary rocks beneath the Telluride conglomerate are exposed generally below 10,000 feet altitude. They include the strata from the Cutler formation to the Dakota sandstone. In the Sneffels district to the northeast, also, the Paleozoic and Mesozoic rocks are exposed in Canyon Creek below 9,500 feet altitude. (See pl. 28, and section along line B-B'.)

The mines of these two districts have been productive for many years and, with deeper transportation tunnels now either being driven or under consideration near and below the base of the volcanic series, the districts may be expected to produce for many years in the future. The more famous mines include the Smuggler Union at Telluride, closed in 1928 after a production record of 52 years. This mine and some adjoining properties have been reorganized as the Telluride Mines, Incorporated, which will continue deeper level work. The Tomboy group of mines, operated by an English company and famous for their gold, silver, and lead production, were closed in 1927 and the company liquidated; they are now included in the reorganized Telluride Mines, Incorporated. The Liberty Bell mine, which produced only silver and gold, was operated from 1898 to 1921; it employed amalgamation and cyanidation. In the Sneffels district the Camp Bird mine is the most famous, having been operated by the Camp Bird, Limited, an English company still owning the property, from 1896 to 1916. The mine was reopened under the King Lease, Inc., in 1926, and has operated continuously since then, recovering much lead in addition to gold and silver. Zinc contained in the concentrates was not recovered until 1942, when the mill was redesigned. Other well known mines producing silver-lead ores include the Virginius, Humboldt, Terrible, Atlas, and Klondyke, but with the exception of the Atlas and Klondyke these mines are partly in San Miguel County. Gold was produced also by these mines, particularly from the Atlas vein.

The lowest ebb in the production of the Telluride and Sneffels districts occurred in the early thirties, but beginning in 1936 the Smuggler Union group was taken over by the La Veta Mines, Inc., which in 1939 acquired the Tomboy holdings and in 1940 organized as the Telluride Mines, Inc. With the installation in their 550-ton mill of a flotation unit in 1940 to recover zinc the production of the districts has gradually increased. The latest large mine development was in 1943 when the Metals Reserve Company, a government agency, loaned the Idarado Mining Company as a war-time measure the capital necessary to extend the Treasury tunnel from Red Mountain westward under the divide and beneath the Old Black Bear mine in San Miguel County. This venture was successful in tapping a substantial vein of ore 900 feet vertically below the old workings. The production which was started in 1945 is accredited to San Miguel County, though the mine portal and 800-ton mill are in Ouray County. The lead, copper, and zinc concentrates which are produced contain precious metal values.

Allowing an estimated $12,000,000 from San Miguel County to be credited to areas south of the San Miguel River, and nearly twice this amount from Ouray County credited to the Uncompahgre and Red Mountain districts, the Sneffels and Telluride districts have yielded over 80 percent of the total production of the two counties, which is somewhat more than one-half of the total production from all districts of the Silverton volcanic center. It seems unlikely that this advantage will be overtaken by other districts in the near future, although ultimately a larger proportion of production may be made from other parts of the area.

The production of the area has come principally from veins within the San Juan tuff, although the uppermost levels of a number of mines were within the Silverton volcanic series which, in this part of the region, ranges between 200 and 800 feet in thickness. The Potosi volcanic series caps only the highest ridges. Where the veins cross ridges capped by the Potosi rocks their position may be marked only by vague sheeting and alteration. Some dikes of pre-mineral age, however, cut up through the capping rhyolite where their course may become irregular, but they help to establish clearly that the main ore deposition was later than the Potosi flows.

Structurally the veins of the area fall into three principal types though there also are some other local types. As shown on plate 28 the vein swarm is characterized by curving fractures that converge at their northwest ends about the Mt. Sneffels intrusion and at their southeast ends they terminate against or interlace with the bounding faults and fractures of the Silverton caldera. In point of origin the oldest fissures are those occupied by dikes, and they generally follow curving courses. Some dikes do not reach the surface. A number of important veins such as the Smuggler Union and the Argentine and Montana veins of the Tomboy group follow the walls of these dikes and form one of the main productive classes. Some of these veins in favorable places have yielded a good grade of ore down into the sedimentary strata beneath the volcanic rocks. Another set of vein fissures, somewhat later in origin have a more uniformly straight northwest course, at places cutting diagonally across or terminating against the curved fissures and dikes. These vein fissures commonly dip outward away from the center of the fissure swarm at lower angles of dip than the others; they are termed "flat veins," although their dips are not generally less than 50 degrees. They also tend to steepen upward and flatten somewhat in depth. The Flat vein of the Smuggler Union, the Black Bear, the Humboldt, and possibly the Liberty Bell are representative veins belonging to this class. They are believed to have originated by tensional rupture chiefly of the San Juan tuff, and consequently may not be expected to yield much ore below the base of this formation or of the Telluride conglomerate. A few veins follow the walls of dikes that are concentric to or which spiral outward from the volcanic center. They strike northerly or northeasterly across the other fissures and may be considered to form a third class, but other than the Camp Bird which is a fault fissure, the production from them has been small.

The mineralogy of the ores is comparatively simple, a few of the common sulfides, pyrite, sphalerite, galena, and chalcopyrite forming the bulk of the veins in a gangue of quartz with some rhodonite, rhodochrosite, and calcite. Repetition of the common sulfides in several stages of vein formation is common. In general base metal sulfides decrease in quantity in later vein stages. the final stages being nearly barren quartz or calcite. The gold-bearing quartz of the Camp Bird contains adularia and minor amounts of the common sulfides. It fills fissures alongside or breaking through the earlier more massive sulfide vein. In some earlier operations in the mine the sulfide vein matter was not mined where it was easily left in the wall. In veins far to the northwest such as the Liberty Bell, very little sulfide was present in the ore. The silver was contained chiefly in argentiferous tetrahedrite, stephanite and argentite. Gold was a late mineral associated with quartz and carbonate. Much of the vein was oxidized and contained a manganese-stained gouge. Native silver and argentite are probably of secondary origin. In veins such as the Virginius that were chiefly silver producers the principal ore minerals were galena and argentiferous tennantite, which were associated with a quartz-carbonate base metal mineralization; but ruby silvers such as proustite formed small bunches of high-grade ore.

As the Telluride and Sneffels districts are fairly well developed by underground workings, some freedom may be allowed in estimating the proportion of undeveloped ground remaining beneath ore shoots that have already produced appreciably in excess of $1,000,000. Assuming the Telluride erosion surface as the bottom, undeveloped ground beneath the principal ore shoots amounts to about 40 percent of total ground from the tops of the mined ore shoots to the Telluride erosion surface. This means roughly 60 percent depletion of the most favorable ground. But if partly developed and possibly favorable ground is added to this, the depletion of the districts is nearer 50 percent. Furthermore as less than 20 percent of the total vein length of the stronger veins is actually developed at all and as some ore shoots are known to extend below the Telluride erosion surface, there remains also some opportunity for discovery of ore shoots not indicated either by underground or surface developments. The tonnages in undepleted favorable ground would amount to 20 or 30 million tons, not allowing for selective mining. While these figures do not by any means represent an exhaustive consideration of individual ore bodies and the economic factors involved in their development, they give from the geologic viewpoint a rough estimate of the future of the district as compared to its past.

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SOUTH TELLURIDE AREA (SOUTHERN PART OF THE UPPER SAN MIGUEL DISTRICT), SAN MIGUEL COUNTY

By D. J. Varnes

The high mountainous region between the Telluride district on the north and the Ophir Valley district to the south has not been as productive of metals as either of those two districts. Although this is due mostly to the less intense mineralization of this area, it is also due to the rugged terrain and inaccessibility of the deposits which have discouraged mining operations.

The general level of the region, except for the lower parts of the larger valleys draining northward toward Telluride, is above the level of the sedimentary formations. The predominant rocks are therefore the flat-lying San Juan tuff and the superimposed andesites and latites of the Silverton volcanic series.

Two main fracture systems are developed in the rocks of the area. One system trends somewhat north of west, the other trends northward at about right angles to the first. A number of the westerly fractures contain vein filling, and it is from this system that the main metal production of the region has come. The northward-trending fissures are generally barren of vein filling.

Production has come mainly from the Alta group of mines in the southern end of the South Telluride area whose output of gold, silver, lead and a little copper is in excess of $4,000,000 in value. That part of the area between the Alta mine and Telluride Valley has yielded $600,000 or $700,000, mostly in gold; the larger producers have been the Nellie and Contention mines in Bear Creek and the Junta group and Lewis mine farther to the east.

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IRON SPRINGS MINING DISTRICT (OPHIR, AMES), SAN MIGUEL COUNTY

By D. J. Varnes

The Iron Springs Mining District centers in Ophir Valley on the Howard Fork of the San Miguel River about 6 miles south of the town of Telluride.

The geology of Ophir Valley is similar to that of the valley at Telluride. Paleozoic and Mesozoic sedimentary rocks are exposed in the bottom of the main westward-draining valley and are successively overlain, on the higher slopes, by the Telluride conglomerate, San Juan tuff, and volcanic formations of the Silverton volcanic series. Several small igneous intrusions ranging in composition from quartz monzonite to diorite have altered the red and maroon shales and sandstones to gray, black, and green dense rocks now composed largely of metamorphic minerals. The thorough alteration precludes the close correlation of these rocks with their unmetamorphosed equivalents in the Telluride Valley, and formations of Triassic to Cretaceous age may also be included in the rocks beneath the Telluride conglomerate.

The main system of veins extends along the sides of the valley westward through the intrusions at the mouth of the valley and on toward the Mt. Wilson stock. In general, this system of overlapping veins trends westward, and the individual veins dip steeply into the north and south sides of the valley. The principal values of these veins are in gold, silver, and lead. Pyrite, galena, sphalerite, chalcopyrite, and gray copper are the more common sulfide minerals. Hematite and magnetite are not uncommon. The gangue material of these veins is largely quartz with considerable amounts of calcite, manganiferous iron carbonate, and barite. Lesser amounts of fluorite and anhydrite have been noted in some veins. The vein matter forms a typical fissure filling with well defined walls although along strongly shattered parts of the fissures the vein fillings show braided or "linked" structure.

Among the more productive of the westerly veins have been the Ida, Butler and other veins, now mined by the Butterfly Consolidated Company, and their eastward extensions worked many years ago by the Carribeau mine. The San Bernardo mine, a short distance south of the valley, is also on a prominent westward-trending vein. Although the Alta mine is included in the Upper San Miguel district, the veins there mined extend somewhat south of east onto the high ridge north of Ophir Valley and are structurally related to the main fissure system in the valley itself.

In addition to the prominent vein system just described, there is a complex network of fissures and altered zones high on the north side of Ophir Valley which trend north and northeast and differ considerably from the westerly system in structure and mineralogy. These veins are seams of quartz and pyrite carrying free gold and some silver. Gold values extend out into the altered and pyrite-impregnated country rock. The principal mines which operated in this small area of gold mineralization were the Suffolk, Globe, and Gold King.

The influence of wall rock upon the veins of this mining district has been largely in the physical response of the rocks to the stresses which produced the initial fractures and in the degree of their permeability to ore-bearing solutions. As a rule, the veins are more sharply defined within the massive San Juan tuff and overlying andesite than within the higher, more thinly laminated rhyolitic flows. The veins also vary in width among different types of intrusive rocks at the west end of the valley. Veins within the sedimentary series are more continuous than might be expected because of induration of the rocks by thermal metamorphism. Replacement deposits are rare and of small extent in this district.

The Telluride conglomerate, immediately underlying the San Juan tuff has been impregnated with pyrite, galena, and sphalerite in the neighborhood of some veins. Local concentrations of sulfides within the upper part of the sandy conglomerate beneath the dense tuff have been worked by several of the smaller mines. In the altered area of gold-bearing veins on Silver Mountain the porous conglomerate has been impregnated with auriferous pyrite. The possibility of gold deposits of low grade but rather large extent should not be overlooked in this area.

Small deposits of less common metals have also been found. In the upper workings of the Silver Bell mine appreciable amounts of manganiferous wolframite occur in the Ida vein and have been worked in a small way for tungsten during periods of high price. Molybdenite is present in small quantities associated with bodies of pegmatitic quartz in quartz monzonite intrusions near the east end of the valley. Molybdenite also occurs as thin coatings on joints in the Silver Tip mine about a mile east of the old town of Ophir. Very little study has been made of the molybdenite occurrences in the valley.

The total value of ore produced in the Iron Springs district (exclusive of the Alta mine) has been about $6,500,000 of which about $1,000,000 has come from the gold area on Silver Mountain. The bulk of production has come from the silver-gold-lead veins worked by the Butterfly Consolidated, Carbonero, San Bernardo, and Carribeau mines.

The history of the camp has been one of intermittent production except for a few large mines which operated fairly continuously. Activity in the camp slackened with the decline in the price of silver, although the larger mines maintained continuous operation. Some new ones became substantial producers during times of favorable metal prices. Several factors have contributed to declining production of the camp, one of the more important being that prospecting has not been actively pursued during a period of several decades in which the technology of milling and the demand for base metals have changed greatly.

Studies by the Geological Survey are in progress for the purpose of mapping the area and gathering data on the district as a whole. Although the area is one of great relief, timber, grass, and landslides obscure many veins so that a geological interpretation of the vein system is here a very necessary guide to intelligent prospecting. When all available information upon the mines, their production, and their geologic setting is assembled and evaluated in the light of present day mining and milling practices it will not be unlikely that this more or less dormant district will again show itself capable of supporting extensive mining operations.

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MOUNT WILSON DISTRICT, SAN MIGUEL COUNTY

By D. J. Varnes

The Mount Wilson mining district is within a group of high peaks which geologically are a part of the San Juan Mountains, but they are separated from the main range to the east by the deep valleys of the San Miguel and Dolores Rivers.

In this area the equivalent of the Telluride conglomerate is a series of sandstone and shale beds about 1,000 feet thick resting upon Cretaceous shales. The San Juan tuff and overlying Silverton volcanic series are exposed on the higher ridges. The main mass of the mountains, however, is composed of a large igneous stock which varies in composition from diorite to monzonite. All the mines of the area are within the stock or in the sedimentary rocks nearby.

The main vein systems strike west and southwest, and are slightly offset by thin barren veins striking north. The more productive veins are quartz-filled fissures containing pyrite, chalcopyrite and arsenopyrite with lesser amounts of galena, sphalerite, tetrahedrite, stibnite, and calcite. The pay streaks within the veins, though generally narrow, carry high values in gold. In veins in the fine-grained facies of the diorite, chalcopyrite and galena commonly indicate high values of gold, and in those in coarser-grained parts of the intrusion the gold is thought to be associated with arsenopyrite. In the eastern part of the area near Bilk Creek the veins contain considerable galena and sphalerite.

The Silver Pick mine, which is the largest in the area, has produced at least $750,000 worth of ore. The Tam O'Shanter and Special Session mines are on prominent veins nearby.

Difficulty of access to this very rugged group of mountains has done much to discourage mining on all but the most prominent veins. Except for the few large explorations in the vicinity of the Silver Pick mine, the mineralized area still remains one of undetermined value.

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RED MOUNTAIN DISTRICT, OURAY COUNTY

By W. S. Burbank

The Red Mountain mining district centers in the high glacial valley of Red Mountain Creek, a tributary at the headwaters of the Uncompahgre River in Ouray County. A small part of the southern end of this district lies at the head of Mineral Creek, a tributary of the Animas River in San Juan County. The district has also been considered to include an area east of Red Mountain ridge in San Juan County tributary to Cement Creek, another branch of the Animas River. The main production of the district, however, has come from the valley of Red Mountain Creek near the old town site of Red Mountain in Ouray County. Altitudes in the district range between 9,600 feet on the floor of Ironton Park at the north end, and about 13,000 feet on the surrounding mountain ridges.

The Ouray and Leadville limestones and the Hermosa formation crop out at the bottom of Ironton Park where they overlie pre-Cambrian quartzite. These basement rocks are faulted down to the south by displacements on faults bounding the Silverton caldera, and their position beneath the more productive parts of the district cannot be accurately determined. These sedimentary rocks here are tilted up against the edge of the ancestral San Juan uplift so that the district lies close to the boundary between the pre-Cambrian and the sedimentary rocks that underlie the volcanic formations (pls. 27 and 28).

The predominant volcanic formations comprise various units of the Silverton volcanic series, although on the west side of the valley a considerable thickness of the San Juan tuff is exposed beneath these rocks. The Silverton volcanic series at this locality thickens abruptly where the rocks fill the basin-like depression of the Silverton caldera. The district lies along the marginal zone of faults of this structural basin, and owing to the complexity of faulting and fissuring here as well as to intense alteration of the rocks, accurate interpretations of the geology and estimates of thickness and positions of various rock formations are difficult to make. In general the Telluride erosion surface from the Telluride district to the west and from the Ouray district to the north lies at altitudes between 9,600 to 10,000 feet, but on the east and south sides of the district across the main fault zone, this surface may be faulted down below its normal position in places as much as several thousand feet but probably less than 1,000 feet over considerable parts of the district.

The rocks are intruded by many plugs and pipes of porphyritic latite and rhyolite and of breccia which range from a few tens of feet to more than 2,000 feet across. Fracturing in and around these volcanic pipes is locally intense and many slightly mineralized fissures abound in the area. In places large bodies of rock are impregnated with finely divided pyrite and alteration products generally typical of ore-forming solutions. Much of the rock, particularly that forming the ridges east of the valley, is highly altered throughout to an aggregate of clay minerals, diaspore, alunite, kaolin minerals and quartz. This weathers to a bright red color that has resulted in the popular name of the mountains. Despite the strong and widespread activity of hydrothermal solutions on the rocks only a comparatively few ore bodies have made an appreciably large production. Some veins both on the west and north sides of the district have yielded an output valued at several hundred thousand to over a million dollars; the largest production came from chimney-like ore bodies in or near breccia pipes and other volcanic plugs. Much of this ore filled open spaces or caves in the rocks and part replaced the porous and altered wall rock. Because of its massive character, some of the ore consisting of nearly solid silver-copper sulfides, a comparatively small tonnage of ore yielded a total production for the district probably in excess of $10,000,000. Much of the lower grade and disseminated mineral matter scattered irregularly in large volumes of altered rock could not be mined. The bulk of the production came from the Yankee Girl, Guston, Genessee Vanderbilt, National Belle, and Congress mines on chimney ore bodies and from the Barstow mine, Kentucky Giant group, and several other mines on fissure veins.

An adequate description of the mineralized pipes of the Red Mountain district cannot be given in a short space, and reference should be made to original sources for this information. The ore bodies are commonly vertical chimney-like stocks of roughly elliptical outline. The ore was bounded on some sides by fracture or fault planes, and at places occurred in typical vein fissures. Within the main breccia bodies ore was concentrated in subsidiary chimneys or in irregular bodies of fractured rock. Most but not all of the solid chimney ore bodies are surrounded by envelopes of silicified country rock. About these silicified masses the volcanic rocks are highly altered. Most of the more highly productive ore bodies were found along a line of fracturing and faulting in a belt less than 1 mile wide and about 4 miles long, bearing about N. 21° E. Some of the ore bodies became pyritic and of lower grade at depth although locally small bodies of higher-grade ore persisted to the bottom of the deepest workings at about 1,000 to 1,300 feet below the outcrops.

The ores contain a higher proportion of copper minerals than the normal vein deposits, and many of the pipes also contain massive bodies of lead and zinc sulfides. Enargite is one of the copper minerals typical of many but not all ore bodies and is commonly associated with considerable pyrite. Rich copper-silver minerals, such as stromeyerite, polybasite, proustite, and bismuth-bearing varieties like cosalite, as well as argentiferous gray copper contributed to the silver values. A tin-bearing variety of gray copper called colusite is found as a mineralogical curiosity, but nowhere has tin been found in quantities to make ore.

The ore deposits of the district were discovered in 1881, and the following period of mining activity persisted until 1896, when the Yankee Girl and Guston closed. A deep level drainage and exploration tunnel was later driven beneath the principal ore zones, but resulted in comparatively little additional production. In the last few years during World War II a small but appreciable output of lead and zinc was made from old workings by a few miners. The future of the district appears to be dependent upon economical methods of developing and treating fairly large bodies of rock that contain irregularly distributed ore and also in devising some method of prospecting for hidden ore chimneys of which a considerable number may remain. The discovery of the Lark pipe on the Cement Creek side of Red Mountain within the last few years has served to focus attention on the weakness of surface indications above some ore bodies. Because of the small diameter of many higher-grade ore bodies, some scarcely more than a few tens of feet across, and because of the widespread general alteration of the rocks some geochemical methods of prospecting may possibly prove applicable.

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SOUTH SILVERTON AREA, ANIMAS DITSRICT, SAN JUAN COUNTY

By D. J. Varnes

The mineralized area south and southeast of Silverton is confined roughly to a belt several miles wide along the southern rim of the Silverton caldera. A wide zone of curved faults within and on the south side of the Animas River Valley mark the margin of the caldera and along them the caldera has subsided 1,500 to 2,500 feet relative to the rim. This subsidence is not expressed in the present-day topography but can be estimated from offsets of the various volcanic units. Within the caldera the predominant rock type is pyroxene andesite, whereas to the south the rocks are rhyolitic, andesitic and latitic flows and breccias which normally occur lower in the section than the andesite. Two of the deep valleys south of Silverton expose pre-Cambrian schists below the volcanic rocks. The irregular pre-Cambrian surface rises to the south so that 4 miles south of the Animas River the schist is well exposed at the surface. Several elongate bodies of quartz monzonite intrude the greatly fractured and weak zone along the marginal faults and were, in turn, fractured and mineralized during the later period of ore deposition.

The more productive veins of this area are approximately radial to the southern rim of the caldera or are in fractures that diverge from the radial veins. Some of these veins, such as the main system of the Shenandoah-Dives mine and the Nevada-Silver Lakė vein are accompanied over part of their extent by dikes of andesitic or latitic composition. Another set of fractures trending more or less concentric to the caldera intersect the radial system at high angles. These are commonly filled with dike material and in places are mineralized, as at the Titusville mine. A series of step-like granite-porphyry dikes extends in a wide arc around the apparent southern limit of the radial vein system.

Within the pre-Cambrian basement exposed in Spencer Basin, fractures both perpendicular and parallel to the nearly vertical foliation are prominent but are not strongly mineralized. The schist has not been an unfavorable wall-rock where cut by larger veins of the Tertiary mineralization. The effect of pre-Cambrian structure upon fracturing and mineralization of the overlying volcanic rocks is shown where the volcanic rocks are relatively thin, but elsewhere the effect is apparently negligible.

The veins on Sultan Mountain, immediately to the southwest of Silverton, are within a large stock of quartz monzonite. The main product of these veins has been silver derived from galena and gray copper. The sulfide minerals occur in a gangue of quartz, siderite, and barite. Hubnerite is also present in small quantities. Gold-bearing pyrite and chalcopyrite in quartz are locally found as bands within the lead-silver veins or in separate fractures. The veins of Sultan Mountain are similar in their mineralogy to the east-west system of veins in Ophir Valley a few miles to the northwest. In the Animas Valley below Silverton several mines are located in the quartzite and limestone overlying the pre-Cambrian schist. Among these are the Molas mine on a silver-bearing vein cutting the schist and quartzite and the Fairview property on a deposit of manganese oxide in the limestone.

East of the Animas River, in Deer Park, some high-grade rusty gold has been mined from small pockets along veins in the volcanic rocks. The largest veins of the area are farther east in Arrastre Gulch, Silver Lake basin, and Cunningham Gulch. The main value of these northwest-trending veins is in silver and lead, but some portions of the veins contain appreciable amounts of gold accompanied by pyrite and chalcopyrite. Close to the Animas Valley system of faults the northwesterly fissures contain some specularite and locally considerable amounts of fluorite. Among the principal producers of the northwesterly system are the Shenandoah-Dives vein, among the largest of the region, the Aspen, and the Silver Lake-Nevada and its related branches. In the Shenandoah-Dives workings the mineralized zone is wide and consists of several parallel and braided veins. Farther to the southeast the vein system splits. The strongest branch continues to the southeast nearly to Mountaineer Creek and is worked by the Highland Mary mine. Though evidence for zoning is not clear, the vein does contain more carbonates, barite, and argentiferous tetrahedrite in the southeast portion than in the section mined from Arrastre Gulch.

The lodes also trend northwest in Cunningham Gulch, a deep valley to the east of and parallel to Arrastre Gulch. The main veins in the upper part of the valley are the Pride of the West and Green Mountain which carry galena, sphalerite, and chalcopyrite in a gangue of quartz and some calcite. The Green Mountain vein cuts through the pre-Cambrian schist at a high angle to the schistosity.

Near the mouth of Cunningham Gulch, in the vicinity of a quartz monzonite stock, the ores change character and consist predominantly of siliceous and pyritic gold-bearing ores with lesser amounts of base metal sulfides. This area of gold mineralization extends eastward from the Old Hundred on Galena Mountain through the Buffalo Boy and Ridgway mines and northeastward to Minnie Gulch. In the vicinity of Minnie Gulch the N. 60°-70° E. veins, such as the Caledonia and Kittimac contain mostly lead-silver-copper ores, with minor amounts of gold.

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EUREKA AND ANIMAS FORKS AREA, EUREKA DISTRICT, SAN JUAN COUNTY

By W. S. Burbank

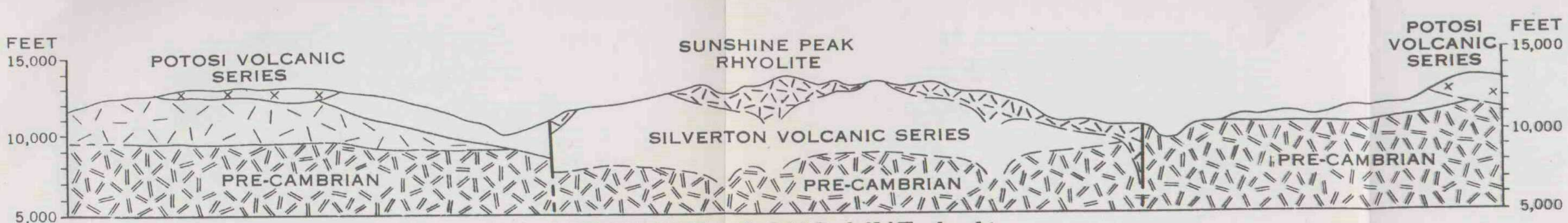
The area about the townsites of Eureka and Animas Forks in San Juan County comprises the drainage basin of the headwaters of the Animas River. This drainage basin includes the most productive part of the Eureka district, which has had a total output of ore worth approximately fifty million dollars. A large part of this came from the Sunnyside and nearby vein systems, but many other properties have contributed to the output. After higher-grade gold and silver-bearing ores were depleted, complex zinc-lead ores were successfully treated on a large scale in the 1,000-ton mill of the Sunnyside mine at Eureka, one of the first large installations of selective flotation in the country. From 1916 to 1927 the Eureka district yielded about 105,000 ounces of gold, chiefly from the Sunnyside and from the Gold King mine in the Cement Creek drainage area, ranking third in total State production of gold for that period. Together with the large mines of the Animas district the output of zinc within the last 20 years has raised the county from fourth to third place in State production of this metal and maintained its position as the third ranking county in production of lead. Since the closing of the Sunnyside mine in 1936, owing to near exhaustion of reserves above the operating tunnel level, the output of the Eureka area has been small. Substantial reserves of ore are known to exist below the last operating level of the Sunnyside mine, but until the completion of a projected mill level tunnel about 3 miles in length from Eureka these reserves are not economically accessible. Potentially, other parts of the area also contain large resources of low-grade ore, although established reserves are not large.

The Eureka-Animas Forks area lies structurally along a northeasterly trending graben on the north side of the caldera, indicated on plate 27 by hachure marks along the main bounding faults. This graben extends across the divide into Hinsdale County, where it joins with the Lake City caldera (pl. 31, and pp. 439-443). Some of the faults have displacements of more than 1,000 feet near the Silverton caldera, notably the Sunnyside fault and associated faults that bound the graben on the northwest. Most of the production has come from a zone within about 1 mile of the central fault block of the main caldera, but some of the larger faults and fissures are mineralized throughout their length and have yielded ore at places along a stretch of more than 6 miles. A series of east-west to southeast-trending faults and fissures are alined with and are essentially parallel to the central fault block, and these have been moderately productive within a belt about 2 miles outside the central block. A crescentic fault zone or ring structure, partly occupied by intrusive rocks and breccia swings around the southern end of the graben and continues north along the west side of California Gulch northeast of Hurricane Mountain (pl. 28). It separates the volcanic formations of the Sunnyside and California Mountain area from those at the head of Poughkeepsie Gulch in the Uncompahgre drainage to the northwest. The rocks of the Eureka area belong entirely to the Silverton volcanic series, and only a few small intrusive bodies of rhyolite and latite are exposed. Mineralization along the northeast veins is essentially limited at the southwest by the edge of the main down-faulted block and perhaps to some extent by the local ring structure mentioned.

The mineralogy of the veins in the Sunnyside mine is typical of many of the veins from which most of the output has been made. Hulin* has distinguished three main successive stages of reopening of the fissures and mineral filling. The first stage is represented by essentially barren vein matter consisting of quartz and pyrite, the second stage by the main base metal sulfides that formed the ore shoots, and the third stage by magniferous veins and ribs consisting mainly of rhodonite. Quartz containing free gold has been found cutting either or both the base metal and rhodonite bodies, indicating that, as in the Sneffels and Telluride districts, gold is a late mineral forming in places a valuable fourth stage of mineralization. As elsewhere in the Silverton area base metal sulfides occur in all vein stages, but their greatest concentration is in the second or base metal stage. The later rhodonite veins as represented at the Sunnyside and nearby veins contain in addition to rhodonite other silicates of manganese among which tephroite, alleghanyite, helvite, and friedelite have been identified.† Small amounts of alabandite and common sulfides accompany the introduction of the complex silicates. The manganiferous stage of mineralization ends with the formation of quartz, rhodochrosite, and other carbonate minerals.

*Hulin, C. D., Structural control of ore deposition: Econ. Geol., vol. 24, p. 32, 1929.

†Burbank, W. S., The Manganese Minerals of the Sunnyside Veins, Eureka Gulch, Colo.: Am. Mineralogist, vol. 18, pp. 513-527, 1933.



SECTION ALONG LINE A–A′

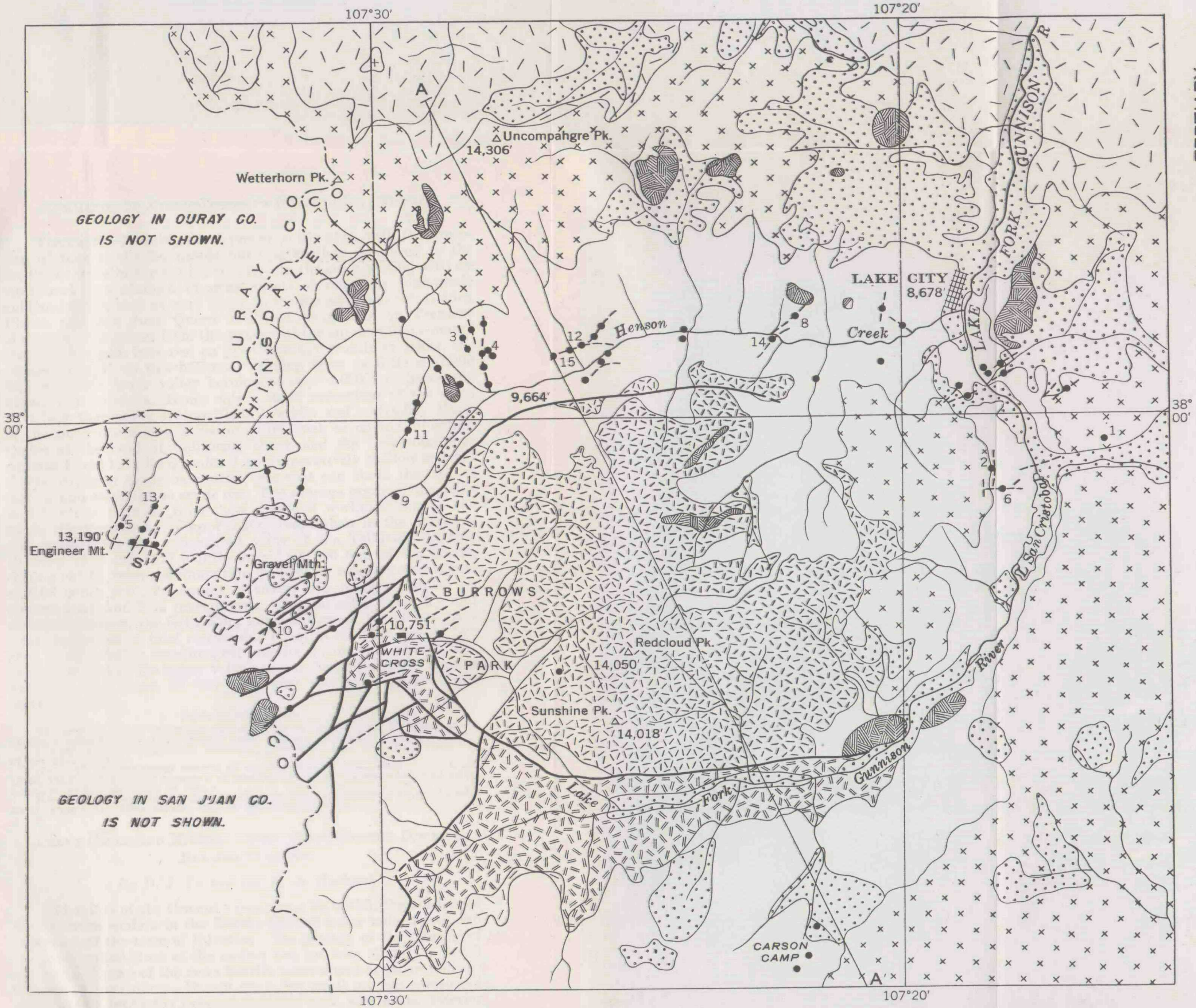


PLATE 31.

EXPLANATION

- Quaternary
- TERTIARY:
  - Intrusive rocks
  - Potosi volcanic series, Fisher latite-andesite, and Hinsdale formation
  - Sunshine Peak rhyolite *(Flows and intrusives)*
  - Silverton volcanic series
  - San Juan tuff and Lake Fork andesite
- Pre-Cambrian rocks
- Fault
- Vein
- Principal mine

LIST OF MINES

1. Belle of the West
2. Black Crook
3. Capitol City
4. Czar
5. Frank Hough
6. Golden Fleece
7. Golconda
8. Hidden Treasure
9. Highland Chief
10. Isolde
11. Moro
12. Ocean Wave
13. Palmetto
14. Ute and Ulay
15. Vermont

After Cross, Larsen and others, U. S. Geological Survey Bull. 843; Irving and Bancroft, U. S. Geol. Sur. Bull. 478, and W. H. Brown.

GENERALIZED GEOLOGIC MAP AND SECTION OF THE LAKE CITY REGION, COLORADO SHOWING THE LAKE CITY CALDERA AND THE PRINCIPAL MINES

0 1 2 3 4 5 Miles

PLATE 31.

The depth of mining development in the area, with the exception of that at the Sunnyside mine, is shallow compared to the depth of the Telluride erosion surface. In the early mining activity most work was confined to small shoots of relatively high-grade gold and silver, such as were found in the Sound Democrat, Golden Fleece, and San Juan Queen in Placer Gulch and on Treasure Mountain. It appears from the geology of the surrounding country that the volcanics here rest on pre-Cambrian granite or schist, the estimated depth to this basement ranging from as little as 1,000 feet below the lower valley bottoms to over 4,000 feet below the higher vein outcrops. Hence only a small percentage of the veins have been thoroughly explored both laterally and vertically. Many of the small operations in recent years, such as on the Mountain Queen at the head of California Gulch and the Columbus near Animas Forks have been confined to comparatively shallow selected shoots of higher-grade base-metal ores that can stand the cost of sorting and shipment as crude ore. The average grade of the veins is difficult to estimate from these scattered workings, but on the whole this appears to be appreciably lower than in the narrower and more uniformly mineralized veins of the Telluride district. Between 1916 and 1927 a little over 1,800,000 tons of ore mined, coming chiefly from the Sunnyside, yielded by recovery an average of 0.06 ounce gold, 2.6 ounces of silver, 1.15 percent copper, 3.1 percent lead, and 3.32 percent zinc. This included some dry and siliceous ore from the Gold King mine in Cement Creek but gives a fair indication of total recoverable metal in complex ores of this area, as afforded by metallurgical practice during that period. The average widths of the larger veins are considerably greater than at Telluride, and stopes 50 feet wide were carried in parts of the Sunnyside mine.

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CEMENT CREEK AND MINERAL CREEK AREAS, EUREKA DISTRICT, SAN JUAN COUNTY

By D. J. Varnes and W. S. Burbank

The mines of the Cement Creek areas lie within the borders of the Silverton caldera in the Eureka district a few miles north and northwest of the town of Silverton. The geology of the interior of the downfaulted block of the caldera has not been studied in detail compared to some of the more heavily mineralized areas around the margins of the caldera. Except for a few small intrusive bodies of rhyolite and latite the exposed volcanic rock within the interior is mostly pyroxene andesite of the upper part of the Silverton volcanic series.

This part of the caldera has been extensively fractured and mineralized, although the mineralization apparently is not concentrated in any particular set of fractures. The factors which controlled fracturing and mineralization within the caldera are still unknown, and the veins have not yet been correlated with the structural pattern of the caldera. The western border extending up Mineral Creek to Chattanooga is a fault line marked by strong alteration of the volcanic rocks exposed east of the valley. This zone forms essentially a southward extension of the even more highly altered zone of the Red Mountain district. The west side of Mineral Creek valley for a few miles above Silverton exposes the Paleozoic sedimentary rocks overlain by San Juan tuff.

Two kinds of metalliferous deposits are found in this area; the first are true veins, the second are chimney deposits within volcanic pipes or within bodies of highly altered rocks. Some evidence is available to show gradations between the vein deposits and the more or less pocket-like masses of ore allied to volcanic pipes.

The vein deposits are represented by two more or less distinct mineralogic types. To the first type belong the quartz-pyrite-gold veins such as worked by the Gold King mine. These veins also commonly contain bunches of galena and other base metal sulfides. They are composed characteristically of white quartz with considerable pyrite. Locally free gold is visible in the quartz, but in much of the lower-grade ore it is not seen. Massive pyrite nearly free from quartz characterizes parts of some veins. The siliceous veins of the Gold King group have produced ore with a gross value of more than $8,000,000. Somewhat allied to the Gold King types are highly pyritic veins such as represented by the Brooklyn vein on the ridge east of Mineral Creek 4 or 5 miles northwest of Silverton. Besides pyrite the vein contains some chalcopyrite and other base metal sulfides and a little quartz. The free gold is a late mineral in places perched on the pyrite and other sulfides in vugs. Rich ore is erratic in distribution.

The second type of veins is represented by the tungsten-bearing quartz veins which occur independently and also as a late stage of mineralization in the walls of the pyritic and base metal sulfide veins. Commonly the hubnerite ore is erratically distributed in large masses of quartz vein matter and silicified rock so that except during times of unusual demand for tungsten the search for and development of high-grade tungsten shoots is not profitable.

Chimney deposits similar to those of the Red Mountain district are found in the area immediately northwest of Silverton on the ridge between Mineral and Cement Creeks known as Anvil Mountain. Typical of the deposits is the ore occurrence at the Zuni mine which formed a pipe-like mass 60 feet long and 15 feet wide at the surface consisting chiefly of massive anglesite (sulfate of lead). Unoxidized guitermanite (lead-arsenic sulfide) and zunyite lay below the sulfate ore, and in depth enargite, pyrite, kaolin minerals, and a little barite were found. There was considerable silver in the enargite ore, and the pyritic ore carried a little gold. Other isolated and small ore bodies of this kind have been mined in this area, and probably many undiscovered ones remain in the large area of altered rocks on the mountain.

Those chimney deposits of the Red Mountain type which have had a large production in the past generally have a prominent outcrop composed of silicified and kaolinized breccia. Recently the Lark mine east of the Red Mountain divide in the Cement Creek drainage area has developed a body of base metal sulfide ore in a chimney deposit which has no prominent outcrop. This find has created considerable interest because of the strong possibility that similar deposits with no pronounced surface expression have been overlooked. Such deposits will be difficult to find, but detailed surface mapping supplemented by modern geophysical and geochemical techniques appears to be a promising way to approach the problem.

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THE MINERAL POINT, POUGHKEEPSIE, AND UPPER UNCOMPAHGRE DISTRICTS, SAN JUAN AND OURAY COUNTIES

By W. S. Burbank

The Mineral Point, Poughkeepsie, and Upper Uncompahgre districts adjoin one another in San Juan and Ouray Counties at the headwaters of the Animas and Uncompahgre Rivers. A small but productive part of the Engineer Mountain area at the extreme northeast lies across the divide in Hinsdale County at the head of Henson Creek in the Gunnison River drainage basin, and hence is tributary to the Galena district of the Lake City region (pp. 439-43). The Poughkeepsie district includes the main branch of the Uncompahgre River known as Poughkeepsie Gulch, which extends from near the San Juan County line south nearly to Hurricane Peak. The area north of this including Hayden Mountain and mountain slopes east of the Uncompahgre River is generally referred to as the Upper Uncompahgre district. In this review only that part south of latitude 38° is included, as north of this line most of the productive deposits belong to the early Tertiary province.

These several districts include swarms of veins extending outward from the northern border of the Silverton caldera. In all more than 100 miles of vein outcrops have been mapped in the area. On the east the vein systems are integral with those of the northern part of the Eureka district along a line west and southwest from Animas Forks.

The output of the districts from 1874 to 1941 amounts to about \$2,000,000 worth of silver, gold, lead, copper, and zinc. Most of this output was made prior to 1900 from 12 to 15 of the larger mines, none of which has yielded more than \$500,000 worth of ore. With considerable depletion of the higher grade and more accessible silver ore shoots and the decline in price of silver in the nineties very few mines were able to continue operations on the remaining low-grade siliceous silver-gold ores or on the base metal ores. Since 1900 small shipments and shortlived operations have predominated. From 1939 to 1946 the largest output has been made from the Mountain Monarch mine in Ouray County about a mile north-northeast of Abrams Mountain. The lead-zinc ore produced was milled at Ouray. Among the more productive mines of the area are included in the Alaska, Forest and Old Lout in Poughkeepsie Gulch, the Bill Young and San Juan Chief near Mineral Point, the Polar Star near Engineer Mountain, and the Michael Breen, Mountain Monarch, and the Silver Link in the Upper Uncompahgre district. The area as a whole deserves more recognition as a potential source of low-grade base and precious metal ores than would be indicated by the past production relative to other parts of the Silverton volcanic center.

At the northwest the deep canyon of the Uncompahgre River exposes pre-Cambrian quartzite and slate, which are deformed into relatively tight and faulted folds of westerly trend. West of the river is a tapering wedge of westward-dipping Paleozoic and Mesozoic sedimentary rocks interposed between the pre-Cambrian rocks and the base of the volcanic series. Most of the mountain slopes facing the main canyon above the base of the volcanic rocks are composed of the San Juan tuff, but in Poughkeepsie Gulch and Mineral Point areas the predominant rocks are the latitic and rhyolitic flows, tuffs, and breccias of the Silverton volcanic series. The San Juan tuff with a thickness of 2,500 feet under Hayden Mountain thins to less than half of this where it underlies the Silverton rocks in Poughkeepsie Gulch, although its reocurrence farther to the east across the Continental Divide in Hinsdale County may indicate continuity beneath the Mineral Point area. Most of the productive veins of the area are within the Silverton volcanic series, but several more important veins and deposits of the Uncompahgre Canyon and lower Poughkeepsie Gulch areas are in the San Juan tuff or in the pre-Cambrian quartzite just below the base of the tuff. Only a very small production has been made from deposits in the limestones, sandstones, and shales of the Paleozoic and Mesozoic formations, but for the most part these formations are buried beneath San Juan tuff on Hayden Mountain, an area which except for a few strong veins of easterly strike was subject only to relatively weak fissuring and mineralization.

Three forms of ore deposits are recognized, fissure and cavity fillings, breccia chimney and dike deposits, and replacement deposits. Typical fissure veins are the common form and consist dominantly of quartz with more or less pyrite, sphalerite, galena, chalcopyrite, rhodochrosite, and barite. The gold- and silver-bearing parts of the veins are commonly separate from the base metal shoots and consist of a gray quartz with argentiferous tetrahedrite, and sparingly contain richer silver minerals, such as ruby and brittle silvers and native gold. Some deposits cropping out near the older high erosion surfaces have been oxidized at the surface and moderately enriched below with argentite, native silver, and gold. In veins at the head of Poughkeepsie Gulch and locally elsewhere sulfobismuthites of lead and silver form rich high-grade pockets of primary ore. Alaskite, a lead-silver sulfobismuthite, is named after the Alaska mine of this area.

Because of relatively poor access to parts of the area there has been little large-scale exploration that would permit an accurate estimate of the average value and continuity of ore shoots. Mine workings are relatively shallow so that the area is essentially virgin for deep development to the base of the volcanic series. Throughout much of the high country adjacent to the Mineral Point and Engineer Mountain area, the depth to the base of the volcanic series is estimated to be as much as 3,000 feet. Also, since the volcanic rocks are probably underlain by pre-Cambrian rocks favorable to fissuring and mineralization, potentially productive ground is not necessarily limited to rocks above the Telluride erosion surface.

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LAKE CITY AREA, HINSDALE COUNTY

By W. S. Burbank

The Lake City mining area lies in the upper drainage area of the Lake Fork of the Gunnison River in Hinsdale County (pl. 31). Altitudes range from about 8,700 feet at Lake City to 14,306 feet on Uncompahgre Peak about 8 miles to the west, but most of the mines are along the slopes of the river canyons below 11,000 feet. The area includes two major districts, the Galena district along Henson Creek, a tributary entering the Lake Fork from the west at Lake City, and the Lake district along the main fork extending south and west to Burrows Park at the headwaters of the stream. Veins at the head of Henson Creek in the Galena district and those in Burrows Park near Whitecross are in part continuous with the veins of the Silverton center of mineralization. Burrows Park is at times referred to as a separate district, and south of the Lake district there is a small district known as Carson Camp. Except for a relatively small quantity of ore valued at a few hundred thousand dollars which is credited to these small districts, the county production came entirely from the Galena and Lake districts.

The mining history of the area began essentially in 1871 with the discovery of the silver-lead ores of the Ute and Ulay veins in the Galena district. The Golden Fleece vein high in gold was discovered three years later in the Lake Fork district and was responsible for a rush of prospecting that resulted in numerous though less important discoveries. By 1895 the production had mounted to nearly three-quarters of a million dollars annually in silver, lead, and gold. Among the principal producing mines were the Golden Fleece, Ute, Ulay, Hidden Treasure, Vermont, and Yellow Medicine. Depletion of the rich ores in the shallow zones of oxidation and enrichment of the veins brought on a decline in annual output to $100,000 or less by 1903. Since then the annual output has exceeded $100,000 only during the period from 1906 to 1910, owing chiefly to ores from the Frank Hough, Highland Chief, and Hidden Treasure mines. Flotation units were installed in a number of the mills during the twenties, but for a few years in the early thirties there was no appreciable production from the county. There was a slight revival in production after 1937 when new flotation units were installed in the Ute and Ulay mill. In 1943 the production of the district, entirely from the Ute-Ulay group, amounted to 9,329 ounces of silver, 5 tons of copper, 191 tons of lead, 16½ tons of zinc, and 34 ounces of gold, in terms of recovered metals. Although sphalerite occurs in some of the veins, zinc recovery has never been large.

Most of the volcanic rocks of the Lake City mining area belong to the Silverton volcanic series, which occupies a steep-walled basin or caldera marked by an oval-shaped down-faulted block between Henson Creek and the Lake Fork (pl. 31). A large part of the central block consists at the surface of rhyolite in flows and intrusive bodies. Except around its borders the central area of the subsided caldera has been relatively unproductive. The structural control of ore deposition appears related to marginal structures. This relation between the veins and the fault block compares somewhat with conditions in the Silverton area, although the surrounding veins do not extend as far from the margins as in the districts of the Silverton caldera. Pre-Cambrian granite is exposed along the south side of the caldera and on the west near Whitecross in Burrows Park. The granite, except where in fault contact with the volcanic rocks, is overlain directly by San Juan tuff or rocks of the Silverton volcanic series and seems to have formed a ridge-like divide on the Telluride erosion surface between the Silverton and Lake City regions. This granite apparently underlies the volcanic rocks throughout much if not all of the Lake City mining area, although a few inclusions of quartzite have been noted in the basal rocks of the Silverton series.

Intrusive rocks in addition to those associated with the central rhyolite complex include bodies of intrusive rhyolite and latite and small bodies of coarser-grained quartz monzonite porphyry. These lie mostly within an area extending about 4 or 5 miles from the margin of the central complex, and a few lie within the central area and along its borders. There is a notable absence of large bodies of coarse-grained nonporphyritic intrusive rocks such as occur west of the Silverton center.

The ore deposits are almost entirely veins, both fissure filling and replacement contributing to the formation of the ore. Mineralogically the veins show similarities with those of the Silverton area, and three principal groups of veins have been distinguished by Irving and Bancroft, based upon relative abundance of the common minerals. These include the quartz-sphalerite-galena group, the tetrahedrite-rhodochrosite group, and the telluride group. The quartz-sphalerite-galena group contain dominant base metal sulfides with considerable pyrite and some chalcopyrite. Silver is an important constituent, more particularly where the veins are enriched near the surface. The tetrahedrite-rhodochrosite group are dominantly galena and argentiferous tetrahedrite with some of the other base metal sulfides in a gangue of quartz, rhodochrosite, and barite. Lead and silver are the important products, and where appreciable tetrahedrite is present the primary ores contain considerable silver. The telluride group contains tellurides of gold and silver disseminated through a fine-grained quartz gangue, with small quantities of the common sulfides and a little barite and hinsdalite. This group is represented by the ores of the Golden Fleece vein, in which krennerite, sylvanite, and petzite have been identified, and the value of gold and silver in the ore was about in the ratio of 1:1. In other veins the ratio of silver is commonly higher. Hessite has been identified in the Frank Hough ore, and sylvanite and hessite in the Gallic and Vulcan veins.

For most vein groups the banding and order of deposition of the various constituents is generally (1) silicification of the wall and formation of pyrite in the wall and fissure; (2) sphalerite, chalcopyrite, galena, and rhodochrosite; (3) tetrahedrite; (4) quartz; and finally, the oxidized minerals and products of secondary enrichment. In the Gallic and Vulcan ore the tellurides and free gold occurred in a second generation quartz following early quartz, base metal sulfides, and tetrahedrite. The minerals of the oxidized zone include limonite, anglesite, cerussite, and a little malachite and azurite. Native copper and native silver are also characteristic of the oxidized zone, the latter particularly in the richer silver veins where it may be the most valuable constituent of the ore as at Creede. Chalcocite, argentite, and the ruby silvers, especially pyrargyrite, were common in the enriched ore immediately beneath the oxidized zone and account for the bonanza ores of the early period of production.

Most of the productive veins of the district lie in the andesites of the Picayune volcanic group which forms the basal part of the Silverton volcanic series. These rocks are the ones exposed in the valleys of the rivers around the north and east sides of the caldera, so that their position relative to the caldera margin appears more significant than their composition or stratigraphic position. Likewise veins in other rocks elsewhere in the district have the same general mineralogic characteristics, affording no grounds for any conclusion that the rocks themselves controlled the character of ore. The Frank Hough vein at the west extremity of the district lies in the Henson tuff, the uppermost unit of the Silverton volcanic series. This vein alone yielded more than half of the entire output of copper for the county. A small production of ore has been made from the pre-Cambrian granite at the head of the Lake Fork in Burrows Park. These veins are of the base metal type with chalcopyrite, and their occurrence in the fractured granite affords further evidence that reactions of the rocks to local forces of fissuring rather than composition or vertical position in the volcanic sequence controlled the distribution of primary ore. The siliceous silver- and gold-bearing veins of the Isolde and Golconda mines also west of the caldera, and between it and the Silverton caldera, occur in the Burns and Eureka flows in the middle of the Silverton volcanic series. On the other hand the reaction of different rocks to fissuring and their individual susceptibility to replacement may effect the widths of veins and ore shoots. The rich silver-copper-gold ore of the Frank Hough formed relatively wide shoots in the Henson tuff, but narrowed where the fissure passed through hard massive flow rocks. In this area near Engineer Mountain there is also reported to be an increase of lower-grade pyritic ore with depth. At many places in the Lake City region, however, changes of the vein structure in depth by branching and pinching of the fissures were more pronounced than mineralogic changes. An exception to this is of course the pronounced mineralogic changes occurring near the base of the oxidized and enriched ores. As in the Creede district this change appears related to the position of the Florida erosion surface, remnants of which are preserved as benches on some of the valley slopes.

The zone of weakness along the margins of the basin or caldera in which the Silverton volcanic series was erupted is believed by the writer to have been the principal structural control of ore localization. The final collapse of the interior of the caldera produced ring faults that partly encircle the central area. Adjustments of the rocks outside these faults to the subsiding block, or along concealed faults in the basement rocks beneath the volcanic cover, presumably caused the final fractures and fissures in which the ore shoots were formed by mineralizing solutions that came up along the marginal zone. There is some evidence both at the Golden Fleece mine and along the fault border of the central block in Burrows Park that some faulting continued along the margins after ore deposition. There are several sectors around the center in which structural and ore-forming conditions vary from place to place. The south margin has been relatively unproductive. The veins in the Galena and Lake districts along the north and east sides are confined mainly to a belt about 2 miles wide. Within this belt individual vein fissures are commonly short and tend to split or fray out both laterally and vertically. This habit of the fissures together with the local overlapping relationships seen at the surface may be considered indicative that the general fissure pattern continues in depth as well as laterally. However, the main valleys follow the caldera margins and thus present a drainage problem adverse to low-cost exploration in depth for additional sources of ore. The narrowness of many higher-grade veins and the unenriched primary base metal ore do not offer sufficient incentive for extensive exploration and development below drainage levels. Despite these unfavorable features the districts may be expected to yield a small output from known veins for many years as there is much low-grade ore. If, as inferred, the pattern of fissuring is repeated in depth, it also follows that possibilities of new discoveries of blind ore shoots above drainage levels are not exhausted.

On the west side of the caldera the pattern of faults and veins extends continuously to the Silverton center, a total distance of more than 6 miles. East of the Hinsdale County line the vertical extent of mineralized ground above drainage levels is as much as 2,000 to 3,000 feet. The area is therefore a potentially large source of low-grade ores, and the records of such veins as the Frank Hough, Golconda, Isolde, Palmetto, Wyoming, and others indicate that small bodies of high-grade ore may also be expected. Brown* has shown that the veins of the Burrows Park area are zoned outward from the granite area, a copper zone occurring at lower altitudes in the granite basement, a lead-zinc zone surrounding this in the volcanic rocks on the west, and a gold-silver-lead-zinc zone covering the high country along the divide between Hinsdale and San Juan Counties. This distribution of ore zones is entirely consistent with the structural control outlined above, since the west contact of the central downfaulted block passes through eastern Burrows Park.

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THE BONANZA (KERBER CREEK) MINING DISTRICT, SAGUACHE COUNTY

By W. S. Burbank

The Bonanza or Kerber Creek mining district is situated in the extreme northeastern part of the San Juan volcanic region. The Tertiary volcanic rocks cover most of the district and rest upon a basement of pre-Cambrian rocks within which are infolded and faulted synclines of the Paleozoic sedimentary formations (pl. 27). At least 4,000 feet of volcanic rocks accumulated locally on the basement and were later invaded by quartz latite and rhyolite intrusive bodies. Moderate doming of the crust may have accompanied the intrusive activity, but the crust broke into numerous small fault blocks and partly collapsed over an area of about 30 square miles, presumably because of sudden or intermittent loss of support from an underlying body of molten rock. During the breaking-up of the crust many small dikes and irregular igneous masses were intruded along openings between the fault blocks. Locally along certain broad bands the broken lava flows were steeply tilted during the collapse and were faulted into step-like overlapping blocks. In general, movements on the faults were downward in successive steps towards the central area of the subsidence. All of the known metallic ore deposits are veins formed either along fault fissures bounding the blocks or in subsidiary tension fissures formed in the walls of large faults. The extreme fracturing of the rocks in the district created conditions that were not favorable to the formation of long continuous veins, and many ore shoots end against cross faults which may or may not be appreciably mineralized.

The pre-Cambrian rocks exposed near and within the district comprise granite, gneiss, and schist. Within the volcanic area of the district these are exposed only in small fault blocks or at the bottoms of the deepest valleys at the northeast. South of the district coarse granite composes the northwest-trending anticlinal axes of the basement folds, and the synclinal folds of the Paleozoic sedimentary rocks are overridden from the south by a large thrust plate of pre-Cambrian granite. This large fault passes beneath the volcanic cover and may join with thrust faults that follow the west slope of the Saguache Range west of the Monarch district, although the direction of thrusting is not the same. The region consequently lies near the junction of several old structures of diverse trends which may have influenced the localization of Tertiary intrusive activity.

The Paleozoic sedimentary formations include the Manitou limestone, Harding sandstone, and Fremont limestone of Ordovician age; the Chaffee formation of Devonian age; the Leadville limestone of Mississippian age; and the Kerber and Maroon formations of Pennsylvanian and Permain age. These formations underlie the lavas in the southern part of the district within an area of weakly mineralized but strongly altered rocks. The possibility that the buried sedimentary strata may contain concealed mineral deposits affords a potential but problematic source of metals. The depths of exploration required to test these sedimentary rocks probably range from less than 1,000 to several thousand feet. But in the absence of known ore deposits in the sedimentary rocks of this area, the risks of exploration appear to be greater than would normally be assumed.

The volcanic rocks (pl. 32) are chiefly andesite, rhyolite, and latite flows and breccias of Tertiary age. The basal unit, the Rawley andesite, is about 1,500 feet thick and has been the most productive of these rocks. A small output has been made also from the rela-

GENERALIZED GEOLOGIC MAP AND SECTIONS
of the
BONANZA MINING DISTRICT
SAGUACHE COUNTY, COLORADO

By W. S. Burbank

1946

PLATE 32.

tively thin Bonanza latite overlying the andesite. Alteration of the volcanic rocks is very intense locally, involving silicification and alteration to clay minerals, pyritization, and alteration to sericite and carbonate minerals. Alunite is a product of alteration in silicified latites and rhyolites and is found particularly northwest of the district near Porphyry Peak. If bodies of large size and adequate purity were to be found, these deposits might form a potential source of potash and alumina.

The lead and silver deposits of the district attracted attention early in the history of the San Juan country, and the town of Bonanza attained considerable importance by 1880. Most of the mining operations were relatively small, however, until the driving of the 6,200-foot Rawley drainage tunnel from Squirrel Gulch in 1911 and 1912 to tap the silver-lead-copper-zinc ore shoot of the Rawley vein at depth. The greater part of the ore in the Rawley shoot above the tunnel level was mined and milled between 1923 and 1930, and the mill was then dismantled. Some lateral exploration was undertaken on veins across the Paragon fault that bounded the ore shoot on the south, but bodies of ore large enough to be of commercial interest at that time were not found. Besides some known and inferred ore remaining within reach of the Rawley tunnel developments, many other veins in the district contain small reserves but none large enough to warrant the construction of a large-scale plant for economical treatment of low-grade ores.

The total production of the district to 1946 has been about $9,000,000, most of which represents the output of the Rawley mine. About 3,000 tons of zinc metal were actually recovered from ores mined in the district (table 6, p. 372); but the equivalent of approximately 5,000 tons of zinc mined with the ore from the Rawley vein was not recovered, and many smaller operations failed to mine or recover zinc. Most of the zinc mined and recovered in the district came from the Cocomongo and Bonanza properties in the Bonanza latite on the west edge of the mineralized area. This ore also contains lead, silver, and copper. Contributions to the gold and silver output of the district were made by the Empress Josephine and St. Louis mines, partly telluride-bearing ores. The Eagle mine in the southern part of the district yielded ore valuable chiefly for the silver content. Manganese ore was also mined from the Pershing mine in the extreme southern part of the district. Lately the output of all metals from the district has ranged between $150,000 and $200,000 annually.

The deposits of the district are chiefly complex base metal ores containing pyrite, sphalerite, galena, chalcopyrite, bornite, enargite, tennantite, and stromeyerite in a gangue of quartz, calcite, rhodochrosite, and barite. Some ores contain a little bismuth, occurring in part as the mineral cosalite. Two principal classes of ore may be distinguished—(1) quartz veins of relatively high sulfide content containing lead, zinc, copper, silver, and a little gold, found chiefly in the northern part of the district, and (2) quartz-rhodochrosite-fluorite veins with only minor quantities of sulfides valuable mainly for their silver content, found in the southern part of the district. A few veins in the northern part of the district contain tellurides of silver and gold in sufficient quantity to have made these metals of dominant value in small shoots. Quartz veins with native gold are not characteristic of the district, and the only productive vein of this kind was found in the Columbia Gulch area south of the district (pl. 27).

Secondary enrichment of the veins was relatively shallow and of importance chiefly in early production. The oxidation of the rhodochrosite veins in the southern area extended to a depth of about 100 feet and in the Eagle vein resulted in moderate silver enrichment. The manganese ores also formed from shallow oxidation of rhodochrosite-bearing veins.

Small production may be expected from the district for many years, and possibly other ore shoots as productive as the Rawley may be found eventually. Exploration of the ground beneath the Whale and other nearby veins south of the Paragon fault from the level of the Rawley drainage tunnel is one of the more outstanding speculative possibilities in the district. The complexity of the structure and the comparative shortness of most ore shoots are unfavorable, however, to sustained large-scale production from many of the mineralized fissures in the volcanic rocks.

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GEOLOGY AND MINERAL DEPOSITS OF THE SNOWMASS MOUNTAIN AREA, GUNNISON COUNTY

By John W. Vanderwilt

This area is listed in the San Juan region as a matter of convenience. The area is about equidistant from the San Juan region and Central Colorado and geologically unrelated to both. The following account is the abstract that appears in U. S. Geological Survey Bulletin 884.

The Snowmass Mountain area is in the Elk Mountains, immediately north of the Crested Butte and Anthracite quadrangles, in the extreme northern part of Gunnison County, Colorado. Mineral deposits were recognized in the early seventies; in early literature the area is referred to as the Rock Creek mining district, but it is now known as the Crystal River district.

The maximum relief is a little over 5,000 feet, with rugged divides and steep slopes on which the geologic features are well exposed by glaciation and subsequent stream erosion.

Pre-Cambrian gneiss, the Paleozoic formations common to central Colorado, Jurassic and Cretaceous formations, and intrusions of Tertiary age are exposed in the area. The gneiss is composed largely of feldspar and biotite and is typical of the pre-Cambrian over large areas in the Sawatch Range, to the east. Sawatch quartzite (Cambrian), 219 to 278 feet thick, rests on the gneiss and is in turn overlain by 81 to 151 feet of Manitou (Ordovician) dolomite. Several feet of Harding quartzite and 60 to 63 feet of Fremont limestone constitute the upper part of the Ordovician. No Silurian is present. The Parting member, the basal part of the Devonian Chaffee formation is composed of about 54 feet of shales, shaly limestones, and dolomites and several feet of quartzite. The upper part of the Chaffee formation, the Dyer dolomite member, is 72 to 97 feet thick and is overlain by 170 to 274 feet of Leadville (Mississippian) limestone. The lower part of the Leadville is interbedded dolomite and limestone through an interval of about 40 feet, above which the formation is a massive limestone. On the Leadville limestone rests the Hermosa (?) formation (Pennsylvanian), composed of 1,228 to 1,316 feet of limestone, sandstone, shale, and rocks of intermediate composition. A breccia of chert and quartzite fragments in shale forms the basal bed of the Hermosa and rests on an erosional unconformity. Above the Hermosa are more than 3,000 feet of Pennsylvanian (?) and Permian strata (Maroon formation), terminated at the top by a strong angular unconformity at the base of the Entrada sandstone (Jurassic), 30 to 40 feet of which in places underlies the Morrison formation (Jurassic), which is about 400 feet thick. Dakota (?) quartzite (Cretaceous), 100 to 150 feet thick, rests on the Morrison, and above the Dakota (?) are Mancos (Cretaceous) shales. Only the lower part of the Mancos shale is present.

All the formations are well developed except the Harding quartzite and Fremont limestone, both of which are relatively thin and represent the northernmost exposures of these beds in central Colorado. The formations can be satisfactorily correlated with those of neighboring areas, including Glenwood Springs, the Crested Butte quadrangle, and the Aspen mining district.

The igneous rocks in the area are of Tertiary age. The oldest are dikes and sills of intermediate composition, after which stocks of granodiorite (Snowmass Mountain) and albite granite (Treasure Mountain) came into place. The albite granite and granodiorite may represent differentiates of a common batholith. The relative ages of the stocks are not known.

The dikes and sills are small. They are confined largely to the southern part of the area and represent the northern ends of dikes and sills of the Anthracite and Crested Butte quadrangles. The dike rocks are all porphyritic and consist of quartz monzonite similar to the Lincoln porphyry of the Mosquito Range, gabbro, lamprophyric rocks, and white felsitic rock. All are more or less altered, and identification is not always possible.

The granodiorite is a stock covering about 40 square miles, most of which lies north of the area. It forms rugged peaks, of which Snowmass Mountain is a representative example. The rock is medium-grained and very uniform in appearance over large areas. It is composed of quartz, orthoclase, oligoclase, and biotite. Marginal facies of the granodiorite are quartz diorite and albite rock in which all the feldspar is albite. The quartz diorite occurs opposite the Maroon formation and is confined to a zone not more than a few hundred feet wide. The albite rock, not to be confused with the albite granite of Treasure Mountain, occurs in a zone several hundred feet wide opposite the Mancos shale and in the area where the intrusion has cut across the Elk Mountain fault zone. The principal minerals are albite and quartz with much biotite and some calcite. The complete absence of veins of any kind and the presence of limestone inclusions has led to the belief that the albite granite was formed in the magmatic stage of the intrusion by mineralizers, probably water and carbon dioxide, derived from the sedimentary rocks. The chief role of the sedimentary inclusions would be to furnish mineralizers in sufficient volume and concentration to cause the concentration of the albite molecule during the magmatic stage; ordinarily the concentration of mineralizers is effected relatively late, as albitization more commonly occurs after a magma is almost completely solidified. The early existence of an albitic magma finds support in the occurrence of albite-aplite dikes and other albitic dikes and sills in the Aspen district.

The albite granite is exposed over a relatively small area, but the areal extent of associated metamorphic rocks is proof of the stocklike nature of the mass. The intrusion arched the formations in the form of an elongate dome and at the same time cut across 1,500 to 2,000 feet of strata. The granite is a pink medium-grained rock composed of quartz, orthoclase, albite, and a small amount of biotite. The marginal facies is porphyritic, with phenocrysts of pink orthoclase and quartz in a pale-pink to white groundmass. Biotite is entirely lacking in places in this marginal porphyritic facies, which ranges in width from a few inches to several hundred feet. The bulk of the mass is well crystallized, and at the crest of the stock pegmatites of orthoclase and quartz are common. The granite is virtually unaffected by metamorphism.

The outstanding structural features, named in order of their relative age, are an angular unconformity at the base of the Jurassic; the Elk Mountain fault zone; the granodiorite stock, of which Snowmass Mountain is a part; and the Treasure Mountain dome, formed by the intrusion of a stock of albite granite.

The beveled edges of the beds below the unconformity at the base of the Jurassic trend N. 40°-50° W. and dip 20°-28° NE., relative to the base of the Jurassic reduced to a horizontal plane. The surface of the unconformity is remarkably uniform.

The Elk Mountain fault zone trends northwest across the area. Along it the Maroon red beds are thrown up against and above 1,000 feet of overturned Mancos shale. The structure is continuous to the northwest with the Grand Hogback fold, on the flank of the White River Plateau; to the southeast it extends at least as far as the Gunnison River. The strike in the area is northwest. It changes to nearly west for several miles northwest of the area, and beyond that it changes to more nearly north. Thrust or reverse faulting is confined to the Snowmass Mountain area; farther northwest the beds lie in a monoclinal fold with normal faults. Local variations in structural detail are dependent on the changing curvature along the strike of the fault zone; the beds are steepest in the areas between the points of maximum curvature. Three large stocks of granodiorite are localized along the Elk Mountain fault zone—Whitehouse Mountain lies to the southeast, Snowmass Mountain within the mapped area, and Mount Sopris to the northwest of the area.

The granodiorite of Snowmass Mountain cuts across the Elk Mountain fault zone; however, the main mass of the stock lies on the northeast side. Where the intrusive mass cuts across the strike of the beds along the fault zone the rocks are crushed and broken for a width of several hundred feet; elsewhere the beds are arched and the bedding is cut at a small angle.

An intrusion of granite brought about the exposure of pre-Cambrian gneiss and all the earlier Paleozoic beds, for it arched the beds into a sharp dome and thus brought them within reach of erosion. Treasure Mountain marks the crest of the dome, which is 3 to 5 miles wide and 5 to 6 miles long, with its major axis trending northwestward. Only a relatively small area of the albitic granite is exposed, but the extent of metamorphism suggests a wider distribution of the granite at depth. All the formations below the Dakota (?) quartzite are uniformly metamorphosed, whether close to the contact or several thousand feet from it. The principal changes are from shale to hornfels, from sandstone to quartzite, from dolomite beds to serpentinized rock that contains much diopside, and from limestone to white marble. In addition, epidote, andradite garnet, and hedenbergite are common in places. The formation of serpentine and diopside has been controlled so closely by the composition of individual beds that these minerals constitute a guide for the identification of horizons in the metamorphic areas.

The area has been glaciated at two stages. The first or high stage is marked by cut-rock benches near the heads of the valleys and by glacial boulders several hundred feet above the benches that were traced as far as Redstone, 12 miles northwest of the area. The second stage filled the lower parts of the present valleys. At the heads of the valleys continuous glaciation may have occurred.

Among the ore deposits zinc-lead ores predominate, although copper-silver and native silver ores also have been productive. The deposit of Colorado Yule marble has been and promises to continue to be commercially more productive than the metals. The total value of the output of metals has been about $500,000, and that of marble several million dollars. Authentic data on production are lacking for both industries. The bulk of the metals came from four mines—the Eureka mine, on Treasure Mountain, and the North Pole mine, in North Pole Basin, both of which produced copper-silver ore; the Black Queen mine, on Sheep Mountain, which produced considerable native silver ore; and the Lead King mine, which produced lead-zinc ore and some silver ore. All the marble has come from one quarry, which was opened in 1908.

Ore deposits are confined to the structural dome of Treasure Mountain and are concentrated on the northeast flank of the dome in a faulted and fissured zone 1 to 3 miles wide and 8 miles long. The zone contains sedimentary beds of Pennsylvanian, Permian, Jurassic, and Cretaceous age. The granite that formed the dome has cut out all the early Paleozoic beds in this part of the dome, but they are present on the crest of the dome and to the southwest. All the beds were metamorphosed prior to sulfide deposition.

The process of mineralization included three major stages, each of which graded into the succeeding one—first, intrusion of the granite of Treasure Mountain, which caused faulting and metamorphism of the overlying Paleozoic and Cretaceous beds; second, deposition along faults and related fractures of large amounts of quartz with locally much pyrite, some specularite, and barite; and last, deposition of sphalerite, chalcopyrite, galena, and silver-bearing tetrahedrite with a gangue of pyrite, fluorite, quartz, and calcite. Evidence of relationship between the first and second stages is suggested by more intense metamorphism where faults are large and numerous and by the common occurrence of hedenbergite in metamorphosed beds and in bands with quartz in veins. The second and third stages were more directly related than the first two, and they were separated by a period of fracturing. The rising solutions followed fault fissures, virtually all of which contain at least some quartz, and also spread out from the fissures along certain horizons to form bedded or blanket deposits. The early quartz, however, is virtually confined to veins, which are particularly numerous and conspicuous in the Dakota (?) quartzite; very little, if any, was deposited along beds. The quartz veins invariably pinch out on passing from quartzite into shale (hornfels). The workable shoots of sulfide occur in veins and in replacement bodies along beds. Blanket deposits are characteristic of the four mines that produced most of the ore.

Zoning is suggested, with copper-silver deposits centering on Treasure Mountain and North Pole Basin and with lead-zinc and silver deposits occurring to the northwest and southeast. For future prospecting the bedded or blanket types of deposits are recommended rather than the conspicuous quartz veins, which seem to have been preferred by the prospector. Veins are promising only where they intersect limey beds known to be favorable for ore.

Marble was recognized as early as 1880, but substantial development and production did not begin until 1908 or 1909, after the railroad was built to Redstone for developing coal deposits on

Coal Creek. The marble quarry is near Marble, 13 miles from Redstone, and is in recrystallized Leadville (Mississippian) limestone. This formation is uniformly recrystallized to a white marble throughout its extent along the Crystal River and Yule Creek. Local development of metamorphic minerals, distribution of bands of chert and dolomite, and location are factors that control the possible commercial value of a particular outcrop. An abundant reserve of marketable material is indicated.

Quarrying is complicated by the presence of joints, chert bands, and irregular masses of dolomite. These features are so closely related to the grain of the marble that quarrying of rectangular blocks is difficult and attended by a large percentage of waste. Nevertheless the quarry is noted for its ability to furnish blocks of large dimensions.

The marble is sold for exterior and interior building and for statuary and decorative use. Much of the marble is finished in the mill at Marble, and considerable unfinished marble, particularly statuary and decorative stock, is shipped. The bulk of the marble goes to western markets, but some is sent to eastern markets. The quarry and mill are owned and operated by the Vermont Marble Co., of Proctor, Vt.

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VANADIUM, FLUORSPAR, AND PEGMATITES

DEPOSITS OF VANADIUM-BEARING SANDSTONE

By R. P. Fischer

Introduction

Deposits of vanadium-bearing sandstone are widely distributed in western Colorado and the adjacent parts of Utah, Arizona, and New Mexico; they have been the principal domestic source of vanadium. The location of all deposits in western Colorado that have yielded 100 tons or more of ore is shown on plate 4. Since their discovery about 1900, approximately 25,000,000 pounds of vanadium has been recovered from ores mined in Colorado, representing more than 80 percent of the total vanadium recovered from the sandstone ores. In recent years the value of vanadium has been nearly $2.00 a pound (generally quoted at $1.10 a pound V_2O_5), but the value in the early days of mining was somewhat higher.

General Geology

The region containing the vanadium deposits is mostly plateau country, ranging from 5,000 to 7,500 feet above sea level. Rocks exposed consist of late Paleozoic to Tertiary sedimentary beds, invaded in a few places by moderate-sized laccolithic or stock-like bodies of Tertiary igneous rocks. In most places the sedimentary beds are nearly horizontal, but in places they have been tilted to low or moderate angles along broad folds or have been broken by high-angle faults.

The vanadium deposits near Placerville are in the Entrada sandstone of Jurassic age; those near Rifle also are in sandstone strata that have been correlated with the Entrada, though actually only the upper part of these strata closely resemble the Entrada of western Colorado and eastern Utah, and the lower part might possibly be an older Jurassic formation. Most of the other productive deposits are in the Morrison formation (Jurassic), but a few in southern Utah and northern Arizona are in the Shinarump conglomerate (Triassic); a few small, slightly productive deposits are scattered through other formations elsewhere in the region. The deposits in the Entrada and Morrison formations are restricted to rather narrow stratigraphic zones.

Ore Deposits

The vanadium deposits have many common characteristic features, even though their size, form, and geologic environment differ somewhat from place to place. The ore consists of sandstone impregnated with vanadium minerals; it is mostly gray, and its color darkens as its vanadium content increases. It ranges in grade from about 1 to 5 percent V_2O_5, mostly averaging between 1½ and 2 percent. The principal vanadium mineral is micaceous, forming minute flakes that coat the sand grains and fill pore spaces. This mineral has not been definitely identified, but its chemical composition is close to or identical with that of roscoelite, the vanadium-bearing mica. Shale pebbles and clay films along bedding planes in the ore also contain concentrations of vanadium. In and adjacent to certain ore bodies in the Morrison and Shinarump formations, fossil plants, consisting of tree trunks, branches, and fragments of plant material, are richly mineralized, but no plant remains have been found in the deposits in the Entrada sandstone. No gangue minerals other than those that constitute the enclosing sandstone are associated with the vanadium deposits.

The vanadium-bearing sandstone mostly forms irregularly tabular layers whose long dimensions lie nearly parallel to the bedding of the sandstone, but the layers are wavy and do not follow the beds in detail, and even individual layers are not confined to a single lithologic type of sandstone. Some small deposits are nearly equidimentional though irregular in shape, and individually they too are not confined to a single bed or type of sandstone. The layers range from less than a foot to several feet in thickness and locally swell to 10, 20, or even 30 feet in thickness. In places two or more layers overlap and some of them connect with each other by curving across the beds whereas others do not seem to be connected. The deposits in the Morrison formation are spotty and may be only a few feet or as much as several hundred feet across. Those in the Entrada sandstone, however, are far more continuous; at Placerville one layer is thought to have been nearly continuous through a belt 1½ miles wide and at least 9 miles long before being cut into separate units by the present stream valleys, and at Rifle a layer has been followed and mined for more than 5,000 feet.

The vanadium-bearing sandstone grades into the enclosing sandstone in places at the edges of the ore deposits, but commonly its limits are fairly well defined and in places sharply defined. The lack of conformity of the ore layers with the bedding is most conspicuous where the limits are well defined, for the edge of the ore is a plane surface that is gently undulant to the bedding or crosses it at a high angle in a smooth curve. These surfaces closely resemble fractures, but they cannot definitely be related either to sedimentary structures or to structures resulting from regional deformation.

Wherever an ore layer, or even one edge of it crosses the bedding in a smooth curve, the structure is called a "roll" by the miners. These rolls have many forms and variations, which are difficult to describe, though they are easily recognized features in the field. They are elongate in plan and range from 10 to 100 feet or more in length; most are fairly straight but some curve. Their long axes lie nearly parallel to the sandstone bedding. Many rolls, including some of the thicker parts of the tabular ore layers as well as some masses that individually make small ore bodies, are of roughly cylindrical form. Some merely express pronounced changes in the attitude of the ore layer, the layer passing from a higher stratigraphic position on one side to a lower one on the other in an "S-like" curve or turning back in a "C" curve.

Most rolls in a single ore body and those in neighboring bodies as well are oriented in about the same direction. Experience in the mining of deposits in the Morrison formation and of those in the Entrada sandstone near Rifle has shown that this direction indicates the elongation of the ore bodies, and the alinement of any adjacent bodies. Thus, mapping of the rolls can be useful in guiding mine development and in prospecting for new ore bodies nearby. In the deposits near Placerville, however, most rolls curve, and therefore can be used only with caution in the projecting of ore trends.

Fossil logs are fairly abundant in the vanadium deposits in the Morrison formation. Though a few appear to have merely fallen over from the position in which they grew, most were rafted into their present position, probably having been carried by flood waters and lodged against sand bars at the time the Morrison formation was being deposited. In many localities these logs have a common orientation and lie parallel to the stream channels in which the enclosing sands were deposited, their alinement being controlled by the stream currents. The rolls in the ore bodies at these localities also have the same general orientation, whether or not they actually enclose the logs. It is therefore concluded that the orientation of the rolls, even though the ore in them was formed after the sands had been deposited, was controlled in some manner by sedimentary structures that originated while the Morrison formation was being deposited.

The vanadium deposits have features similar to concretionary structures. Some of the cylindrical rolls resemble concretionary masses in general shape, though they exceed the dimensions of most concretions. Concentric banding of rich and lean ore is evident in many places where the ore layers have well-defined adges, especially in the rolls. Similarly, the sandstone adjacent to the ore commonly contains parallel bands of minerals that do not form a constituent part of the ore; these bands are separated from the ore, and from each other if more than one is present, by thin layers of barren sandstone. These bands differ locally in composition and their component minerals have not been fully determined. In the deposits in the Morrison formation, where all of the ore mined so far has come from the zone of oxidation, these bands appear to be merely limonitic stains in the sandstone and the primary mineral from which they were derived, if any was present, has not been identified. In the deposit in the Entrada sandstone near Rifle, however, the ore layers are bordered on one side by a band of finely disseminated galena, rarely more than an eighth of an ich thick, and this in turn is bordered by a few inches of gray or green, weakly vanadiferous sandstone. At Placerville the ore layer is underlain by a layer of light-green sandstone, colored by a finely disseminated, micaceous, chromium-bearing mineral. Though this chromium layer is not as intimately related to the edge of the vanadium ore as the other examples mentioned, it may have a similar genetic relationship; at least, its occurrence is closely similar to that of the vanadium.

The structural environment of the vanadium deposits differs from place to place. The ore-bearing and associated beds in general dip at low angles, having been tilted by broad folds, but some typical deposits occur in steeply-dipping beds whereas others occur in horizontal beds several miles from areas of deformation. High-angle faults with displacements ranging from a few inches to a hundred feet or more are common in places, but neither the distribution of the deposits in general nor the character of individual deposits seems to be genetically influenced by them. Where exposures allow satisfactory observations, all such faults that have been studied seem clearly to have displaced the ore and to be post-mineral. Along these faults no vanadium minerals have been observed except those that can be clearly recognized as secondary minerals or as gouge or breccia derived from the vanadium-bearing layers. Vertical joints are also common in the competent sandstones, but they too seem to be post-mineral and show no definite genetic relationship to the deposits. The sedimentary rocks in the vanadium-bearing region have been invaded in places by moderate-sized, laccolithic or stock-like bodies of Tertiary igneous rock, and of course the Placerville district is near the large area of Tertiary igneous rocks in the San Juan Mountains. The deposits as a whole, however, seem to be distributed without regard to these intrusive bodies, and many of them are miles from any known sign of igneous activity; furthermore, the mineral composition of the deposits is not characteristically hydrothermal. Nonetheless, it must be noted that the region contains scattered vein deposits of precious and base metals that are almost certainly of hydrothermal origin, and it is true that some of these veins also are at least several miles from known igneous rocks.

Origin

The origin of the vanadium deposits and the controls that localized the ore bodies have not been definitely determined, nor can all the factors pertaining to these problems be presented in a brief statement, but the following suggested origin is believed to explain most satisfactory the general characteristic features of the deposits. Unfortunately this suggestion has to be based largely on reasoning and on negative evidence opposing other possible modes of origin, for positive evidence favoring this suggestion is either lacking or subject to different interpretations. If some of the deposits eventually present exceptions to the features generally observed and on which this suggestion is based, they may necessitate a modification of the interpretation offered.

It is suggested that the vanadium deposits were formed by precipitation from ground waters before regional deformation and perhaps shortly after the deposition of the ore-bearing beds. Why the deposits are restricted to certain stratigraphic zones, where other sandstone beds of similar character are present in places above and below the ore-bearing zone, cannot be fully explained, but it must be inferred that conditions particularly favored the localization of ore in these zones. As mineralization involved impregnation rather than replacement, it can be considered as of low-intensity type, such as might result from deposition caused by relatively slight changes in the composition of the ore-bearing solutions. In such an environment, concretionary structures might develop in the ore, once the state of aggregation was established, and the delicate banding adjacent to the ore layers might result from reactions at the time of ore deposition or later. Reaction of the ore-bearing solutions with constituents of the enclosing sandstone, such as the organic material in the Morrison and Shinarump formations, could have been a factor causing deposition. Not all of the organic material in these formations, however, is selectively mineralized, and no organic material is recognized in the deposits in the Entrada sandstone. Other constituents that vary from place to place in the ore-bearing sandstone, such as the lime or iron content, do not seem to have been localizing factors. The ore layers themselves, being gently undulant and crossing the beds, resemble the plane of a slightly uneven water table, or the contact between ground waters of two types, and it is possible that deposition in places resulted from changes in the composition of waters along such a plane or contact.

Many of the larger deposits in the Morrison formation are found in sandstone that was deposited in the main stream channels, as evidenced by bedding, lensing, and the concentration of the larger fossil logs. At least until regional deformation disrupted their continuity, it seems reasonable to expect that these lenses would have been the main channels of ground-water flow, particularly as long as their original dip was maintained and as long as the flow of surface waters was in the same general direction. At Placerville the vanadium-bearing belt coincides closely with the edge of the basin in which the overlying Pony Express limestone member of the Wanakah formation was deposited; thus, the localization of some of the deposits seems to be related in some way to sedimentary structures in the ore-bearing beds and possibly to surface conditions shortly after the deposition of these beds.

The original source of the vanadium is not apparent. It could have been introduced by surface waters or it could have been picked up by the solution of minute quantities of vanadium widely distributed in the adjacent beds and concentrated in the present ore bodies. The relatively large amount of vanadium in these deposits seems to require conditions that would permit the supply of a considerable quantity of ore-bearing solution. It is perhaps doubtful whether circulation would have been very active through these beds in late Cretaceous time, when the region was below or near sea level and the thick Mancos shale and Mesaverde formation was being deposited.

As no definite relationship has yet been demonstrated between the special distribution or the character of the vanadium deposits and such geologic structures as folds, faults, and igneous intrusives, the writer is inclined to eliminate the possibility of mineralization by hydrothermal solutions or by ground waters after regional deformation. Considering all factors, it is difficult to rationalize the localization and character of the deposits as originating from hydrothermal or ground-water solutions that might have been introduced into the ore-bearing beds along through-going, vertical structures resulting from regional deformation, and it is almost equally difficult to consider the deposits as having formed by ground waters moving laterally along the beds after regional deformation, especially after faulting.

The interpretation that accords most closely with the observed facts, therefore, is that the deposits were formed by ground water circulating along the more accessible channels during late Jurassic time—after deposition of the Morrison formation but before its deep burial beneath Cretaceous strata and before its deformation by folding and faulting.

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FLUORSPAR INVESTIGATIONS

By Ralph E. Van Alstine

The Federal Geological Survey began making detailed field investigations of the fluorspar deposits of Colorado in 1930-34, when Goddard studied the Jamestown district, Boulder County. Since 1942, when the current program of fluorspar investigations was started by the Survey, in cooperation with the State Geological Survey Board and the Colorado Metal Mining Fund, about ten Survey geologists have had assignments on Colorado fluorspar deposits.

The field studies of the fluorspar deposits were made to gather geologic data for various war agencies, to supply the mine operators with current geologic information, to determine sites for prospecting and exploration, to map and study the major deposits in detail, and to estimate the fluorspar resources of the State.

Fluorspar may be defined as a mineral aggregate containing sufficient fluorite (CaF_2) to be of commercial interest. Fluorspar is used chiefly as a flux in the basic open-hearth process of making steel. The second most important use is in the chemical industry; hydrofluoric acid or its derivatives are used mainly in refrigerants, insecticides, and in the manufacture of aluminum and 100-octane gasoline. The ceramic industry consumes considerable tonnages of fluorspar in making enamels and opaque and colored glass.

The three commercial grades of fluorspar, based almost entirely on the proportions of CaF_2 and impurities, are listed below;[1] price adjustments are usually made for material of lower grade.

	Minimum percent of CaF_2	Maximum percent of impurity SiO_2	$CaCO_3$	Fe_2O_3
Acid-grade	98	1	1	—
Ceramic-grade	95	3	1	0.12
Metallurgical-grade	85	5	—	—

Although fluorspar from the Western States is generally more siliceous than that from the Illinois-Kentucky district, the leading fluorspar district of the United States, the large national demand for fluorspar insures the marketing of the finished product from western deposits.

The estimates of fluorspar resources in the four chief centers of production in Colorado, which are described in this paper, total more than 1½ million tons of fluorspar containing about 50 percent of CaF_2. From 1880 through 1944 Colorado's output of fluorspar amounted to 368,400 short tons valued at more than $6,000,000.[2] Shipments in 1944 amounted to 65,209 short tons valued at $1,604,-

[1]Hatmaker, Paul, and Davis, W. H., The fluorspar industry of the United States with special reference to the Illinois-Kentucky district: Ill. Geol. Survey Bull. 59, pp. 64-83, 1938.

[2]Davis, H. W., Fluorspar and cryolite: Minerals Yearbook, 1941-1944.

043, establishing a new record for the State's output and constituting about 15½ percent of the shipments of fluorspar from all mines in the United States.[3]

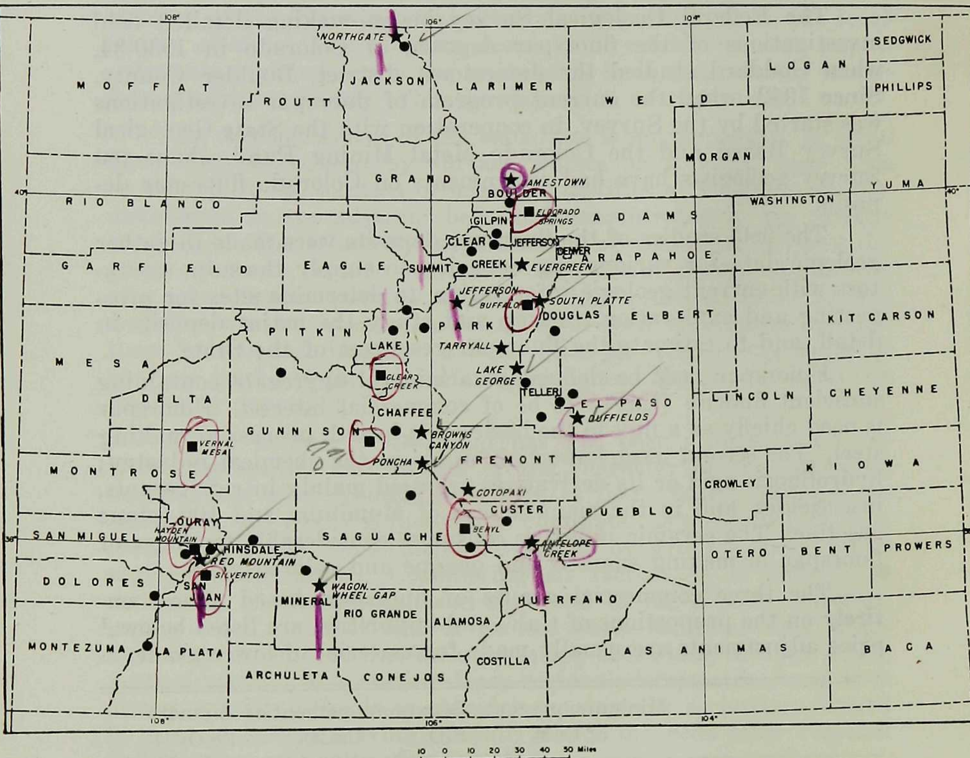

FIGURE 10.—Index map of Colorado showing distribution of fluorspar deposits. ★ Productive fluorspar districts; ■ districts with small fluorspar veins; ● districts with fluorspar as gangue. After Cox, (Colo. Sci. Proc., Vol. 14, no. 6, p. 269, 1945).

Fluorspar has been mined and marketed in Colorado from only 14 of the 47 districts plotted in figure 10 by Cox. The four main centers of production are: the Jamestown district, Boulder County; the Browns Canyon district, Chaffee County; the Northgate district, Jackson County; and the Wagon Wheel Gap deposit, Mineral County. Deposits in all of these districts except Wagon Wheel Gap were studied by Survey geologists during the recent war. Other fluorspar deposits in Colorado, from which only small tonnages were produced, are located in Custer, Dolores, El Paso, Fremont, Gilpin, Jefferson, Montrose, Ouray, Park, and Saguache Counties. Many of them were examined by Survey geologists investigating deposits of strategic minerals in Colorado.

[3]Davis, H. W., Fluorspar and cryolite: Minerals Yearbook, pp. 6, 12, 1944.

Jamestown District, Boulder County

The Jamestown district,[4] in the central part of Boulder County, was chiefly a gold-producing area for many years, but during 1942 and 1943 the mining of fluorspar was strongly revived and became the principal activity in the district. During the period 1903-44, a total of 65,838 tons of metallurgical-grade fluorspar and 33,826 tons of acid-grade fluorspar was shipped from the district.

The Jamestown district is in the foothills of the Front Range at the extreme northeast end of the Colorado mineral belt. The fluorspar deposits are localized in an area of Silver Plume granite of pre-Cambrian age which contains inclusions of schist. These rocks have been cut by stocks of Tertiary granodiorite and sodic granite-quartz monzonite porphyry, and related dikes.

The fluorspar deposits occupy veins and breccia zones in altered granite and granodiorite on the west and south sides of the sodic granite-quartz monzonite porphyry stock. The breccia zones are from 10 to 70 feet wide and from 50 to 400 feet long. Most of the exploited veins range from a few feet to 20 feet in width and from 150 to 1,000 feet in length. Some deposits are enclosed in large nearly barren breccia zones. In nearly all the deposits, early coarse-grained fluorite is thoroughly brecciated and cemented by fine-grained fluorite mixed with clay minerals, quartz, pyrite, and some carbonates. Fragments of sulfide minerals, chiefly galena and pyrite, are found in some deposits, and minute grains of pitchblende are sparingly present. The fluorite ranges in color from nearly white through purple to very deep violet (almost black).

Mineralization seems to have been related to the sodic granite-quartz monzonite porphyry stock, and it is believed that the vein fissures and breccia zones were produced by forces resulting from the intrusion of the stock. Some fluorite was dissolved by later solutions, and available evidence suggests that the brecciation of the deposits resulted from collapse and gradual settling of the porous bodies thereby developed.

Most of the fluorspar veins contain from 60 to 85 percent of CaF_2, and the breccia zones commonly contain from 5 to 60 percent. Crude ore shipped in the past has contained about 73 to 85 percent of CaF_2 and from 5 to more than 12 percent of silica. In 1943, crude ore containing 45 to 73 percent of CaF_2 and 12 to 32 percent of silica was being mined and milled to produce fluorspar of both acid and metallurgical grade.

The fluorspar deposits have been mined to depths ranging from 50 to 480 feet below the surface, and many give promise of extending several hundred feet below the present workings. The resources are therefore estimated to be fairly large, and deeper exploration of most of the productive deposits seems justified. Some of the large nearly barren breccia zones, which contain only small amounts of fluorspar at the surface, are also considered favorable

[4]Abstract of a paper by Goddard, E. N., Fluorspar deposits of the Jamestown district, Boulder County, Colorado: Colo. Sci. Soc. Proc., vol. 15, no. 1, pp. 1-47, 1946.

locations for future exploration. Goddard[5] estimated the resources of crude fluorspar in the Jamestown district as of January 1, 1944, as follows:

CaF_2 content	Indicated ore within 300 feet of surface with a few exceptions (short tons)	Inferred ore between 300 and 500 feet beneath the surface (short tons)	Totals
45 to 75 percent (average 60 percent)	305,000	340,000	645,000
20 to 45 percent (average 30 percent)	170,000	160,000	330,000

Fluorspar was first mined in the Jamestown district in appreciable quantities in 1903, and was mined intermittently up to 1940. In 1940, the General Chemical Company acquired several mines in the district and began producing acid-grade fluorspar in its flotation mill east of Boulder. Also in 1940, Harry M. Williamson & Son leased several properties from the Boulder Fluorspar and Radium Company and since 1941 have produced fluorspar of metallurgical and acid grade from jigs and flotation cells in the remodeled Wano mill at Jamestown. A small mill was also operated at Jamestown by Clark H. Clark. In April 1946 the old Wano mill was sold to the Mahoning Mining Company of Rosiclare, Ill.

[5]Goddard, E. N., idem.

Browns Canyon District, Chaffee County

The Browns Canyon fluorspar district is in Chaffee County, about 8 miles northwest of Salida. The district covers an area of about 9 square miles, bounded on the east by the Arkansas River and on the west by U. S. Highway 285. From 1929 through 1944, about 85,000 tons of fluorspar, chiefly of metallurgical and ceramic grades, was shipped from this district. Two flotation mills are supplying fluorspar in the district: the mill of Colorado Fluorspar Mines, Inc. is a few hundred feet south of the mine entrance, and the mill of the General Chemical Company is about a quarter of a mile west. The latter mill was bought from the Fluorspar Processing Company in January 1946.

In the northern part of the district the bedrock is chiefly a pink, coarse-grained gneissoid granite of pre-Cambrian age.[6] In the southern part coarsely banded hornblende gneiss and schist of pre-Cambrian age are cut by granite and many pegmatite dikelets and quartz veinlets. These pre-Cambrian rocks are locally covered by Tertiary volcanic rocks and gravel. The maximum relief of the district is about 500 feet.

[6]Andrews, T. G., Memorandum report on the fluorspar deposits in Chaffee County, Colorado: U. S. Geol. Survey Strategic Minerals Investigations Confidential Report, p. 2, 1943.

The fluorspar occurs as epithermal fissure veins along faults in pre-Cambrian granite and metamorphic rock, in Tertiary rhyolite porphyry, and between rocks of these ages. In some deposits fluorspar replaced fault breccia extensively enough to form ore bodies. Some faults that are partly mineralized are more than a mile long; ore shoots along them are as much as 1,500 feet long and may average 5 or 6 feet in width.[7] The maximum width of vein is more than 40 feet, and the greatest vertical distance through which any of the veins has been exposed is about 400 feet.[8] According to Andrews,[9] the fluorspar is a white fine-grained variety and occurs mainly as large irregular masses and bands along faults. Surfaces of the masses commonly are botryoidal, mammillary, and locally stalactitic. Some of the ore is nodular and is composed of fluorite almost concentrically banded about a nucleus of country rock. An hypothesis of origin for this nodular type of fluorspar, so common to epithermal fluorspar deposits of many districts throughout the world, has been presented by the writer.[10]

Silica, the most abundant impurity in the veins of the Browns Canyon district, occurs chiefly as grains, veinlets, and large bands of chalcedony. Some of the silica is intimately intergrown with fine-grained fluorite. Small quantities of $CaCO_3$, Al_2O_3, and Fe_2O_3 are found in analyses of the fluorspar. Manganese oxides locally form veinlets and line vugs in the veins.

Fluorine is present in the warm water that issues underground and from some springs in the district. A sample of water at a temperature of 72° F., collected from a warm spring near the mill of the General Chemical Company, contains 15 parts per million of fluorine. Another sample, collected at a temperature of 65° F. on the 100 level of the Colorado mine, contains 13 parts per million of fluorine. A third sample, taken from Poncha Hot Springs at a temperature of 153° F., contains 12 parts per million of fluorine.[11] Poncha Hot Springs, from which water is piped to the municipal swimming pool near Salida, is about 7 miles by road southwest of Salida and is only about 2,000 feet from the Poncha Springs fluorspar deposit. The fluorine in these warm alkaline waters, which are high in sodium, bicarbonate, sulfate, and chlorine content, may have come from fluorite dissolved from some nearby veins, or it may indicate that the warm waters and the fluorspar deposits have a common origin and are closely related in age. The concentration of fluorine in a saturated solution of calcium fluoride at 77° F. is 20 parts per million, not much greater than the quantity in the warm waters analyzed.

[7]Cox, D. C., Suggestions for exploration in the Browns Canyon fluorspar district, Chaffee County, Colorado: U. S. Geol. Survey Strategic Minerals Investigations Confidential Report, p. 1, 1944.

[8]Cox, D. C., General features of Colorado fluorspar deposits: Colorado Sci. Soc. Proc., vol. 14, No. 6, pp. 275, 277, 1945.

[9]Andrews, T. G., idem.

[10]Van Alstine, R. E., The fluorspar deposits of St. Lawrence, Newfoundland: Econ. Geol., vol. 39, pp. 122-123, 129, 1944.

[11]These three samples were collected in 1945 by D. C. Cox and T. A. Steven, geologists, and were analyzed by C. S. Howard, chemist, U. S. Geological Survey.

Almost all of the fluorspar from the Browns Canyon district has come from properties controlled by the following: Colorado Fluorspar Mines, Inc., American Fluorspar Corp., United States Fluorspar, Inc., and Kramer Mines, Inc. Colorado Fluorspar Mines, Inc. bought the holdings of the Colorado Fluorspar Corp. in February 1945, and in January 1946 the General Chemical Company acquired the property of the American Fluorspar Corp. in this district. Colorado Fluorspar Mines, Inc. and the American Fluorspar Corp. have mined chiefly from adjacent properties on a single fluorspar vein which strikes N. 30°-50° W. and dips about 85° S.W.[12] Several large ore bodies have been exposed by two adits, two sublevels, stopes, a shaft, and open cuts. It has been estimated[13] that this vein contains 17,700 tons of measured fluorspar ore, 83,900 tons of indicated ore, and 110,000 tons of inferred ore to a depth of about 225 feet. The grade of this material was estimated to average 70 to 75 percent of CaF_2.

The deposits of United States Fluorspar, Inc., which were acquired in September 1945 from the Chaffee County Fluorspar Corp., lie about a mile northwest of the deposit of Colorado Fluorspar Mines, Inc. Several adits and winzes at the Chimney Hill deposit show that fluorspar occurs in silicified Tertiary rhyolite as lenses, 20-30 feet long and 7-8 feet wide, and as a network of small veinlets.[14] At the nearby Manganese Hill deposit, two inclined shafts expose an ore body averaging 4 or 5 feet in width and cutting pre-Cambrian granite.

The fluorspar deposit known as the Kramer mine[15] lies about a mile northeast of the mine of Colorado Fluorspar Mines, Inc. In 1942 Kramer Mines, Inc. leased the property from Universal Mines, Inc., formerly the Salida Fluorspar Corp. A flotation mill, built at the mine in 1942, supplied fluorspar of ceramic and acid grades until destroyed by fire in July 1944.

At the Kramer mine a fault strikes N. 60° W. and dips 60° N.E. in pre-Cambrian coarse-grained gneissic granite. The fault locally consists of a sheeted zone of granite containing veinlets of intimately intergrown fluorite and chalcedony. The wall rock and breccia of granite are partly replaced by fluorite and silica. The fluorite is commonly of a white, pink, or brown dense variety, but in places it is green and more coarsely crystalline. Lenses rich in fluorite range in thickness from a few inches to about 3 feet. The

[12]Andrews, T. G., idem, pp. 5-8.

Cox, D. C., Suggestions for exploration in the Browns Canyon district, Chaffee County, Colorado: idem, p. 3.

[13]Andrews, T. G., idem, pp. 20, 27.

[14]Cox, D. C., Memorandum report on the Chaffee County Fluorspar Corp. property, Browns Canyon district, Chaffee County, Colo.: U. S. Geol. Survey Strategic Minerals Investigations Confidential Report, 1943.

Cox, D. C., Suggestions for exploration in the Browns Canyon fluorspar district, Chaffee County, Colorado: idem, p. 5.

[15]Andrews, T. G., Memorandum report on the property of Kramer Mines, Inc., Chaffee County, Colorado. U. S. Geol. Survey Strategic Minerals Investigations Confidential Report, 1943.

Cox, D. C., Memorandum report on the geology of the Kramer mine, Browns Canyon fluorspar district, Chaffee County, Colorado: U. S. Geol. Survey Strategic Minerals Investigations Confidential Report, 1943.

sheeted zone has been mined for fluorspar through a thickness as great as 2.5 feet in an open cut.

Open cuts, adits, and a shaft with three levels have exposed two fluorspar bodies averaging about 30 percent of CaF_2 in the fault zone. The southeast shoot is about 450 feet long and averages 6 to 8 feet in width on the upper levels; below, the fluorspar pinches to narrow stringers in the granite. The northwest shoot is about 400 feet long and in a sheeted section has a maximum width of about 25 feet. On the lower level the fluorspar pinches to small veins.

Northgate District, Jackson County

The Northgate fluorspar district is in Jackson County, on the southwest flank of the Medicine Bow Range. It is about 13 miles north of Walden and about 4 miles north of the much smaller town of Cowdrey in North Park. The deposits range in altitude from 8,200 to 9,200 feet above sea level. Most of the following data have been taken from reports by Ladoo,[16] Burchard,[17] Goldring,[18] and Cox.[19]

The first fluorspar claim in the Northgate district was located in 1918. From 1922 to 1925 shipments of flourspar were made to the plant of the Colorado Fuel & Iron Corp. in Pueblo, Colorado. Only a few small shipments were made from 1926 through 1941. In 1941 the Western Fluorspar Corp. leased most of the holdings in the district. Production started again in 1942 but was halted when the mill burned late in the year. In 1943 a new 450-ton mill of the sink-float type was built by Defense Plants Corp.[20] In 1943 also, the Camp Creek deposit was discovered and leased by E. L. McElroy to Kramer Mines, Inc.

The output from the entire district was estimated to have been nearly 24,000 tons of fluorspar from 1922 through 1943.[21] Of this quantity, 19,776 tons was of metallurgical grade, 2,254 tons was of lower grade for use in a cement plant, and 1,948 tons was of ceramic grade after concentration by flotation at Salida.

The bedrock of the Northgate district consists chiefly of pre-Cambrian granite, hornblende gneiss and schist, and biotite schist. One of the fluorspar veins is partly in arkose, sandstone, and conglomerate, probably of Tertiary age.

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[16]Ladoo, R. B., Fluorspar mining in the Western States: U. S. Bureau of Mines Rept. Inv. 2480, pp. 28-31, 1923.

Ladoo, R. B., Fluorspar, its mining, milling and utilization, with a chapter on cryolite: U. S. Bur. Mines Bull. 244, pp. 116-119, 1927.

[17]Burchard, E. F., Fluorspar deposits in Western United States: Am. Inst. Min. Met. Eng. Tech. Pub. 500, pp. 12-14, 1933.

[18]Goldring, E. D., An occurrence of ilsemannite: Am. Mineralogist, vol. 27, pp. 717-719, 1927.

[19]Cox, D. C., Preliminary report on the fluorspar deposits of the Northgate district, Jackson County, Colorado: U. S. Geol. Survey Strategic Minerals Investigations Prelim. Rept., in preparation.

[20]Gillson, J. L., Fluorspar deposits in the Western States: Am. Inst. Min. Met. Eng. Tech. Pub. 1783, pp. 23-24, 1945.

[21]Cox, D. C., idem.

The fluorspar occurs as epithermal deposits along several steep faults and shear zones. Two zones, one striking N. 10° W. and the other striking N. 40° W., were extensively mineralized with fluorite, chalcedony, and a little pyrite and calcite. The fluorite is found in fissure veins, as reniform and botryoidal masses in fault breccia, and as replacement bodies in fault breccia. The deposits range in size from veinlets a few inches thick and a few tens of feet long to commercial bodies as much as 45 feet wide and 1,000 feet long. Individual fissure veins of high-grade fluorspar, commonly 5 inches to 2 feet thick, are abundant and locally attain a thickness of 5 feet.

Five fluorspar deposits are exposed by underground and surface workings: the Fluorspar, Gero, Penber, Fluorine, and Camp Creek deposits. The Fluorspar deposit consists of two nearly parallel, steep veins occupying a fault zone in granite interbanded with schist and gneiss. On the 200 level the veins are about 50 feet apart. The fault zone strikes N. 10° W. and has been explored for more than 1,500 feet along the strike. The sink-float mill is located near the entrance to the underground workings on the Fluorspar veins.

The Gero deposit is about 1,000 feet south of the Fluorspar deposit, and appears to be in the same fault zone. The average width of the vein where exposed in an adit 160 feet long is between 4 and 5 feet.

The Penber deposit is about 700 feet S. 60° E. of the Gero deposit. A fluorspar vein that strikes about N. 40° W. and dips 75° N.E. has been traced for approximately 200 feet. It is composed of high-grade fluorspar, averaging between 5 and 6 feet thick.

The Fluorine deposit is on the mountain top, about 1½ miles east-northeast of the Fluorspar deposit. Fluorspar forms veinlets and replacement bodies in a fault breccia zone. A large open cut exposed a mineralized zone that strikes N. 40° W., is almost vertical, and ranges in width from a few feet to 45 feet.

The Camp Creek deposit is about 4,000 feet from the Fluorine deposit and probably along the same fault zone; the area between the two deposits, however, is heavily forested, almost completely covered with overburden, and lacks fluorspar outcrops. At the Camp Creek deposit a nearly vertical zone containing fluorspar strikes N. 40° W. The deposit is exposed for 200 feet and ranges in width from 9 to more than 17 feet.

The fluorspar reserves of the Northgate district have been estimated by Cox[22] to be very large. Measured ore, however, was exposed only in the Fluorspar deposit, where it amounted to 4,000 tons. The average grade of this material is about 55 percent of CaF_2. The $CaCO_3$ content of samples ranges from less than 1 percent to about 8 percent, and the Fe_2O_3 content, from 2 to 7 percent. For the five deposits at Northgate the reserves of indicated ore, in partly explored bodies, totals 213,000 tons probably averaging 40-50 percent of CaF_2. In addition 370,000 tons of fluorspar averaging more than 35 percent of CaF_2 is inferred.

[22]Cox, D. C., idem.

Wagon Wheel Gap Deposit, Mineral County

The Wagon Wheel Gap deposit lies in Mineral County, 1¼ miles south of the Wagon Wheel Gap station on the Denver & Rio Grande Western Railroad. It is on the east side of Goose Creek, directly across the valley from Mineral Hot Springs.

Production of fluorspar from the Wagon Wheel Gap deposit began about 1911, and in 1913 the American Fluorspar Mining Co. shipped 5,000 tons of fluorspar to Pueblo, Colorado.[23] Until 1924, when the deposit was bought by the Colorado Fuel & Iron Corp., the production of fluorspar was intermittent; up to 1921, a total of 40,000 to 50,000 tons was shipped.[24] The total output of fluorspar from the deposit through 1928 had a value of more than $1,000,000.[25] A total of 110,000 tons of fluorspar was mined by 1936.[26] The product from the jig mill at the site of the deposit was chiefly fluorspar of metallurgical grade and was shipped for use in the steel plant of the Colorado Fuel & Iron Corp. at Pueblo.

The main fluorspar deposit has been traced eastward up the hillside for more than half a mile and extends through a vertical range of at least 700 feet. One or more nearly vertical fluorspar veins lie within a sheeted zone that strikes approximately east in rhyolitic tuffs and breccias of Miocene age. According to Burchard,[27] the thickness of the fluorspar ranges from a few inches to 35 feet, and in the main working the average thickness is about 6 or 8 feet.[28] The fluorite is mainly a white fine-grained variety and commonly forms botryoidal and mammillary masses with a radiating fibrous structure. Minerals locally found with fluorite in the veins are pyrite, barite, quartz, chalcedony, calcite, halloysite, creedite, and gearksutite.

Two hot springs appear to be associated with the main fluorspar deposit at Wagon Wheel Gap,[29] for they, the main fluorspar vein, and a deposit of travertine are alined. The travertine deposited from the hot springs contain 0.22 percent of fluorine and appreciable quantities of barium and zinc. The hot springs had a temperature of 135°-150° F., but were not analyzed for fluorine.

[23]Aurand, H. A., Fluorspar deposits of Colorado: Colorado Geol. Survey Bull. 18, pp. 61-67, 1920.

[24]Ladoo, R. B., Fluorspar, its mining, milling and utilization, with a chapter on cryolite: U. S. Bur. Mines. Bull. 244, pp. 113-116, 1927.

[25]Cross, Whitman, and Larsen, E. S., A brief review of the geology of the San Juan region of southwestern Colorado: U. S. Geol. Survey Bull. 843, p. 129, 1935.

[26]Hatmaker, Paul, and Davis, H. W., The fluorspar industry of the United States with special reference to the Illinois-Kentucky district: Ill. Geol. Survey Bull. 59, p. 27, 1938.

[27]Burchard, E. F., Fluorspar deposits in Western United States: Am. Inst. Min. Met. Eng. Tech. Pub. 500, pp. 8-10, 1933.

[28]Ladoo, R. B., op. cit., p. 113.

[29]Emmons, W. H., and Larsen, E. S., The hot springs and mineral deposits of Wagon Wheel Gap, Colo.: Econ. Geol., vol. 8, pp. 235-246, 1913.

PEGMATITES

By John B. Hanley

Introduction

The pegmatites of Colorado are in pre-Cambrian schists, gneisses, and igneous rocks that occur throughout the Rocky Mountains. The greatest number of pegmatites occur in the Front Range within a belt about 155 miles long and as much as 40 miles wide, extending from Canon City to the Cache La Poudre River. The distribution of the pegmatites in Colorado is shown on plate 33. All are granitic pegmatites of pre-Cambrian age except those in two small areas in the Sawatch Range; these are pegmatites in rhyolite of Tertiary age.

The information presented in this section is the result of the investigation of more than 100 pegmatites in Colorado by the Federal Geological Survey during 1942-44. Many pegmatites were mapped and studied in detail and the grades of a number of pegmatites were determined.

Characteristic Features of the Pegmatite

Size, Shape, and Attitude.—Pegmatite deposits of Colorado are mostly small, but range from a few feet in length and width up to bodies about one mile in length and 600 feet in width. The productive bodies commonly are less than 500 feet long and 50 feet wide. Most Colorado pegmatites are tabular or lenticular bodies, but many are wider at one end than the other and have surface exposures that are shaped like tad-poles. Some, however, are extremely irregular and have many branches and off-shoots. Most of the pegmatite bodies are nearly vertical or steeply dipping, but the attitudes of the pegmatites differ in various parts of the State.

Zoning.—Many of the pegmatite bodies contain structural and lithologic units of contrasting composition and texture. The units are mostly zones, which have the form of shells and lenses that reflect the shapes of the pegmatite walls. The zoned bodies commonly contain (1) a border zone, generally only a few inches thick, of fine-grained pegmatite directly in contact with the wall rock; (2) a wall zone, which has essentially the same composition as the border zone; (3) an intermediate zone (or zones), which differs from the wall zone both in composition and texture, and lies inside of it; and (4) a core or innermost zone, which commonly is very coarse grained and has a different mineral composition from the other zones. In Colorado the intermedite zone and the core generally contain the productive deposits of commercially valuable minerals.

The intermediate zone is commonly discontinuous, and may occur only on one side or one end of the pegmatite body. The intermediate zone in the Devil's Hole pegmatite body, in Fremont County, as illustrated on plate 34, is almost continuous around the core; however, the intermediate zone in the Meyers' Ranch body, in Park County, is formed only around part of the core, and

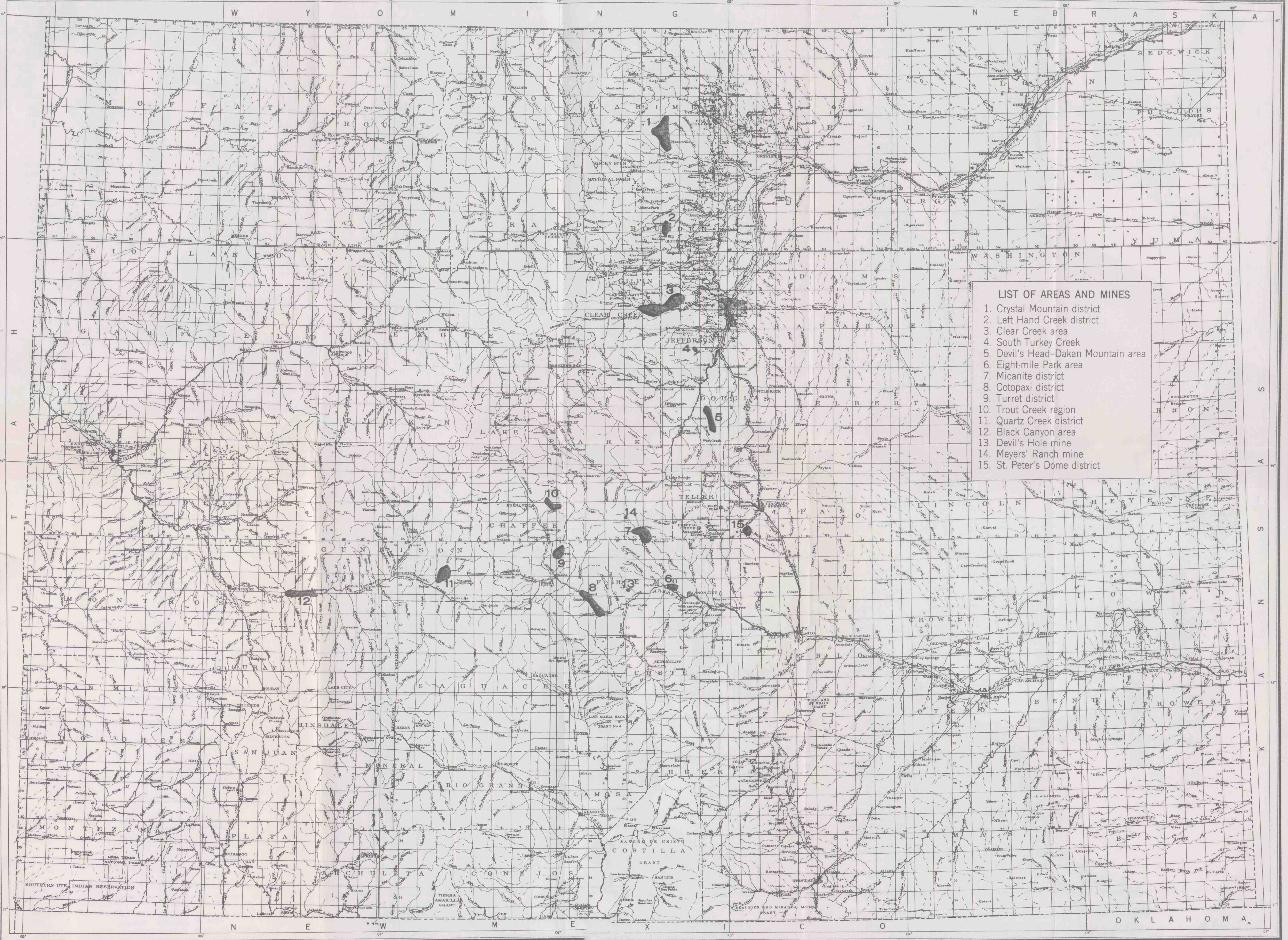
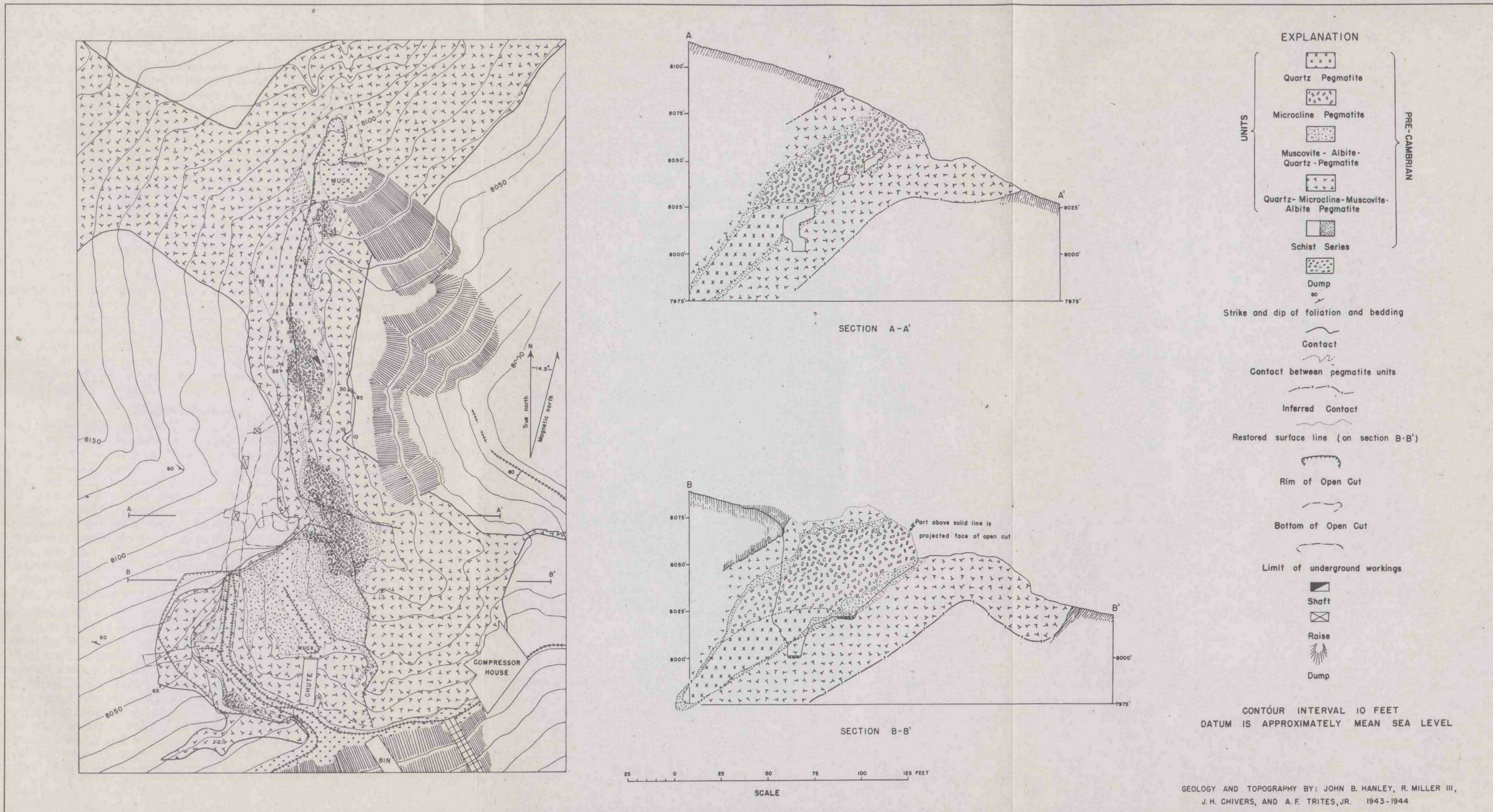


PLATE 33.

MAP SHOWING LOCATION OF MAJOR PEGMATITE AREAS OF COLORADO, AND LOCATIONS OF CERTAIN MINES OUTSIDE THE AREAS.



GEOLOGIC MAP AND SECTIONS, DEVIL'S HOLE MINE, FREMONT COUNTY, COLORADO.

the intermediate zone in the Mica Lode body, in Fremont County, is formed only on the footwall side of the core.

The core commonly is a lens near the center of the pegmatite, although in some bodies it is nearer one wall or one end than the other. In a few bodies the core consists of a series of pods or disconnected segments near the center.

Many of the productive bodies of pegmatites in Colorado contain a wall zone composed of plagioclase (generally blocky albite), quartz, and microcline; an intermediate zone composed of plagioclase (generally sub-platy albite), quartz, and muscovite, and a core composed either of microcline and quartz or quartz alone. Some of the best examples of this type of zoned pegmatite, in addition to the three mentioned above, are the Hyatt pegmatite in Larimer County, the Bigger pegmatite in Jefferson County, and the New Anniversary and many other small pegmatites in Gunnison County.

The zonal sequence and structure of some pegmatite deposits is obscured or complicated by units of irregular shape and structure, which may have been formed by hydrothermal replacement either along fractures or pre-existing zones.

Because the commercially valuable minerals occur most abundantly in zoned pegmatites and are commonly restricted to a particular zone or group or zones, an understanding of the general zonal structure of pegmatites is of great assistance in the appraisal and mining of any pegmatite.

Mineral Deposits

The pegmatites of Colorado are classified as beryllium, lithium, muscovite, columbium-tantalum, potash feldspar, or rare-earth pegmatites according to the commercially valuable minerals they contain. A single body of pegmatite, however, may comprise two or more zones containing minerals in commercial quantity. The Devil's Hole pegmatite, for example, has an intermediate zone containing scrap mica, beryl, and columbite, whereas its core contains potash feldspar. In addition, because the mining of pegmatite is extremely sensitive to fluctuations in demand, most operations are short lived, and the common practice has been to mine selectively for only one mineral, discarding as waste all the other material moved in the operation; consequently the same pegmatite has been mined at various times for different minerals.

Beryllium Minerals.—Beryllium pegmatites occur in most of the pegmatite areas of the State. Beryl is the most abundant beryllium mineral, but chrysoberyl, phenakite, and gadolinite, as well as such alteration products as bertrandite, also are found. Beryl occurs in all zones of the pegmatites, but beryl recoverable by hand cobbing is most abundant in intermediate zones. The wall zones of some pegmatites, particularly the Hyatt pegmatite, contain deposits of fine-grained beryl that can be recovered only by milling.

The most common variety of beryl is subhedral to euhedral (hexagonal prisms) and bluish-green. In the wall-zone deposits it is associated with abundant plagioclase, muscovite, quartz, and microcline. Beryl in the intermediate zone and the core deposits occurs with large books of wedge-shaped muscovite, sub-platy albite, massive quartz, and columbite-tantalite. White and pale pink beryl that probably contains a high proportion of alkalies and a low content of BeO occurs only in lithia pegmatites, in which it commonly is associated with lepidolite, cleavelandite, and quartz.

The average diameter of the beryl crystals in wall zones is less than half an inch, and in the intermediate zones and cores is about 6 inches.

The BeO content of the beryl sold in 1943-44 ranged from 11.04 to 12.62 percent. The beryl content of the intermediate-zone deposits in some pegmatites is estimated to be as much as 2 percent, but in most minable deposits the beryl content in the wall and the intermediate zones probably ranges from 0.5 to 1 percent.

Chrysoberyl crystals as much as 3 inches long have been mined at the Wisdom Ranch pegmatite in Larimer County, and chrysoberyl that contained as much as 19.15 per cent BeO is reported from the Drew Hill pegmatite in Jefferson County.

Prior to 1945 at least 450 tons of beryl had been mined from Colorado pegmatites, chiefly from the Devil's Hole pegmatite. Total inferred and indicated quantity of unmined beryl is estimated to be between 2,000 and 5,000 tons, much of which cannot be recovered by hand-sorting. The district around Crystal Mountain in Larimer County appears to contain the largest quantity of beryl, but most of this beryl is so fine-grained that it could be recovered only by milling. The Eight Mile Park district in Fremont County probably contains the largest amounts of hand-separable beryl.

Lithium Minerals.—Lithium pegmatites are most numerous in the Quartz Creek district of Gunnison County; only a few occur in the Crystal Mountain and Eight Mile Park districts. Lepidolite is the common lithium mineral, although specimens of spodumene, amblygonite, and zinnwaldite have been obtained from a few deposits. The lepidolite commonly is lilac or lavender, but green lepidolite is found rarely. It occurs most abundantly as flakes about 3 millimeters in size or as felted aggregates of flakes, but books as large as 10 inches across the cleavage surfaces occur in the Brown Derby pegmatite. Cleavelandite, quartz, and topaz are the abundant associated minerals and lithia tourmaline, beryl, and microlite are accessory minerals. Lepidolite occurs in deposits in intermediate zones and cores, but only core deposits are large enough to be mined. The lepidolite contents of the core deposits range from 15 to 75 percent. The lithia content of the mineral ranges from one to five percent in different pegmatites or even within the same pegmatite.

At least 250 tons of lepidolite was produced from the Quartz Creek district in 1942-44, and the reserves in the district are estimated to be several times the quantity produced. The reserves in other parts of the State are very small.

Muscovite.—The muscovite pegmatites of Colorado are of two types: one type contains punch and sheet mica as well as scrap mica; the other can supply only scrap mica. Muscovite occurs in both types as light green to rum-colored flakes and books. The flakes commonly are less than 2 inches in diameter, but the books are as much as 27 inches long. Muscovite generally is associated with albite and quartz. Beryl and columbite-tantalite also occur with muscovite, particularly in scrap-mica deposits.

Sheet mica-bearing pegmatites are most numerous in the Micanite district of Fremont and Park Counties, and a few are known in Jefferson and Clear Creek Counties. However, the Ajax pegmatite in Clear Creek County was the only sheet mica mine active in 1943-44. Sheet mica deposits generally occur in wall and intermediate zones, but sheet mica is disseminated uniformly throughout the Famous Lodge pegmatites in Park County. Scrap mica deposits occur in the intermediate zones and cores of many pegmatites—particularly those that contain beryl.

About 1,000 pounds of full-trimmed punch and sheet mica was produced in Colorado during 1943-44, and the total known output of scrap mica prior to 1945 is about 28,000 tons. The reserves of punch and sheet mica probably are small, but the reserves of scrap mica probably are at least equal to the past output.

Columbium-tantalum Minerals.—Columbite-tantalite and microlite are the most abundant columbium and tantalum minerals, although others, such as euxenite, samarskite, betafite, and fergusonite, occur as minor accessory minerals in some pegmatites.

Columbite ($FeCb_2O_6$) and tantalite ($FeTa_2O_6$) form an isomorphous series; hence, all gradations in the ratio of Cb_2O_5:Ta_2O_5 are possible. The Ta_2O_5 content of the mineral is greater in specimens with high specific gravity. Most deposits in Colorado contain columbite-tantalite with a high columbium content and a low tantalum content, but one deposit in the Crystal Mountain district contains tantalite that has a Ta_2O_5 content of about 75 percent. The Ta_2O_5 content of the columbite-tantalite appears to be higher the nearer it occurs to the core of the pegmatite.

Microlite commonly forms in dark-brown crystals and spherical masses which range in size from less than one millimeter to 13 millimeters. It has resinuous luster and subconchoidal fracture. The microlite from the Brown Derby pegmatite contains about 68 percent Ta_2O_5.

Columbite-tantalite commonly is associated with beryl, quartz, albite, and muscovite in beryllium pegmatites, and microlite occurs with lepidolite, cleavelandite, quartz, and topaz in lithium pegmatites. Columbite-tantalite is most abundant in intermediate zones, and microlite is most common in cores.

The output of columbium and tantalum minerals has been very small, and the reserves probably are also very small. The largest reserves probably are in the microlite-bearing pegmatites of the Quartz Creek district.

Potash Feldspar.—Potash feldspar pegmatites are the most numerous type of pegmatite in the State, but only those that were reported to contain critical and strategic minerals were examined by Survey geologists during 1942-44. However, the cores of most of the beryllium pegmatites contain deposits of commercial feldspar, and feldspar has been the chief mineral mined from several of the larger beryllium-bearing deposits. Feldspar that can be recovered by hand sorting generally is abundant only in core deposits. The output of feldspar in Colorado has amounted to at least 250,000 long tons, and the inferred reserves undoubtedly are several times this quantity.

Rare Earth Minerals.—Rare earth pegmatites, in which the rare earth minerals are the only accessory minerals of commercial interest, are not abundant in Colorado. In the few known deposits cerite, euxenite, samarskite, monazite, or allanite are distributed erratically throughout the feldspar-rich cores of pegmatites that typically contain only small quantities of muscovite. No rare earth minerals occur in deposits large enough to be mined for them alone, but a small quantity might be recovered as a byproduct of feldspar mining. The Trout Creek region of Chaffee County contains most of the known rare-earth mineral deposits.

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PART III. INVESTIGATIONS OF STRATEGIC MINERAL RESOURCES[1]

By W. M. Traver, Jr.[2]

INTRODUCTION

Congress, by the Strategic Materials Act, designated the Bureau of Mines, United States Department of the Interior, in cooperation with the Geological Survey of the same department, to investigate the Nation's essential minerals, of which the quantities or grades obtainable from known domestic sources were inadequate. The metals generally considered as critical at the time the program was initiated were antimony, chromium, manganese, mercury, nickel, tin, and tungsten.

With the entry of the United States into World War II, the situation changed immediately, and the agency's work was expanded to include investigation of all types of minerals necessary for successful prosecution of the war. It was concerned chiefly with determining the extent and quality of ore deposits, suitable methods of mining, beneficiating the ores, and estimating production costs. At the same time, the duty was assigned of examining and reporting on mines where Federal access-road assistance had been requested.

The program, of necessity, was curtailed somewhat at the end of the war. However, the work is important enough to our peacetime economy to justify its continuation.

A great deal of information regarding the mineral industry of Colorado was collected as a result of this activity; and, although some of these data are of a confidential nature and not permitted to be published immediately, a considerable amount of general information can be made available.

At the request of John W. Vanderwilt in behalf of the Colorado Mineral Resources Board, as an aid in its appraisal of the State's mineral possibilities, a summary is submitted of the Bureau's accomplishments under the direction of the Colorado Field Office.

MINE EXAMINATIONS

The owners of nearly 500 mines, located in 40 different counties of the State, have requested examination of their properties since the establishment of the Colorado Field Office in 1942. Approximately 100 of these requests were either withdrawn as prior investigation proved the mine workings were inaccessible or were not considered justified. Examinations of some 35 mines are still pending (Sept., 1946).

From the 265 properties examined, those considered most worthy of additional exploration were selected and recommended

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in preliminary War Minerals Reports, suggesting the type and amount of exploratory and metallurgical work proposed. These reports were submitted to the Salt Lake City Divisional Office and in turn, were sent to Washington for final approval.

All proposed projects are listed with those recommended from other mining States and are assigned on a nation-wide basis, within the limits of funds available, in the order of the urgency of demand at the time for the metal contained. The intent of the Bureau is the discovery of new ore deposits or the expansion of known reserves and does not include production or development.

The following tabulation lists, by counties, the Colorado mines that have been examined or upon which examinations are pending. Cognizance should be taken of the fact that mines have been examined and reports submitted only when a request was received from the owner, and the absence of many worthy mines from the list is no criterion for establishing an adverse evaluation. Moreover, some of the mines that were not examined and possibly some of those examined and not recommended for further exploration are entitled to receive future consideration.

MINES EXAMINED AND RECOMMENDATIONS DEFERRED

Name of Property	Location	Mineral Sought
Boulder County		
Annabert Mine	Jamestown Mining District	Copper
Buena Vista Mine	Sec. 21, T. 2 N., R. 71 W.	Barite
Last Chance Mine	Sec. 12, T. 2 N., R. 72 W.	Mercury
Rogers Patent	Boulder Creek, 11½ miles west of Boulder	Fluorspar
Struggler Group	Sec. 30, T. 2 N., R. 72 W.	Copper
Utica Mine	Sec. 12, T. 1 N., R. 72 W.	Copper
Chaffee County		
Aksarben Mine	Sec. 15, T. 49 N., R. 8 E.	Fluorspar
Iron Chest Mine	Summit of Trout-Creek Pass	Lead-zinc
Josephine Mine	Sec. 23, T. 12 S., R. 79 W.	Cobalt
Lily Mine	Sec. 23, T. 50 N., R. 6 E.	Copper
Lost and Found Mine	Twin Lakes Mining District	Molybdenum
Marvel Mine	Sec. 33, T. 50 N., R. 9 E.	Mica
Picuris Placer Mine	Secs. 23, 25, 26, 29, and 36 T. 14 S., R. 78 W.	Vanadium
Rock King Mine	Sec. 34, T. 51 N., R. 9 W.	Beryl-feldspar
Salida Manganese Mill (16 mines)	Various	Manganese
Sedalia Mine	Sec. 18, T. 50 N., R. 9 E.	Copper
Sparton Mine	Turret Mining District	Manganese
Stockton Mine	Sec. 10, T. 49 N., R. 9 E.	Tungsten-copper
Tiger Lode	Cleora Mining District	Manganese

Name of Property	Location	Mineral Sought
Clear Creek County		
Back Bone Mine	Griffeth and Queen Mining District	Lead-zinc
Bald Eagle Mine	Virginia Mining District	Lead-zinc-copper
Bard Creek Mine	Sec. 3, T. 3 S., R. 75 W.	Lead-zinc
Commonwealth Mine	Georgetown Mining District	Lead-zinc
East Lake Mine	Sec. 23, T. 3 S., R. 73 W.	Lead-zinc
Gem Dump	Seaton Mountain, 4 miles northeast of Idaho Springs	Lead-zinc
Hamill Tunnel	Sec. 22, T. 4 S., R. 75 W.	Lead-zinc
Humboldt Mine	Sec. 12, T. 3 S., R. 74 W.	Lead-zinc
Little Josephine Mine	Fall River Mining District	Lead-zinc
Lombard Group	Fall River Mining District	Lead-zinc
Mattie Consolidated Mines, Inc.	Chicago Creek Mining District	Lead-zinc
Omaha Mine	Secs. 21 and 28, T. 3 S., R. 74 W.	Lead-zinc
Quartz Mill Lode	Leavenworth Gulch, Central City	Uranium
Red Elephant Metals, Inc.	Lawson	Lead-zinc
Senator Group	Montana Mining District	Lead-silver
Stanley Mine	West Idaho Springs	Copper
Stevens Mine	6 miles west of Silver Plume	Lead-zinc
Winsor Pegmatite Deposit	Beaver Brook Canyon	Beryl-feldspar-mica
Conejos County		
Copper King Mine	Sec. ? T. 33 S., R. 75 W. 12 miles east of Romeo	Copper
Forest King Mine	Platora Mining District	Molybdenum
Mammoth Mine	Sec. 22, T. 36 N., R. 6 E.	Lead-zinc
Opportunity Mine	Sec. 16, T. 36 N., R. 4 E.	Copper
Custer County		
Big Horn Mine	Secs. 14 and 15, T. 46 N., R. 11 E.	Copper
Deceiver Mine	Sec. 5, T. 22 S., R. 72 W.	Lead-zinc
Defender Mine	Silver Cliff-Westcliffe Mining District	Lead-zinc
Feldspar Lode	Sec. 7, T. 21 S., R. 70 W.	Barium
Hoza Ranch	Secs. 4 and 5, T. 22 S., R. 70 W.	Zinc
Marion Mines, Inc.	Sec. 3, T. 24 S., R. 69 W.	Zinc
Rosita Hills	Secs. 20 and 30, T. 22 S., R. 71 W.	Aluminum
Skek City Mine	Hardscrabble Mining District	Nickel
Stacey Claims	Secs. 14 and 15, T. 46 N., R. 11 E.	Molybdenum
Victory Claims	Hardscrabble Mining District	Manganese
Vidler Shaft	Silver Cliff-Westcliffe Mining District	Lead-zinc
Wild Goose Mine	Sec. 34, T. 22 S., R. 70 W.	Nickel

Name of Property	Location	Mineral Sought
Delta County		
Iron Cap Mine	Sec. 27, T. 15 S., R. 94 W.	Iron
Molly Group	Sec. 7, T. 11 S., R. 91 W.	Molybdenum
Dolores County		
Calico Peak Alunite Deposit	Secs. 20 and 29, T. 40 N., R. 11 W.	Aluminum
Cimarron Beryl Deposit	4 miles east of Cimarron	Beryl
Copper Claims	Secs. 20 and 21, T. 40 N., R. 10 W.	Copper
Douglas County		
Devil Head Copper Mine	Sec. 17, T. 9 S., R. 68 W.	Copper
Saddle Rock Ranch	Secs. 5 and 8, T. 8 S., R. 68 W.	Quartz crystals
Eagle County		
Ground Hog Mine	Sec. 33, T. 9 S., R. 88 W.	Copper
Glengarry Mine	Unsectionalized Holy Cross Mining District	Lead-zinc
El Paso County		
Cobalt Claims	Sec. 4, T. 16 S., R. 67 W.	Copper
Winfield Scott Stratton Group	Secs. 5, 8, and 17, T. 15 S., R. 67 W.	Lead
Fremont County		
Florence Group	Sec. 31, T. 18 S., R. 73 W.	Copper
Isabel Mine	Secs. 29, 30, 31, and 32, T. 16 S., R. 72 W.	Zinc
Phantom Lode	Sec. 15, T. 17 S., R. 69 W.	Beryl
Garfield County		
Doppelmayr Group	Secs. 27, 28, 29, 35, and 36, T. 4 S., R. 93 W.	Vanadium
Sunshine Mine	Sec. 15, T. 4 S., R. 92 W.	Zinc
Gilpin County		
Banta Hill Mine	Secs. 19 and 20, T. 3 S., R. 72 W.	Lead-zinc
Boodle Mine	Sec. 11, T. 3 S., R. 73 W.	Lead-zinc
Chain O Mines	Quartz Hill Mining District	Lead-zinc
Chihuahua Tungsten Mine	Sec. 1, T. 3 S., R. 73 W.	Tungsten
Evergreen Mine	Sec. 21, T. 2 S., R. 73 W.	Copper
Foster Mine	Sec. 21, T. 3 S., R. 72 W.	Tungsten
Old Town Group	Sec. 23, T. 3 S., R. 73 W.	Copper
Pozo and Jones Mine	Nevadaville Mining District	Lead-zinc
Silver Dollar Mine	Sec. 19, T. 3 S., R. 72 W.	Copper

Name of Property	Location	Mineral Sought
Grand County		
Forstall Mine	Willow Creek Mining District	Nickel
Gunnison County		
Barium Group	Spring Creek Mining District	Manganese
Doctor Mine	Sec. 25, T. 14 S., R. 84 W.	Lead-zinc
Manganese Production Co.	Doyleville	Manganese
May Queen Mine	Sec. 13, T. 47 N., R. 3 W.	Lead-copper
Morning Star Group	Sec. 34, T. 50 N., R. 5 E.	Lead-zinc
Paymaster Claims	Sun Creek, T. 50 N., R. 2 W.	Manganese
Hinsdale County		
Dolly Varden No. 172	Sec. 16, T. 43 N., R. 6 W.	Copper
Ferrara Ranch	Sec. 29, T. 45 N., R. 4 W.	Optical calcite
Gallic Vulcan Mine	Sec. 35, T. 44 N., R. 6 W.	Lead-zinc
Mary-Holbrook Mine	Secs. 6, 7, and 18, T. 37 N., R. 5 W.; Secs. 1, 12, and 13, T. 37 N., R. 6 W.	Copper
Pelican Dumps	Lake City Mining District	Lead-zinc
Huerfano County		
Lost Gulch Mine	Sec. 34, T. 24 S., R. 68 W.	Lead-zinc
Jackson County		
Village Bell Mine	Secs. 7, 8, 17, and 18, T. 11 S., R. 78 W.	Copper
Wolverine Group	Sec. 2, T. 11 N., R. 82 W.	Copper
Jefferson County		
Osirio Mine	Secs. 25 and 36, T. 7 S., R. 72 W.; Sec. 31, T. 7 S., R. 71 W.	Nickel
Sunrise Peak Mine	Sec. 22 or 27, T. 4 S., R. 71 W.	Quartz crystals
Lake County		
McCreer Copper Mine	Secs. 7 and 8, T. 8 S., R. 81 W.	Copper
La Plata County		
Copper Hill Property	W½ of T. 36 N., R. 11 W.	Copper
Escalante Mine	10 miles west of Hesperus	Lead-zinc
Honey Dew Mine	Sec. 3, T. 36 N., R. 11 W.	Lead-zinc
Iron King Mine	Sec. 16, T. 36 N., R. 11 W.	Copper
Silver Star Mine	Bowman Mining District	Lead-zinc

Name of Property	Location	Mineral Sought
Larimer County		
Abandon Mine	Sec. 6, T. 7 N., R. 71 W.	Beryl
Bashor Mine	Sec. 12, T. 4 N., R. 72 W.	Fluorspar-barite
Heline Property	Secs. 23 and 24, T. 8 N., R. 72 W.	Tungsten
Hyatt Ranch	Sec. 28, T. 6 N., R. 71 W.	Beryl
Mason Ranch	Secs. 3, 4, 9, and 10, T. 6 N., R. 70 W.	Tungsten
Mt. Olympia Mine	Secs. 21 and 27, T. 5 N., R. 72 W.	Mica-tantalum
Plans View, Big Boulder, and White Rock Claims	Secs. 31 and 36, T. 7 N., R. 72 W.	Beryl
Redfeather Quartz Deposit	Sec. 26, T. 10 N., R. 74 W.	Quartz crystals
Red Mountain Lode	Sec. 6, T. 8 N., R. 71 W.	Lead-zinc
Treasurer Hill Mine	Secs. 10 and 15, T. 9 N., R. 70 W.	Nickel
Mesa County		
King Property	Sec. 25, T. 12 S., R. 101 W.	Mica
Ranch View Mine	Sec. 34, T. 14 S., R. 101 W.	Molybdenum
Moffat County		
Bromite Group	Douglas Mountain Mining District	Copper
Ouray County		
Dunmore Mine	3 miles south of Ouray	Tungsten
Gold King and Jack Pot Mine	Bear Creek, T. 43 N., R. 7 W.	Lead-zinc
Hidden Treasure Mine	Sec. 22, T. 43 N., R. 8 W.	Lead-zinc
Molly and Mammoth Mine	Sec. 36, T. 43 N., R. 7 W.	Molybdenum
Mountain King Mine	Sec. 1, T. 42 N., R. 8 W.	Lead-zinc
Newsboy Mine	Paguin Mining District, 4 miles North of Ouray	Copper
Whippoorwill Mine	Ouray Townsite	Manganese
Park County		
Bonanza Group	Sec. 21, T. 9 S., R. 78 W.	Lead-zinc
Fannie Barrett Mine	Secs. 4 and 9, T. 9 S., R. 78 W.	Manganese
Garo Vanadium Prospect	Garo Mining District	Vanadium
Guernsey (Kenosha Pass) Mine	Sec. 17, T. 7 S., R. 75 W.	Fluorspar
Lake George Mine	Sec. 18, T. 12 S., R. 71 W.	Fluorspar

Name of Property	Location	Mineral Sought
Park County (Continued)		
Mineral Park Mine	Secs. 26 and 35, T. 8 S., R. 78 W.	Lead-zinc
New Bonnet Group	Sec. 10, T. 9 S., R. 78 W.	Lead-zinc
Oro Grande Group	Sec. 8, T. 9 S., R. 78 W.	Lead-zinc
Peerless Mine	Sec. 10, T. 10 S., R. 79 W.	Lead-zinc
Round Mountain Mine	Sec. 3, T. 12 S., R. 72 W.	Tungsten
Pitkin County		
Ground Hog-Gypsum Mine	Sec. 33, T. 9 S., R. 88 W.	Lead
Routt County		
Emancipation Group	Sec. 14, T. 10 N., R. 85 W.	Molybdenum
Greenville Mine	Sec. 34, T. 9 N., R. 85 W.	Lead-zinc
Saguache County		
Smith Mercury Mine	Secs. 32 and 33, T. 41 N., R. 2 E.	Mercury
Saint Louis Mine	Kerber Creek Mining District, Bonanza	Lead-zinc
Warwick	Kerber Creek Mining District, Bonanza	Lead-zinc
San Juan County		
Boston-Dewitt and London	Unsectionalized T. 43 N., R. 7 W.	Lead-zinc
Como Consolidated Mine	Sec. 10, T. 42 N., R. 7 W.	Lead-zinc
Gold Belt Nos. 1 to 4	Cascade Creek north of Durango	Copper
King Group	Secs. 29 and 30, T. 41 N., R. 7 W.	Manganese-lead-zinc
Lackawanna Mine and Mill	Silverton	Lead-zinc
Lead Carbonate Claims	Sec. 22, T. 42 N., R. 7 W.	Lead-zinc
Marcella Mine	Animas River, 1 mile south of Silverton	Manganese-zinc
Mayday Mine	Sec. 6, T. 42 N., R. 7 W.	Lead-zinc
Silverton Area Tungsten Mill		Tungsten
Ruby Mine	Maggie Gulch	
Tom Moore Mine	Eureka, Sec. 20, T. 42 N., R. 6 W.	
Galty Boy Mine	Cement Creek, above Gladstone	
Yukon Tunnel	Cement Creek, above Gladstone	
Silver Ledge Mine	Sec. 28, T. 42 N., R. 7 W.	

Name of Property	Location	Mineral Sought
San Juan County (Continued)		
Gold Thread Mine	Cement Creek, above Gladstone	
Bismark and Adams Mine	Cement Creek, above Gladstone	
Mystery Gold Group	Sultan Mountain	
Treasure Mountain Mine	Secs. 7 and 8, T. 42 N., R. 6 W.	Lead-zinc
San Miguel County		
Butterfly Consolidated Mine	West Slope Yellow Mountain, Ophir	Tungsten-lead-zinc
San Bernardo Mine	Sec. 5, T. 41 N., R. 9 W.	Lead-zinc
Silver Bell Mine	East slope Yellow Mountain, Ophir	Tungsten
Silver Eagle Mine	Sec. 8, T. 42 N., R. 10 W.	Lead-zinc
Summit County		
Andy Mine	Breckenridge District, T. 7 S., R. 78 W.	Molybdenum
Quail Dump	Montezuma Mining District	Lead
Royal Tiger Mine	Breckenridge District, T. 6 S., R. 77 W.	Lead-zinc
Superior Mine	Sec. 3, T. 6 S., R. 76 W.	Lead-zinc
Thunderbolt Mine	Wilkinson Mining District	Lead-zinc
Teller County		
Emma L. Mine	Secs. 19, 24, 25, and 30, T. 15 S., R. 69 W.	Nickel
Gedney Claims	Sec. 35, T. 15 S., R. 70 W.	Titanium
Weld County		
Furney Prospect	8 miles east of Hereford	Manganese
Keota and Iliff Deposits	Sec. 34, T. 10 N., R. 59 W. (also Logan County)	Silica

MINES EXAMINED OR INVESTIGATED AND PROJECTS RECOMMENDED OR OPERATED OR THE MINE CONSIDERED AT THE TIME AS ENTITLED TO FUTHER CONSIDERATION

Name of Property	Location	Mineral Sought
Archuleta County		
*Colorado Minerals Company	Secs. 7, 22, and 35, T. 35 N., R. 2 W. (also Hinsdale County)	Optical calcite

*Project operated.

Name of Property	Location	Mineral Sought
Boulder County		
*Boulder County Tungsten District (See project list of mines page 489)		Tungsten
**Copper King Mine	Sec. 14, T. 1 N., R. 72 W.	Nickel-copper
*Jamestown District		Fluorspar
Blue Jay Mine	Sec. 30, T. 2 N., R. 71 W.	Fluorspar
Nations Treasure Mine	Sec. 24, T. 2 N., R. 72 W.	Fluorspar
Chaffee County		
**Brown's Canyon Fluorspar		
American Fluorspar Mine	Sec. 34, T. 51 N., R. 8 E.	Fluorspar
Bapp Mine	Sec. 34, T. 51 N., R. 8 E.	Fluorspar
Colorado Fluorspar Mine	Sec. 34, T. 51 N., R. 8 E.	Fluorspar
Chaffee County Fluorspar Mine	Secs. 21, 22, and 28, T. 51 N., R. 8 E.	Fluorspar
Kramer Mines, Inc.	Secs. 22, 23, 26, and 27, T. 51 N., R. 8 E.	Fluorspar
Lionell Mine	Sec. 27, T. 51 N., R. 8 E.	Fluorspar
*Jewel Tunnel and Mining Co. (see page 491)	Secs. 15 and 22, T. 50 N., R. 6 E.	Lead-zinc
**Madonna Mine	Sec. 4, T. 49 N., R. 6 E.; Secs. 27 and 28, T. 50 N., R. 6 E.	Lead-zinc
*Pershing Mine	13 miles west of Villa Grove	Manganese
Clear Creek County		
**Minerals Reclamation Service Mill		Lead-zinc
Brighton Mine	Seaton Mountain	
Camp Bird Mine	Soda Creek	
Idaho Bride Mine	Seaton Mountain	
Park Mine	Seaton Mountain	
Harrison Mine	Trail Creek	
Silver Age Group	Silver Age Gulch	Lead-zinc
*Silver Plume District		Lead-zinc
Dives-Pelican Mine	West Silver Plume	
Mendota Mine	West Silver Plume	
Terrible Mine	West Silver Plume	
Seven-thirty Mine	West Silver Plume	

*Project operated.
**Project recommended.

Name of Property	Location	Mineral Sought
Custer County		
**Big Stake Nickel Property	Secs. 16 and 21, T. 22 S., R. 7 W.	Nickel
Bull Domingo Mine	Sec. 8, T. 22 S., R. 72 W.	Lead-zinc
Terrible Mine	Secs. 17, 18, 19, and 20, T. 21 S., R. 70 W.	Lead
Denver County		
*Denver Basin Manganese	Colorado Front Range	Manganese
Dolores County		
Barlow Group	Sec. 10, T. 40 N., R. 10 W.	Vanadium
**Rico Argentine	Sec. 36, T. 40 N., R. 11 W.	Lead-zinc
*Vanadium Mines (See project list page 486)		Vanadium
El Paso County		
**Timberline Mine	Sec. 20, T. 15 N., R. 67 W.	Fluorspar
Fremont County		
**Devil's Hole Beryl Deposit	Sec. 20, T. 18 S., R. 73 W.	Beryl-tantalum
Garfield County		
Parker Mine	Secs. 17 and 18, T. 4 S., R. 92 W.	Lead-zinc
Strong Mine	Sec. 18, T. 5 S., R. 88 W.	Lead-zinc
Gilpin County		
**Minerals Reclamation Service Mill		Lead-zinc
Gold Cup Mine	Nevadaville Mining District	
Hubert Mine	Nevadaville Mining District	
Silver Dollar Mine	Sec. 19, T. 3 S., R. 72 W.	
Martin Mine	Nevadaville Mining District	
Katherine Mine	Nevadaville Mining District	
Old Dougherty	Excelsior Gulch	Copper
Grand County		
Beaver Mine	Sec. 33, T. 2 N., R. 76 W.	Mica
Gunnison County		
**Brown Derby Mine	Sec. 34, T. 50 N., R. 3 E.	Lithium-tantalum
Clara L. Mine	Sec. 35, T. 12 and 13 S., R. 84 W.	Lead-zinc
Golden Dream Mine	West Slope of Augusta Mountain	Lead-zinc
Puritan Group	Sec. 12, T. 12 S., R. 87 W.	Lead-zinc

*Project operated.
**Project recommended.

Name of Property	Location	Mineral Sought
Jackson County		
*Northgate Fluorspar		Fluorspar
Camp Creek Claims	Secs. 3, 4, and 10, T. 11 N., R. 79 W.	
Western Fluorspar Corp.	Secs. 4, 5, 8, 9, and 17, T. 11 N., R. 79 W.	
Lake County		
**Garibaldi Tunnel	Sec. 28, T. 9 S., R. 79 W.	Lead-zinc
*Leadville Dumps (See project list page 492)		Lead-zinc
*Leadville Ore		Lead-zinc
Mesa County		
*Colorado Copper Company	Sinbad Valley (also Montrose County)	Copper
*Vanadium Mines (See project list page 486)		Vanadium
Montrose County		
*Vanadium Mines (See project list page 486)		Vanadium
Ouray County		
*Camp Bird Mine	Mt. Sneffels Mining District	Lead-zinc
**Hayden-Camal Mine	Uncompahgre Mining District	Lead-zinc
**Idarado Mining Company	Mt. Sneffels, Imogene Districts	Lead-zinc
Black Bear Mine		
Barstow Mine		
Imogene Mine		
Treasury Tunnel		
Lost Day Mine	Sec. 33, T. 43 N., R. 7 W.	Lead-zinc
**Revenue Tunnel	Sec. 21, T. 43 N., R. 8 W.	Lead-zinc
Rouville Mine	Red Mountain Mining District	Lead-zinc
Park County		
**Record Mill (Alma District) (Mines mostly inaccessible)		Lead-zinc
Orphan Boy Mine	Park City	
Kennebec Dump	Park City	
Red Cross Mine	Buckskin Gulch	
Alma Syndicate Shaft	East Slope Mt. Bross	

*Project operated.
**Project recommended.

Name of Property	Location	Mineral Sought
Park County (Continued)		
Mineral Park Shaft	East Slope Mt. Bross	
Hock Hocking Mine	Park City	
Sweet Home Mine	Buckskin Gulch on Mt. Bross	
King Lear Mine	Buckskin Gulch on Loveland Mountain	
American Mine	Mosquito Gulch	
American Flag Mine	Buckskin Gulch on Loveland Mountain	
Moose Mine	Mt. Bross	
Russia Mine	Mt. Lincoln	
Walker Mine	Mt. Bross	
Hill Top Mine	Sec. 1, T. 10 S., R. 79 W.	
Pitkin County		
**Smuggler Mine	Aspen District, Smuggler Mountain	Lead-zinc
Pueblo County		
The Stone City Clay Deposit	Stone City	Aluminum
Rio Grande County		
Marble Mountain	Secs. 8 and 17, T. 37 N., R. 5 E.	Aluminum
Saguache County		
**Bonanza District	16 miles up Kerber Creek from Villa Grove	Lead-zinc
Antoro Mine		
Cliff Mine		
Little Jennie Mine		
Oregon Mine		
Cocomongo Dump		
Rawley Mine		
Superior-Erie Mine		
San Juan County		
Burns Gulch Group	T. 42 N., R. 6 W.	Lead-zinc
Frederika Mine		
Great Eastern Mine		
Klondike Mine		
Silver Wing Mine		
Tom Moore Mine		
Caledonian Mine	Secs. 28, 29, 32, and 33, T. 42 N., R. 6 W.	Lead-zinc

*Project operated.
**Project recommended.

Name of Property	Location	Mineral Sought
San Juan County (Continued)		
Galty Boy Mine	Secs. 16, 20, and 30, T. 42 N., R. 7 W.	Tungsten
Graham Mine	Secs. 19 and 30, T. 42 N., R. 7 W.	Lead-zinc-copper
**Kittimac Mine	Sec. 33, T. 42 N., R. 7 W.	Lead-zinc
Little Ida Mine	Sec. 2 T., 42 N., R. 7 W.	Lead-zinc
San Antonio Mine	Secs. 13 and 24, T. 42 N., R. 8 W.	Lead-zinc
**San Juan District		Lead-zinc
Mines in Brown Mountain and Poughkeepsie Gulch Area		
Silver Ledge Mine	Sec. 23, T. 42 N., R. 8 W.	Lead-zinc
San Miguel County		
**Alta Mine	Ophir District	Lead-zinc
Meldrum Tunnel	Telluride Mining District	Lead-zinc
**Telluride Mines, Inc.	Telluride Mining District, Ts. 42 and 43 N., R. 8 W.	Lead-zinc
Summit County		
*Big Four Mine	Secs. 10, 14, and 15, T. 2 S., R. 80 W.	Zinc
Country Boy Mine	Sec. 32, T. 6 S., R. 77 W.	Lead-zinc
*Kokomo District		Lead-zinc
Kimberly Mine	Sec. 22, T. 7 S., R. 79 W.	
Lucky Strike Mine	Sec. 27, T. 7 S., R. 79 W.	
Wilfley Mine	Sec. 22, T. 7 S., R. 79 W.	
**Monte Cristo Mine	Secs. 1 and 2, T. 7 S., R. 78 W.	Lead-zinc
**Montezuma District	Ts. 5 and 6 S., Rs. 75 and 76 W.	Lead-zinc
Bullion Mine	Collier Mountain	
Erickson Mine	Keystone Gulch	
Fisherman Mine	Snake River, ½ mile north of Montezuma	
Ida Belle Mine	Independence Mountain	
Morgan Mine	Morgan Gulch	
New York Mine	Morgan Gulch	
Pennsylvania Mine	Decatur Mountain	
Rose Mine	Collier Mountain	
Shoebasin Mine	Decatur Mountain	
Silver King Mine	Glacier Mountain	
Superior Mine	Sec. 3, T. 6 S., R. 76 W.	
Waterloo Mine	Collier Mountain	
Waunita Mine	Sec. 26, T. 5 S., R. 76 W.	

*Project Operated
**Project Recommended

MINE EXAMINATIONS PENDING

Name of Property	Location	Mineral Sought
Boulder County		
Caribou and Boulder County Mine	Secs. 34 and 35, T. 1 N., R. 73 W.	Lead
Minnie Foy	Sec. 11, T. 1 S., R. 75 W.	Tungsten
Chaffee County		
Washburn-Elser Mine	Sec. 5, T. 12 S., R. 81 W.	Molybdenum
White Star and Spar King Mine	Secs. 27 and 28, T. 12 S., R. 81 W.	Fluorspar
Delta County		
Movelock Mine	Duke Creek near Silt	Molybdenum
Dolores County		
Exception Mine	2 miles west of Rico, T. 40 N.	Copper
Eagle County		
Rio Grande and Copper Queen Mine	Secs. 2 or 3, T. 2 S., R. 83 W.	Copper
Grand County		
Mt. Vasquez Mine	Unsectionalized T. 2 S., R. 76 W.	Lead-zinc
Gunnison County		
Belcher Mine	Irwin, T. 13 S., R. 87 W.	Lead-zinc
Carbonate King Mine	Secs. 28, 29, and 32, T. 51 N., R. 3 E.	Lead-zinc
Fluorandi Claims 1 and 2	Martz Creek, Pitkin	Fluorspar
Forest Hill Mine	Taylor Park, T. 13 S., R. 83 W.	Lead-zinc
O. F. Lode	Sec. 16, T. 12 N., R. 86 W.	Lead-zinc
Vanadate Mine	Sec. 8 or 17, T. 47 N., R 1 W.	Vanadium-lead
Whopper-Teller Mine	Sec. 1, T. 12 S., R. 87 W.	Lead-zinc
Hinsdale County		
Hidden Treasure Mine	Sec. 22, T. 43 N., R. 8 W.	Manganese
Ute and Ulay Mine	Henson Creek, Lake City	Lead-zinc
Jackson County		
Non-Magmetic Mine	Sec. 24, T. 8 N., R. 82 W.	Fluorspar

Name of Property	Location	Mineral Sought
Lake County		
Belle Placer	Secs. 14 and 15, T. 9 S., R. 79 W.	Lead-zinc
La Plata County		
Flicker Group	Lightner Creek, T. 36 N., R. 10 W.	Vanadium
Moffat County		
Mantle-Jamison Group	18 miles west of Elk Springs, T. 6 N., R. 101 W.	Lead-zinc
Ouray County		
Kentucky Giant Mine	Sec. 31, T. 43 N., R. 7 W.	Lead-zinc
Park County		
Hill Top Mine	Sec. 1, T. 10 S., R. 79 W.	Lead-zinc
Pitkin County		
Colorado Nickel Mine	Mt. Sopris, southeast of Carbondale	Nickel
Montezuma-Tam O' Shanter Mine	Sec. 2, T. 11 S., R. 84 W.	Lead-zinc
San Juan County		
Auburn Group	Tower Mountain, Eureka District	Lead-zinc
Gold Hub Mine	Cement Creek District	Lead-zinc
Gold King Mine	Sec. 16, R. 7 W., T. 42 N.	Lead-zinc
Green Mountain Mine	Sec. 19, T. 41 N., R. 6 W.	Lead-zinc
Lark Lode	Sec. 13, T. 42 N., R. 8 W.	Lead-zinc
Mountain View	Sec. 34, T. 42 N., R. 8 W.	Lead-zinc
Old Hundred Mine	Cunningham Gulch	Lead-zinc

PROJECT WORK

Subsequent to the establishment of the Colorado Field Office in July, 1942, and up to December 31, 1945, the Bureau completed or had in progress 16 exploratory projects in the state. Selection of properties for exploration was made from those, which appeared from preliminary examination, to have the most promise with respect to the national objective. Many properties were examined and projects recommended where available funds were not adequate to permit the conduct of additional exploration beyond the original examination.

Essentially all the conventional methods of developing ore reserves were applied and one of the most successful was core drilling. A brief description of the Colorado projects follows:

Vanadium Region.—It became apparent late in 1942, in order to meet the requirements of new treatment plants established in the vanadium region of western Colorado and eastern Utah, as well as those already in operation, that it would be necessary to open new mines and stimulate production from old ones. The increased production was expected to come from independent operators whose funds for development and exploration were limited. Available information indicated that extensive exploration would be necessary to insure sustained production and accordingly, the Bureau of Mines initiated a diamond drilling program early in 1943 in cooperation with the Federal Geological Survey. The Survey made geological maps of the areas to be drilled. The actual drilling, sampling, and assaying of drill cores were done by the Bureau of Mines, and the estimates of reserves were made from the combined data obtained by the two agencies. With the substantial decreased demand for domestic vanadium in December of 1943 and increased imports, the program was terminated. Production from smaller operators ceased almost entirely with the discontinuance of ore purchases by the Metals Reserve Company on February 29, 1944.

Eight hundred and ninety-five holes, aggregating 38,510 feet, were drilled on 46 different properties. Holes were drilled to a maximum depth of 114 feet, the average depth being 43 feet.

It is estimated that core drilling by the Bureau of Mines, mapping by the Geological Survey, and other types of exploration increased the minable[1] reserves of the region by 51,210 short tons with an average V_2O_5 content of 2.3 per cent and a minimum grade of 1.25 percent, the lowest grade of ore acceptable at Metals Reserve Company stockpile. Core drilling alone established 34,600 tons of minable ore with an average grade of 2.5 percent V_2O_5 and this ore, on the basis of prices current in December 1943, had a gross value of approximately $600,000. An additional 23,000 tons of ore was established in minable bodies containing a minimum of 0.75 percent V_2O_5 and averaging 1.01 percent. This ore is available if at a later date the purchasing requirements are lowered. If ore bodies less than 1 foot thick are considered, a much larger reserve has been established.

Approximately 16,000 tons of ore valued at $270,000 were mined by various operators in the district while the project was in operation. Most of this ore was produced as a result of the drilling, but the tonnage is not included in the reserve estimates.

An appreciable amount of uranium ore was established while drilling for vanadium, which reserves were of considerable value in the development of the atomic bomb.

Vanadium reserves outlined by the project will be available to operators in the district, if requirements for the metal again become critical.

The following vanadium deposits in the region of western Colorado and eastern Utah were drilled by the Bureau of Mines.

[1]Minable ore is considered to be ore in bodies 1 foot or more thick.

MINE NAME	LOCATION
Thompsons Area	
*1. Flat Top No. 1 Claim	Sec. 25, T. 22 S., R. 22 E., Grand County, Utah
*2. Red Vanadium Claims	Sec. 26, T. 22 S., R. 22 E., Grand County, Utah
Polar Mesa	
*3. Eva M. and Adjoining Claims	Public Domain, Grand County, Utah
*4. Rim Rock and Rim Rock No. 2 Claims	Public Domain, Grand County, Utah
*5. Polar No. 3 Claim	LaSal National Forest, Grand County, Utah
*6. Polar No. 2 Claim	LaSal National Forest, Grand County, Utah
East Gateway Area	
7. Hidden Treasure Claim	Sec. 4, T. 50 N., R. 18 W., Mesa County, Colorado
8. Hummer and Great Hesper Claims	Sec. 9, T. 50 N., R. 18 W., Mesa County, Colorado
9. Calamity Nos. 13, 17, and 18 Claims	Secs. 1, 2, 3, 11, and 14, T. 50 N., R. 18 W., Mesa County, Colorado
10. Calamity No. 27 Claim	
11. Calamity Nos. 7, 8, 9, 23, and Crackerjack Claims.	
12. Calamity No. 20 Claim	
13. Calamity Nos. 1, 3, and Triangle Claims	
14. Calamity No. 3 Claim	
15. Dixie Mine	
Gypsum Valley District	
16. Raven and Adjoining Claims	Secs. 4 and 5, T. 45 N., R. 19 W., Montrose County, Colorado
17. Gyp and Gyp No. 1 Claims	Sec. 10, T. 45 N., R. 19 W., Montrose County, Colorado
18. Roosevelt Mine	Sec. 3, T. 45 N., R. 19 W., Montrose County, Colorado
19. Aztec Mine	Sec. 33, T. 46 N., R. 19 W., Montrose County, Colorado
20. Lost Claim	Sec. 33, T. 45 N., R. 18 W., San Miguel County, Colorado
21. Riverview Claim	Sec. 33, T. 45 N., R. 18 W., San Miguel County, Colorado
22. Pay Day Claim	Sec. 34, T. 45 N., R. 18 W., San Miguel County, Colorado
23. Pitchfork Mine	Sec. 33, T. 44 N., R. 16 W., San Miguel County, Colorado
24. Jack Knife Claim	Sec. 21, T. 45 N., R. 18 W., San Miguel County, Colorado
25. Main Street Mine	Sec. 16, T. 45 N., R. 18 W., San Miguel County, Colorado

*Mines located in Utah.

MINE NAME	LOCATION
Egnar-Slick Rock District	
26. Lower Group	Sec. 23, T. 44 N., R. 19 W., San Miguel County, Colorado
27. Charles T. Group	Sec. 10, T. 43 N., R. 19 W., San Miguel County, Colorado
28. Legin Group	Secs. 28 and 29, T. 43 N., R. 19 W., San Miguel County, Colorado
29. Buckhorn and Cone Claims	Sec. 30, T. 44 N., R. 19 W., San Miguel County, Colorado
30. Radium No. 2 and Adjoining Claims	Sec. 4, T. 43 N., R. 19 W., San Miguel County, Colorado
31. Radium No. 4 Claim	Secs. 8 and 9, T. 43 N., R. 19 W., San Miguel County, Colorado
32. Radium No. 6 Claim	Secs. 8 and 9, T. 43 N., R. 19 W., San Miguel County, Colorado
33. Hogback Mine	Secs. 19 and 29, T. 43 N., R. 19 W., San Miguel County, Colorado
34. Marie Mine	Secs. 19 and 29, T. 43 N., R. 19 W., San Miguel County, Colorado
35. Hawk and Frankie Claims	Sec. 16, T. 43 N., R. 19 W., San Miguel County, Colorado
36. Mucho Grande Claim	Sec. 6, T. 42 N., R. 17 W., San Miguel County, Colorado
37. Uncle Sam Claim	Sec. 1, T. 42 N., R. 18 W., San Miguel County, Colorado
Cottonwood Canyon District	
*38. Big Hole Mine	Unsectionalized T. 37 S., R. 21 E., San Juan County, Utah
*39. Birthday and Adjoining Claims	Unsectionalized T. 37 S., R. 21 E., San Juan County, Utah
*40. Basin Claim	Unsectionalized T. 37 S., R. 21 E., San Juan County, Utah
*41. Blue Bird Claim	Unsectionalized T. 37 S., R. 21 E., San Juan County, Utah
*42. Hangover and Ridge Claim	Unsectionalized T. 37 S., R. 21 E., San Juan County, Utah
*43. Corvusite Nos. 1, 2, and 3 Claims	Secs. 19 and 20, T. 25 S., R. 26 E., Grand County, Utah
*44. Yellow Circle Group	Sec. 3, T. 28 S., R. 23 E., San Juan County, Utah
45. Shamrock Group	Sec. 29, T. 48 N., R. 17 W., Montrose County, Colorado
*46. Happy Jack Mine	Sec. 13, T. 32 S., R. 23 E., San Juan County, Utah

*Mines located in Utah.

Boulder County Tungsten.—A project similar to the vanadium drilling was carried out in the Boulder County ferberite district during 1942 and 1943, where reserves were explored on 25 properties. Exploration for ore bodies was also done by bulldozing along vein outcrops.

Twelve thousand, four hundred and eighty-two feet of drilling disclosed new ore on 11 of the 25 properties drilled and developed reserves of measured, indicated, and inferred ore aggregating approximately 7,930 tons averaging 2.13 percent WO_3, a total of 16,860 units.

Newly acquired knowledge of the district, derived from Bureau of Mines project work and studies by the Federal Geological Survey, indicates that additional reserves may be disclosed by further exploration.

The following mines were included in the project:

MINE NAME	LOCATION
Illinois Mine	Sec. 11, T. 1 S., R. 73 W.
*Dorothy Mine	Secs. 29 and 32, T. 1 N., R. 71 W.
Princess Mine	Sec. 29, T. 1 N., R. 71 W.
McClaim Mine	Sec. 31, T. 1 N., R. 71 W.
*Cross Mine	Sec. 8, T. 1 S., R. 72 W.
Grayback Mine	Sec. 11, T. 1 S., R. 73 W.
Sunday Mine	Sec. 19, T. 1 S., R. 72 W.
*Phillips Extension Mine	Sec. 12, T. 1 S., R. 73 W.
*Quay Mine	Sec. 11, T. 1 S., R. 73 W.
*Lower Rambler Mine	Sec. 24, T. 1 S., R. 73 W.
Pueblo Belle Mine	Sec. 31, T. 1 N., R. 71 W.
*Nancy Henderson Mine	Sec. 7, T. 1 S., R. 72 W.
*Forest Home Mine	Sec. 7, T. 1 S., R. 72 W.
Windy Tunnel Mine	Sec. 19, T. 1 S., R. 72 W.
*Good Friday Mine	Sec. 36, T. 1 N., R. 32 W.
*Big Six Mine	Sec. 13, T. 1 S., R. 73 W.
Spider Leg Mine	Sec. 11, T. 1 S., R. 73 W.
Oregon Mine	Sec. 33, T. 1 N., R. 72 W.
Rogers Mine	Sec. 3, T. 1 S., R. 72 W.
Dillon Mine	Sec. 7, T. 1 S., R. 72 W.
Hugo No. 2 Mine	Sec. 5, T. 1 S., R. 72 W.
*Vasco No. 2 Mine	Sec. 8, T. 1 S., R. 72 W.
*Clark Tunnel	Secs. 17 and 18, T. 1 S., R. 72 W.
Brace Mine	Sec. 24, T. 1 S., R. 73 W.
*Vasco No. 7 Mine	Sec. 8, T. 1 S., R. 72 W.

*Ore reserves estimated.

Silver Plume District.—The Silver Plume district of Clear Creek County was investigated early in 1942; and a project of mine rehabilitation, started in September, was continued until April 1943. The project was recessed at that time, resumed in September of 1943, and continued until February 1944. The last phase consisted of additional rehabilitation work, followed by approximately 1,100 feet of diamond drilling. About 50 percent of the work originally proposed was completed.

Examination and sampling of reopened mine workings, core drilling, and studies of available engineers' reports indicated that four of the larger mines of the district, the Dives-Pelican, Mendota, Terrible, and Seven-Thirty, contain conservatively 160,000 tons of minable ore. Core drilling at the Mendota established 440 tons of this estimated tonnage as indicated ore, and the remainder is classed as inferred ore. The estimates do not include extensive reserves of stope filling believed to exist, as it was impossible to substantiate the tonnage and grade of this type of ore.

Funds were not available to rehabilitate the mines sufficiently to permit more accurate estimates of possible ore reserves. However, the work which was completed made accessible mine workings from which a certain amount of production has resulted and also established with reasonable assurance the presence of considerable new ore for development by the operators.

Only one of the properties explored has been operated actively since completion of the project. This is the Mendota-Frostberg mine, leased and operated by the Utze Lode Company, which has produced enough ore to provide for continuous operation of a 50-ton mill on the property.

The known production from all the properties investigated is a small portion of the amount indicated by the work. Exploration of many other properties in the vicinity of Silver Plume is warranted after further investigation and might result in obtaining increased production for the district.

Big Four Mine.—A core-drilling program was carried out in the Big Four Zinc mine near Kremmling in northern Summit County during the spring and summer of 1944. The Bureau completed 10 diamond-drill holes, with an aggregate length of 1,638 feet, and sampled the mine workings extensively. The limits of the present ore body were definitely established by the work and a basis laid for future development and mining operations. The general area surrounding the mine merits additional prospecting.

Denver Basin Manganese Deposits.—Manganese, in the form of impregnations in sedimentary beds, is found in the plains area a few miles out from the Rocky Mountain front range. These deposits are reported to occur over a distance of 200 miles.

Seven deposits in the Denver Basin and one near the Wyoming line, 100 miles northeast of Denver, were examined; in three of the deposits, ore reserves of approximately 80,000 long tons of 5 to 8 percent manganese inferred. As there is a large area in which similar geologic conditions exist and as float manganese ore has been found at many places, existence of many more deposits is suspected.

Six deposits of nodular manganese were found on the Buckley Field bombing range and a seventh deposit near Franktown, Douglas County. Two of the deposits on Buckley Field were explored by 21 test pits 4 to 9 feet deep, 8 trenches 10 to 31 feet long, and 116 post holes 0.5 to 3.5 feet deep.

Although no commercial deposits of manganese were disclosed, the general region warrants reconnaissance work to determine the potentialities for economic production in case of national emergency.

Colorado Copper Company Deposits.—The copper deposits of the Colorado Copper Company in Sinbad Valley, Mesa and Montrose Counties, were examined by the Federal Bureau of Mines and the Federal Geological Survey early in 1942, resulting in an exploratory project being conducted during the last 3 months of the year.

Exploration consisted of (1) trenching and open-cutting to expose the formations thought to contain copper mineralization, (2) channel sampling of the trenches and mine workings, (3) surveying of the surface trenches, open-cuts, outcrops, and mine workings, and (4) metallurgical testing of the ore.

The work disclosed only a small tonnage of low-grade copper ore, mostly unsuitable for acid leaching. Flotation recoveries were also unsatisfactory. The deposits are not adaptable to large-scale, open-cut mining operations, and additional exploration was not considered justified. The structure of the deposits is such that large reserves of ore are not to be expected.

Colorado Minerals Company.—A group of properties in Archuleta and Hinsdale Counties owned by the Colorado Minerals Company were examined in August 1943 as possible sources of suitable calcite crystals of optical grade. Increased demand for this material by the armed forces and industry had found the supply from known sources entirely inadequate. Several out-cropping veins were found, and although optical calcite had been reported in some of them none was found near the surface.

In order to explore the deposits at greater depth, a project was initiated and exploration conducted between November 11, 1943, and January 7, 1944.

The work consisted of trenching across the vein outcrops and lines of float with a bulldozer; where results were encouraging, the trenches were deepened by hand-dug pits and one 30-foot shaft was sunk. In one instance an area of 4,000 square feet was entirely stripped of soil to uncover a series of lenses.

All of the calcite encountered occurred as lenses and veins in the Mancos shales, and no material of optical grade was found at depths up to 30 feet.

Jewell Tunnel and Mining Company.—The Jewell Tunnel property, 3 miles north of Garfield, Chaffee County, was examined and a field project started September 16, 1944. It was recessed from December 26, 1944, to May 15, 1945, due to adverse winter weather conditions and was finally suspended July 12, 1945, when rehabilitation of the New York Tunnel workings was completed to the point desired.

Project work consisted of construction of one-half mile of access road, a cabin at the portal of the New York Tunnel, cleaning of drainage ditches, and repair to the track in the tunnel to a bypass junction, a distance of 880 feet. The bypass branch of the tunnel around a serious cave in the main heading was completely rehabilitated for 525 feet. When the project was reopened, the main tunnel beyond the junction with the bypass was cleared to the Indianapolis vein.

The New York crosscut tunnel was reported to have intersected the Indianapolis vein 346 feet below the Indianapolis Tunnel, where the vein is exposed in the face 3.5 to 5 feet wide.

The vein was not found in recognizable form in the bypass crosscut, and in the main crosscut tunnel several mineralized seams were inferred to represent the complexly faulted Indianapolis vein.

It was recommended at the time operations were suspended that a detailed geologic study of the area be made before further exploratory work is undertaken.

Leadville Drainage Tunnel.—The Leadville Drainage Tunnel, started in December 1943, was advanced from 2,673 to 6,600 feet between January 1 and September 1, 1945, when operations were postponed due to lack of funds. Unforseen difficulties contributed heavily to expenses until the more solid formations were encountered, after which exceedingly good progress was made. The tunnel breast is approaching a point where it will start draining several important mines, and it is hoped that funds necessary to complete the job will be made available.

It is conservatively estimated that 3 to 4 million tons of ore will become available when the tunnel is completed and the basins drained. A large portion of the ore consists of lead and zinc sulfides, much of which is expected to be of smelting grade. In addition to the sulfides, there are large tonnages of lead-zinc carbonates and black oxide of manganese and manganosiderite. Owing to the lack of direct market for some of these ores, the Bureau of Mines is investigating fuming processes for recovery of values from oxidized lead-zinc ores and is also conducting metallurgical testing on manganosiderite and low-grade oxidized manganese ores of the district. Concurrently, field exploration is progressing to establish reserves of the various types of ores presently above water level and will continue and be expanded as the water recedes.

Leadville Ore.—Several mines in the Leadville district have been sampled in a search for carbonate ores. The field work started in August 1944 and has been carried on in conjunction with other activities in the area. Preparations are being made to rehabilitate some of the older inaccessible mine workings so as to expand the exploration program as funds will permit.

A geophysical survey of the Poverty Flat and Fairview Hill areas in the fall of 1944 was followed by core drilling to establish the existence of commercial oxidized manganese ore bodies. This work is still in progress and results have been encouraging.

Leadville Dumps.—After a preliminary survey of the district, the Bureau of Mines undertook detailed sampling of 5 of the more important mine dumps at Leadville between September 1942 and March 1943. A supplemental program was conducted from August 1944 to June 1945, in which 9 additional dumps were sampled by less detailed methods. In April and June of 1944, between the two programs, two other dumps were sampled employing the less detailed method. In all, a total of 16 dumps were sampled.

The first 5 dumps were sampled by sinking shafts entirely through them, and the remaining 11 dumps were sampled by hand-dug cuts. One of the latter dumps was resampled later by means of a rotary drill sinking nine 8-inch vertical holes completely through the dump or to the limiting depth of the drill.

Dump sampling in Leadville established approximately 792,000 tons of sulfide milling ore averaging 1.72 percent lead, 3.63 percent zinc, 3.02 ounces silver, and minor amounts of gold and copper a ton.

Metallurgical testing of all the individual dumps sampled consisted of (1) gravity concentration by heavy media, jigs, and tables and (2) selective flotation of the combined gravity concentrates.

Two plants in the district operated on the material sampled and through July 31, 1945, had milled approximately 500,000 tons. The gross and net value of the concentrates produced is not known.

The following dumps were sampled during the two programs:

Maid of Erin	Little Ellen
R. A. M.	Greenback
Wolftone (3 dumps)	Tucson
Robert Emmet	North Moyer
Col. Sellers (upper)	Yak Tunnel
Mahala	Jamie Lee
Mab	Colorado No. 2

Kokomo Zinc.—A core-drilling program was started at Kokomo, Summit County, in the fall of 1944. Both surface and underground drilling were included on three lead-zinc properties, and the project is still in operation. Considerable information has been obtained concerning the ore-bearing limestones in the area and has aided the operators in their development programs.

A total of 2,783 feet of drill hole had been completed to October 1945. On that date the project was recessed temporarily because winter conditions interfered with efficient surface drilling operations. The project was reopened December 18, 1945, and preparations are under way to drill several underground holes in the Wilfley mine with government-owned equipment.

Northgate Fluorspar.—To stimulate fluorspar production, underground exploration was started in the Northgate area, Jackson County, in June 1944 and is still in progress.

Core drilling was attempted unsuccessfully on the Camp Creek claims of the Kramer Mines Company. The highly brecciated condition of the ground made core and sludge recovery difficult; as a consequence, underground methods were adopted, supplemented by surface trenching by bulldozer. This type of exploration was also extended to include the property of the Western Fluorspar Corporation, where a substantial tonnage of millable fluorspar is estimated to exist from extensive trenching, shaft sinking, and cross-cutting on the Fluorine claims, and at the Penber mine.

Camp Bird Mine.—A core-drilling project was started at the Camp Bird mine, Ouray County, in December 1944. The object was to test the favorable sedimentary formations, the main Camp Bird vein below the 14th level ore shoots, for commercial ore bodies.

Four holes, aggregating 2,104 feet in length, were completed by October 12, 1945, when the project was recessed. Two of the holes intersected the vein approximately 125 feet below the 14th level. No commercial ore was found, but the vein showed the average width and the same general characteristics as above the 14th level. The other two holes penetrated the sedimentaries beneath the San Juan tuff close to the vein and indicated the possible presence of a large body of low-grade zinc-sulfide ore in the lower Telluride conglomerate.

The project was resumed early in 1946 and a core-drilling program similar to the first was continued under another 14th-level ore shoot.

San Juan Region.—An investigation of the lead-zinc-silver veins in the Brown Mountain area of the San Juan region was started in the fall of 1945. The great vertical extent of the ore at other localities in the region, notably at the Treasury Tunnel, Sunnyside, and Smuggler-Union Mines, indicate that other veins in the area may be productive at greater depths. Work on this project was resumed as early in 1946 as the weather permitted and will be continued through 1947. It is hoped that preliminary detailed mapping and core drilling may justify recommendations of a deep exploratory tunnel.

Jamestown Fluorspar.—A core-drilling program at Jamestown, Boulder County, has been approved, and government-owned equipment moved to the Blue Jay mine. Operations started in December, 1945 and continued through 1946.

Paonia Coal.—The Fuels and Explosives Branch of the Bureau conducted a core-drilling project in the Minnesota Creek field, Gunnison County, between September 1943 and October 1944, exploring for coking coal.

Operations were carried on entirely separate from the projects supervised by the Colorado Field Office with reports submitted direct to the Pittsburgh Station.

Six holes were drilled and all were reported to have intersected five to seven coal seams from 4 to 16 feet thick. It is assumed that an appreciable coal reserve was established but information regarding the quality is not immediately available.

ACCESS ROADS

Congress, by enactment of the Defense Highway Act of 1941 (55 Stat. 765) as amended, authorized the Commissioner of Public Roads to provide for the construction, maintenance, and improvement of access roads to sources of raw materials, when such roads were certified to the Federal Works Administration as important to national defense. The act further provided that such certification could be made by the chairman of the War Production Board.

Examinations of mineral deposits, to which access roads were requested, were made by the Bureau of Mines. Following approval by the Bureau of Mines and War Production Board, the Public Roads Administration designated the agency, generally the Grazing Service or the Forest Service, to construct the road. A few roads were constructed by the State Highway organization.

Approval of access roads was based upon the actual or potential quantity of ore, shown by examination, that could reasonably be expected to be hauled over the road, the reliability of the management, and the amount of strategic equipment required to assure production. If these factors balanced favorably against the cost of construction and maintenance of the road, it was approved.

Of 143 mines examined by the Bureau of Mines in Colorado, 89 were recommended for consideration by the War Production Board, which approved 70 of them. The program was started in July 1942 and continued to the end of the war.

The following tabulation gives the pertinent data concerning the 70 access roads in Colorado approved by the Bureau of Mines and War Production Board that were completed or under construction.

COLORADO DEFENSE ACCESS ROADS APPROVED BY BUREAU OF MINES AND WAR PRODUCTION BOARD, COMPLETED OR UNDER CONSTRUCTION

ROAD	COUNTY	LENGTH MILES	MINERAL PRODUCED
Alexite	Gunnison	22.0	Vermiculite
Alta	San Miguel	4.1	Lead-zinc
Atkinson	Montrose	6.2	Vanadium
Barlow Creek	Dolores	3.35	Vanadium
Blue Flame	Moffat	2.0	Coal
Brown Derby	Gunnison	2.0	Lepidolite-Microlite
Burns Gulch	San Juan	4.0	Lead-zinc
Mt. Queen	San Juan	3.0	Lead-zinc
Calamity-Mesa Creek	Mesa and Montrose	45.0	Vanadium
Carpenter Flats	Montrose	15.0	Vanadium
Conny-North Star	Ouray	0.504	Lead-zinc
Cottonwood	Mesa	2.8	Vanadium
Country Boy	Summit	0.6	Lead-zinc
Devil's Hole	Fremont	6.2	Beryl-feldspar-mica
Dolores Group	Various Utah and Colorado	162.8	Vanadium
East Lake	Clear Creek	0.76	Lead-zinc

ROAD	COUNTY	LENGTH MILES	PRODUCED MINERAL
Erickson	Summit	6.5	Lead-zinc
Flat Top	Mesa	11.8	Vanadium
Fluorspar Mines	Jackson	5.5	Fluorspar
Foster	Mesa	3.0	Vanadium
Gateway-Whitewater	Various	42.695	Vanadium
Genesee Tunnel	Ouray	1.1	Lead-zinc-copper
Graham	San Juan	1.2	Lead-zinc
Grasso	Mesa	6.95	Coal
Great Grizzly Gulch	Clear Creek	0.25	Lead-zinc
Great Western	Park	0.4	Lead-zinc
Gypsum Valley	San Miguel	19.4	Vanadium
Hunter Gulch	Mesa	7.75	Coal
Hyatt Ranch	Larimer	6.64	Beryl
Ida Bell	Summit	4.65	Lead-zinc
Island Mesa	San Miguel	13.0	Vanadium
Johnnie's Mine	Routt	3.0	Coal
Kittimac	San Juan	1.75	Lead-zinc
Lackawanna	San Juan	0.5	Lead-zinc
Lark	San Juan	0.5	Lead-zinc-copper
LaSal Creek	Montrose	1.5	Vanadium
Lead Carbonate	San Juan	1.5	Lead-zinc
Legin	San Miguel	5.2	Vanadium
Lion Creek	Montrose	14.0	Vanadium
Long Park	Montrose	13.0	Vanadium
Lost Day	Ouray	0.6	Lead-zinc
Lucky Strike	Summit	0.36	Lead-zinc
Lumsden Point	Mesa	1.25	Vanadium
Michael Breen	Ouray	2.0	Lead-zinc
Minnesota Creek (U. S. Bureau of Mines drilling)	Gunnison and Delta	7.0	Coal
Monte Cristo	Summit	1.04	Lead-zinc
Moore	Mesa	3.0	Vanadium
New Cashin	Montrose	3.24	Vanadium
North Beaver	Mesa	9.0	Vanadium
Outlaw	Mesa	2.5	Vanadium
Pennsylvania-Shoe Basin	Summit	6.5	Lead-zinc
Mongram Park-Dry Creek	Montrose and San Miguel	26.2	Vanadium
Paonia Farmers	Delta	2.8	Coal
Red Mountain Mines	Ouray	1.4	Lead-zinc-copper
Rifle Creek	Garfield	9.0	Vanadium
Rose and Quail	Summit	2.87	Lead-zinc
Sally Barber	Summit	1.2	Lead-zinc
Silver Star	LaPlata	1.1	Lead-zinc
Spud Patch-Snyder	San Miguel	6.0	Vanadium
Staley	Moffat and Rio Blanco	9.5	Coal
Stone Canon	Garfield and Mesa	9.45	Coal
St. Paul	San Juan	1.2	Lead-zinc-copper
Superior	Summit	1.38	Lead-zinc
Toltec	San Juan	2.0	Lead-zinc
Tenderfoot	Mesa	10.3	Vanadium
Upper John Brown	Mesa	3.0	Vanadium
Urad	Clear Creek	1.5	Molybdenum
Vermiculite	Gunnison	1.0	Vermiculite
West Gateway	Mesa	20.0	Vanadium
Wilfley	Summit	0.88	Lead-zinc

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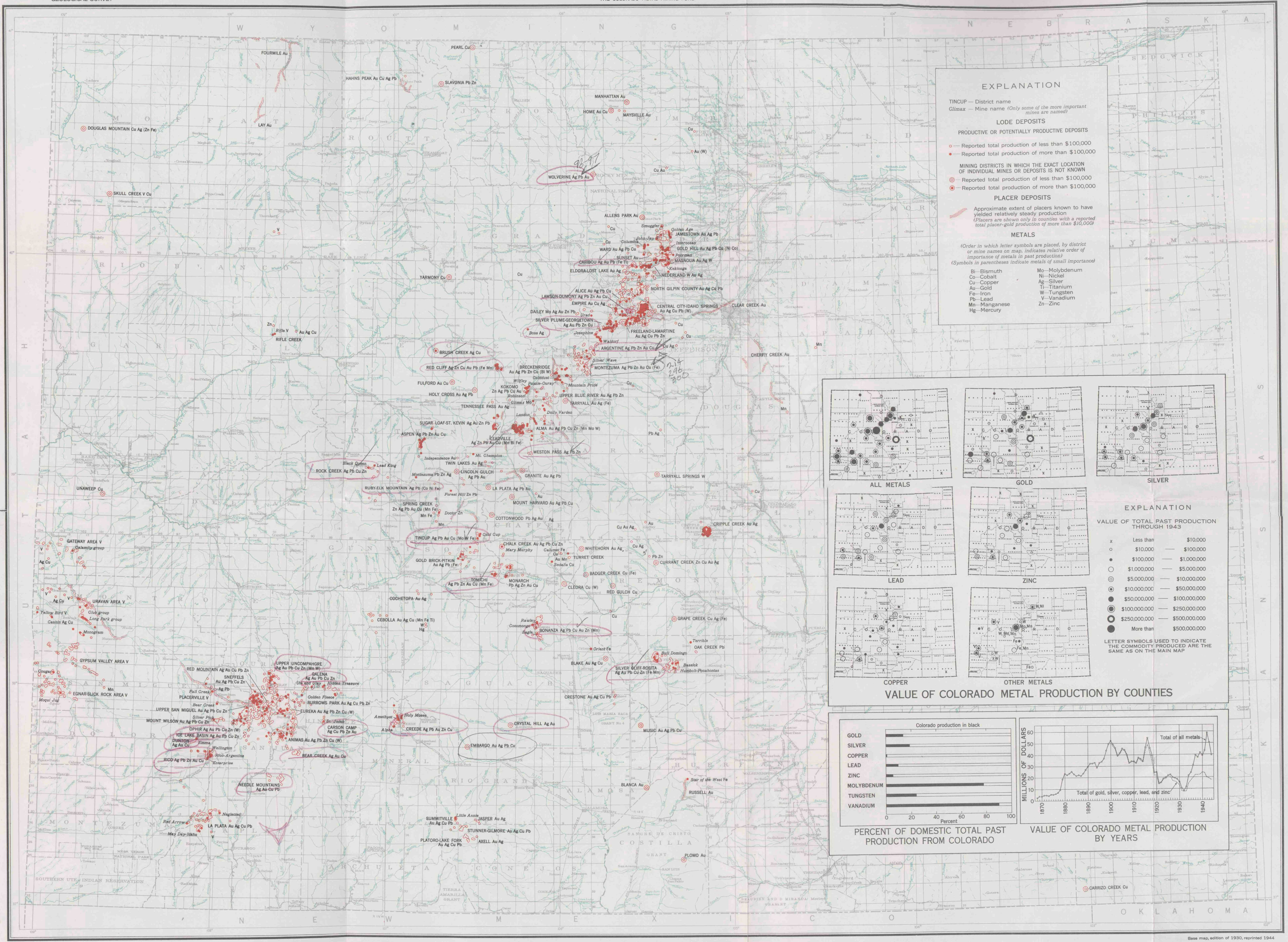
PLATE 4.
Mineral Resources of Colorado.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PREPARED WITH THE COOPERATION OF
THE COLORADO STATE GEOLOGICAL SURVEY BOARD AND
THE COLORADO METAL MINING FUND



SOURCES OF INFORMATION
Published and unpublished data of the U. S. Geological Survey
Published and unpublished data of the U. S. Bureau of Mines
Publications of the Colorado Geological Survey
Publications of the Colorado Scientific Society
Technical and trade journals

MAP SHOWING
METALLIC MINERAL DEPOSITS OF COLORADO

Compiled by R. P. Fischer, Wilbur Burbank, Helen Cannon, W. B. Myers, A. H. Koschmann, and Don Dow

Scale 1:1,000,000

1946

METALLIC MINERAL DEPOSITS OF COLORADO

By R. P. Fischer

Colorado ranks first among the states in the total production of silver, molybdenum, and vanadium; second in gold; third in tungsten; fourth in lead; sixth in zinc; and eighth in copper. It has also produced a relatively small amount of iron, manganese, bismuth, cobalt, nickel, and arsenic ore, and in addition some antimony, bismuth, and cadmium have been recovered at smelters treating Colorado ores. The total production in terms of the value of recovered metals from 1858 through 1944 slightly exceeds $2,150,000,000.[1] The production record and the known and inferred ore reserves seem to indicate a good outlook for continued production at a high rate under favorable economic conditions.

The Map.—The accompanying map is primarily an index map showing the general distribution of the metalliferous deposits of Colorado. It was compiled from reports and maps prepared by the United States Geological Survey and the Colorado Geological Survey and from papers published in the Proceedings of the Colorado Scientific Society and other scientific journals. Production data were compiled partly from these sources but mainly from Mineral Resources and Minerals Yearbook series of the Geological Survey and Bureau of Mines of the United States Department of the Interior, and from the files of the Bureau of Mines. The compilation of a map to show the general relations between ore deposits and the major geologic features in Colorado is believed desirable but, until such a map can be prepared, it is hoped that the issue of this map in its present form will serve a useful purpose.

Productive and potentially productive deposits and mining districts are shown by symbols on the accompanying map. The well known districts are named, and where space permits some of the important mines are identified. Most of the metalliferous deposits in Colorado are complex in the character of the ore, containing varying proportions of gold, silver, copper, lead, and zinc, and some of them containing small quantities of minor metals as well. A few, such as the Climax molybdenum deposit and the tungsten deposits in the Nederland district, are mainly monometallic. Metals produced are indicated by letter symbols arranged in the order of importance of past production; metals produced in relatively small quantities or present in accessory amounts are shown in parentheses.

As far as the map scale permits, each productive and potentially productive lode deposit that could be accurately located from available information is shown individually with a small circle. Mining districts in which the exact locations of the mines or deposits are not known but which have been productive sometime during the period 1905 to 1945, are shown by a larger circle enclosing a small one. A few mines and deposits are not shown on the map because of lack of data on locations, but few if any of these mines are known to have had an appreciably large production. Even so, some of them no doubt have been more productive than some of the mines that are shown.

Within the limits of error resulting from lack of complete recorded production data, changes of mine names, and other omissions in the records, all mines having a production thought to be worth $100,000 or more are shown with a solid circle, and those thought to have a smaller production are shown with an open circle. Likewise, mining districts in which individual mines cannot be located are shown with a solid inner circle if their total production appears to be worth $100,000 or more, and districts with a smaller total production are shown with an open inner circle. In choosing individual deposits to be shown, an attempt was made to select those that have produced ore worth at least $1,000, thus eliminating the numerous prospects that are present in every mining district, except in the few places where large and potentially productive deposits without recorded production are shown. In some places away from the major mining districts prospects have been shown if their exact locations are known, in order to indicate the distribution of mineralization, even though the available data may not fulfill the qualifications noted above.

The total value of production from each county of all metals collectively, the precious and base metals individually, and the other metals (ferrous and minor metals) collectively are shown by insert maps. The yearly total production of all metals from 1868 to 1944 and of gold, silver, copper, lead, and zinc from 1900 to 1944 is shown by a graph. The percent of the total Colorado production to the total domestic production of several metals is shown by a bar chart.

Gravels containing placer gold are widely scattered in Colorado, but only the placer areas known to have yielded relatively steady production in counties with a reported placer-gold production of more than $10,000 are shown on the map.

History, production, and outlook.—A detailed account of the history of mining in Colorado to 1923 is given by Henderson[2] and will be reviewed only briefly here.

The first organized prospecting and mining in Colorado was in 1858 on the placer deposits near the present site of Denver. During the rush of prospectors to the territory in 1859 and 1860, gold placers and some of the lode deposits in the mountainous country extending from Boulder County southwest to Lake County were found, and considerable gold was taken from the placers. Lode mining at many places in this region was under way by the middle and late sixties. Although some of the deposits in the San Juan Mountains region were discovered in the early seventies, the rush to that part of Colorado began in 1874 and soon resulted in active mining. The deposits in the Aspen district, Pitkin County, and those near Red Cliff, Eagle County, were discovered in 1879. Although a few fragments of gold ore were found in the area surrounding the Cripple Creek district, Teller County, as early as 1874, the rich deposits were first discovered in 1891. The presence of molybdenite at Climax, Lake County, was recognized in the late nineties, but significant production did not begin until World War I. Most of the important mining districts in Colorado were discovered and were active before 1900, although it was not until 1900 and later that the tungsten and vanadium deposits became productive.

In most of the Colorado mining districts the lure of gold first attracted the prospector, and many camps were dominantly gold producers in their early history. In some of these camps the interest soon shifted to the rich silver ores, and the period of major silver production was accompanied by or closely followed by a large production of lead. Generally speaking, substantial recovery of zinc did not occur until most mining districts were well past their early stages of development. In many districts the value of the copper produced has been incidental to that of the other metals, but nevertheless it has contributed substantially to the total value of the ore.

The need to recover a high proportion of the total value of the complex ores in Colorado, especially those containing zinc, has inspired many improvements in milling practices. Although the complex ores are difficult to treat. their content in several metals has helped to sustain operations at times when the price of one or two metals was low.

The average yearly value of metals produced in Colorado from 1858 to 1944 is about $25,000,000. Although production dropped below this yearly average for 17 years following World War I, it rose rapidly in the middle thirties, and in 1942, stimulated by war demands for metals, the production exceeded $58,000,000, an all-time high for Colorado. Before 1933 the production of gold, silver, copper, lead, and zinc dominated the production of metals in Colorado, amounting to about 96 percent of the total value. Since 1933 one mine, that at Climax, has contributed a large part of the total value of Colorado metal production, but the values of the precious and base metal production, especially the latter, also increased substantially over the production in the 1918-1933 period. The curtailment of gold mining during World War II has appreciably affected the production curves since 1942.

The diversified character of Colorado ore deposits, the ability of the mining industry to increase production in response to the stimulus of rising metal prices and the National need for metals, and the known and inferred reserves of ore in some of the major mining districts seem to indicate a good outlook for continued production at a high rate under favorable economic conditions.

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[1] Because of Government restrictions, uranium and radium are not included in this appraisal of Colorado metalliferous resources, nor is their distribution in deposits shown on the accompanying map.

[2] Henderson, C. W., Mining in Colorado: U. S. Geol. Survey Prof. Paper 138, 1926.