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R. D. GEORGE, State Geologist

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THE GEOLOGY
OF THE
WARD REGION, BOULDER COUNTY, COLORADO

BY
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LETTER OF TRANSMITTAL

State Geological Survey,
University of Colorado, November 22, 1920.

Governor Oliver H. Shoup, Chairman, and Members of the Advisory Board of the State Geological Survey.

Gentlemen: I have the honor to transmit herewith Bulletin 21 of the Colorado Geological Survey.

Very respectfully,

R. D. George,
State Geologist.

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The Geology of the Ward Region, Boulder County, Colorado

CHAPTER I

INTRODUCTION

PURPOSE OF THE REPORT

The area covered by this report lies north of the "Main Tungsten Area" of Boulder County and west of the "Sugarloaf District," which have been described, respectively, by R. D. George in the first annual report of the Colorado Geological Survey, and in a thesis by R. D. Crawford.

It is planned by Professor George, who is head of the Department of Geology at the University of Colorado, and also State Geologist, to have other areas mapped and described, until eventually it will be possible to make a complete report in monograph or bulletin form on the Geology of Boulder County, Colorado.

FIELD WORK

In 1906 Mr. B. H. Jackson began a survey of this region, but after partially mapping the areal geology of four square miles east of Ward he gave up the work.

In the fall of 1909 the writer started to prepare a topographic map of an area of about nine square miles, that lies mainly west and south of Ward, but which includes the town of Ward and the adjacent mining communities, Frances, Puzzler, Bloomerville and Sunnyside. This map was completed in 1911. In 1913 the topography of this area was mapped by the United States Geological Survey, and it is included in the Longs Peak Quadrangle map published in 1915. The map, west of 105° 30′, as it appears in this report is, however, entirely the work of the writer.

The geologic work was carried along with the topographic mapping during 1910 and 1911, and the areal geology was nearly finished in the spring of 1911. The economic geology could not be satisfactorily worked out during this period because so few mines were unwatered. This report has been delayed for several years on account of the writer's desire to make a thorough study of the underground geology. He hoped that from time to time old mines would be reopened or new ones developed, and he has taken advantage of such conditions whenever they have come to his attention. It has been impossible, however, to make a complete study of the mines of the district, and this report is therefore presented with the understanding that it represents an attempt to cover in detail only the areal geology. The notes on the economic geology are fragmentary and at best are unsatisfactory.

OFFICE AND LABORATORY WORK

The office work has included the preparation of the maps and the report as it is herewith presented. The laboratory work included examination of about 200 thin sections of igneous rocks; the fire assaying of many samples of ore; and the qualitative analysis of a large number of minerals.

HISTORY OF THE REGION

In the early sixties when the mining industry in Colorado was in its infancy the western half of Boulder County was divided into many small mining communities, each of which was a more or less independent governmental unit having local rules and regulations to control mining, prospecting and other affairs of a public nature. These units were called "districts," and most of them were named for the largest, and, in many cases the only settlement in the community. The term "district" persists in the records of mining claims and in other literature at the present time, although its former significance has long since disappeared. It is to be hoped that gradually the use of the names of the various districts will be discontinued, for whatever value such a classification once may have had, it certainly results only in confusion when used now.

The Ward "district" was one of the first to be located, and it has been always one of the very important mining localities of Boulder County.

The region described in this report includes not only the Ward "district," but parts of the Grand Island and Gold Hill districts which adjoin it respectively on the south and east.

It has been exceedingly difficult to get reliable data regarding the production and the early development of the region. The mint reports and other official publications give only incomplete data. It has not been possible to procure complete sampler or smelter returns from the ores produced in the district. Many mines have changed ownership several times and records have been lost. Dates and estimates of production kept in a man's head for forty or fifty years are generally subject to correction when compared with records in black and white. While many of the old settlers in the district have furnished considerable first hand information, and while all available records have been consulted, it must be understood that the following statements present only an approximate outline of the development of the district.

The first gold was discovered in 1861 by Calvin Ward. This discovery was made on the hillside north of Lefthand creek, just east of Indiana gulch, in what is known as the Ward Lode. The following year John Deardorf discovered the Columbia vein, and this discovery led to the establishment of the town of Ward. In 1863 a wagon road was extended up Lefthand creek from Boulder to Ward. The Nelson mine was located about the same time as the Columbia and the Chathem, Gold Queen, Stoughton, Baxter, Columbia No. 5, B. and M. and several others were discovered before 1870. Then came the Colorado, Morning Star, Utica, Modoc, Humboldt, Celestial, Grandview, Dolly Varden and many others. More recently still the Copper Glance, Golden Chest, Ward Rose, White Raven, Lois, Milwaukee, Ruby and dozens of other mines have been developed.

In Hollister's "Mines of Colorado," page 266, the statement is made that the first mill built in the district was put up in Indiana gulch in the autumn of 1861, by Davidson and Breath, and that the mill ran from time to time until 1865, when it was sold. This statement is challenged by others who say that the Niwot mill, which was built in 1865, was the first mill in the district.

The machinery for the Niwot mill, which had 50 stamps, was hauled across the plains from Kansas City in ox carts. The stamps weighed 650 pounds each. Timbers for the construction of the mill were obtained from a saw mill on Lefthand creek, about one-half a mile away. Hollister states (page 268) that the Niwot mill ran about a month before it was burned down. Mr. John Rice of Ward says that the mill burned to the ground on the day the first run was to be made. At any rate the mill burned. It was immediately reconstructed and it ran steadily for many years. Mr. Israel Benson who worked in the mill told the writer that it cleared up $2,500 a day for many months.

Since the days of the old Niwot mill many mills have been built in the hope of perfecting a suitable process for the economical treatment of low grade sulphide ores, and nearly as many processes, as there are mills, have been introduced, but none of them have been entirely successful.

Mining has been carried on more or less spasmodically ever since the first discovery of gold was made. The drop in the price of silver in 1893 had little effect on the production of the district, but litigation, poor management, an unfortunate tendency on the part of a few individuals to promote fake mining companies, and to raise money to develop properties of doubtful value, combined with the inability to successfully treat the low-grade sulphide ores, have kept the district from the development it otherwise would have had. In the United States Mint report for 1898, this reference to Boulder County is found: "A spirit looking to the development of mines for sale rather than for profit in working the same, it is alleged, served somewhat to minimize the county's production. The county is bountifully supplied with new and old process mills. In many instances the erection of mills antedated the discovery of the contiguous mining properties." While this statement may or may not be true of the Ward district, it is significant in that it illustrates certain tendencies which have been of too common occurrence in this county. It is reassuring, however, to note that this old spirit is largely a thing of the past, and that the work now being done is carried on in a legitimate fashion, which argues well for the future development of the Ward district and the adjoining regions.

PREVIOUS SURVEYS

The Hayden survey made topographic maps and geologic reports that covered the area under consideration, but the work of this survey was strictly reconnaissance in nature, and as the development of the region was in its infancy at the time the survey was made no important additions to the geology of the region can be procured from this report.

This area was also covered in a general way by the King survey of the 40th parallel, but only incidental mention is made of this district.

Several individuals have studied certain dikes within the area; and the results of their study have been printed in the *Proceedings of the Colorado Scientific Society*. Reference to these reports will be made in the bibliography and in the discussions of the igneous rocks.

No other attempts have been made, so far as the writer knows, to map or describe in a serious way the general geology of this region.

ACKNOWLEDGMENTS

To Professor R. D. George, who made the work possible, and who has given his advice freely and fully when it has been sought, the writer's sincere thanks and appreciation are extended.

Professor R. D. Crawford has made many valuable suggestions and criticisms pertaining to the microscopic determination of the igneous rocks, and his kindly interest is gratefully acknowledged.

Messrs. Roy M. Butters and Howard H. Barker made fire assays of many samples of gold and silver ore, under the direction of Professor Crawford. Messrs. Donald C. Kemp and Ross L. Heaton made 27 microscopic examinations of rocks of this district under the supervision of Professor Crawford, and their notes have been in part used in the descriptions of the following rocks: Quartz monzonite porphyry, latite porphyry, diorite porphyry, monzonite porphyry and andesite porphyry. To all of these men the writer is deeply indebted.

Many mine owners and operators have been called upon in one way or another for information, or for permission to study the underground workings, and all have responded readily to such requests.

The topography of the eastern two-thirds of the area was taken from the Boulder Quadrangle topographic sheet that was published by the United State Geological Survey in 1904. The culture of this map has been modified by the writer to show the changes that had taken place since that map was made. The rest of the topography of the area included in this report has recently been mapped by the United States Geological Survey, and it has been published as part of the Longs Peak Quadrangle sheet, but the topography of the western third of the region embraced in this report is entirely the work of the writer.

The areal gology of approximately four square miles, including the section in which Burnt Mountain is situated, the two sections east thereof and one west, was mapped by Mr. B. H. Jackson. His map and notes are incorporated in this report.

As is hereby acknowledged, the writer has had considerable assistance and has received valuable advice in the preparation of this report, but he accepts full responsibility for the conclusions expressed herein.

CHAPTER II

GEOGRAPHY AND TOPOGRAPHY

LOCATION

The region here described is situated in the western part of Boulder County. Ward, the most important town, is about 15 miles northwest of Boulder. Other settlements in the area are: Frances, Bloomerville, Puzzler, Sunnyside, Sunset and Copper Rock, all of which, with the exception of Sunnyside were on the Denver, Boulder and Western Railroad.

Ward is 19 miles by wagon road and 27 miles by railroad from Boulder. For many years, during the summer months, a combination passenger and freight train was run from Boulder to Ward. The train service was more or less irregular, but usually there were at least two trains a week, and when there was much mining activity, or when the tourist season resulted in heavy traffic, there were daily trains. During the winter, the train service to Ward was usually suspended on account of light traffic, heavy snows and deep drifts. If there was freight enough to warrant it, however, the road was kept open.

In 1919, the railroad was abandoned and the equipment sold to a wrecking company. As this report is being written the rails are being pulled up. Daily automobile stages now run between Boulder and Ward, and there is irregular automobile service from Boulder to the other mining camps in the district.

Because of its location, near the continental divide, its beautiful and picturesque scenery, its pure water, fine summer climate, and well-stocked trout lakes and streams, the Ward region has gained considerable well-deserved recognition as a summer resort. In this respect its fame has been increased because of the automobile roads that run; one, north from Ward, through Peaceful valley and Allen's Park, to Estes Park; and another from Ward to Glacier Lake, Lakewood, Nederland and Boulder. These roads afford most delightful drives that should be taken by all visitors of this region.

RELIEF AND TOPOGRAPHY

The whole area included in this report is of high relief. The lowest elevation is near Copper Rock on Fourmile creek, where the altitude is 7,400 feet. The highest place in the district is the summit of a hill directly west of Ward, where the altitude above the sea is 10,400 feet. This difference in elevation of 3,000 feet within a distance of six miles indicates the general character of the relief of the entire district.

The canyons of Fourmile and Lefthand creeks are steep-walled and deep. A narrow circle separates them except at the west where the streams head on the steep east facing slopes of Bald Mountain. The northern portion of the district, beyond Spring Gulch and near Gold Lake is the only part of the area that has not been deeply eroded by streams. This region, which is a highland of rather low relief, is part of the old uplifted peneplain that once extended eastward from the continental divide to the crest of the foot-hills which lie at the western border of the great plains. Remnants of this peneplain are found farther south within the area, but they are not nearly so conspicuous as in the vicinity of Gold Lake.

VULCANISM

There has been a great amount of volcanic activity in the district, and Sunset might be considered almost the center of such disturbances. Great dikes and stocks of felsite, latite and monzonite were formed in the gneisses and schists, and these intrusions, because of their great resistance to erosion, form the crests of many ridges or summits of hills that now stand conspicuously above the general level of the surrounding country. Burnt, Bald and Sugarloaf mountains are good examples of such erosion remnants.

GLACIATION

Glaciers were important agents in producing the present topography of the northwest portion of the Ward district. In California Gulch, above the old railroad bridge and in the Duck Lake region there are great moraines, some of which are 50 feet or more high. These moraines unite near the Lois mine and extend westward toward Redrock Lake. Other glacial deposits are irregularly distributed south and west of Ward, but most of them are outside the district under discussion.

All the hills near the west side of the area have been rounded off and the projections on the sides of hills and valleys have been removed by glacial erosion.

DRAINAGE AND WATER SUPPLY

All the larger valleys have been cut to grade with the exception of their heads. The two main creeks, Fourmile and Lefthand, are throughout their lower courses highly overloaded, because very much more material has been carried in from the sides of these valleys by small tributaries than the large streams of lower gradient can carry away. Hundreds of alluvial fans or cones fringe the main streams. In many places the valleys have been filled clear across to depths of not less than 40 or 50 feet with materials brought in by tributary streams.

Fourmile and Lefthand creeks have a strong flow of water during all but the summer months. At this time the flow is much reduced, but the creeks very seldom dry up. Usually there is water enough available for the concentrating mills that may be running.

RESERVOIR AND POWER SITES

There are several good power sites within or west of the area. One good natural site is on Fourmile creek, between Sunset and Sunnyside. At present there are no hydroelectric plants in this region.

LAKES

Gold Lake is the only lake in the whole district. The basin is largely, if not entirely artificial, but it is situated in an exceptionally favorable natural location. The lake is used as a reservoir to store water for irrigation purposes. Some of the water from South St. Vrain creek is diverted to Gold Lake, by the Lefthand ditch. Water released from the lake flows into Lefthand creek and is taken out by canals near the plains.

CLIMATE

The situation of this region, on the east slope of the continental divide, at an average elevation of about 8,500 feet insures cool summers and relatively cold winters.

The Weather Bureau records do not give complete data regarding the temperature and precipitation, winds, etc., of the region, but a volunteer station at Frances furnishes fairly typical data, and a summary of the temperature and precipitation records from this station for 1917 is given here.

Elevation, 9,300 feet. Length of temperature record, 13 years. Annual mean temperature, 38°F. Highest temperature, 79°F. June 29, and on subsequent dates. Lowest temperature, —15° Jan. 16.

Precipitation, length of record, 12 years. Total precipitation for 1917, 23.38 inches, which was 0.8 inches below normal. Greatest monthly precipitation 5.06 inches in May. Least monthly precipitation, 0.39 inches in June. Total amount of snowfall, 241.3

inches. Number of rainy days, 147. Number of clear days, 102. Number of partly cloudy days, 217.

Frances is near the northwest corner of the area and considerably higher than the average elevation of the region. The precipitation decreases and the temperature increases rapidly with decreased altitude and distance east. An idea of these changes can be obtained by comparing part of the summary given above with one taken from the records of the Boulder station for the same year, 1917.

Boulder elevation, 5,347. Length of temperature record 22 years. Annual mean temperature, 51°F. Highest temperature, 99°, June 29. Lowest temperature, –11°, Jan. 22. Total precipitation for the year 13.99, which is 4.15 inches less than normal. Total snowfall, 75.0 inches. Number of rainy days, 57. Number of clear days, 173. Number of partly cloudy days, 104.

The western side of the area has climatic conditions, indicated by the summary of the Frances records, while the climate of the eastern part of the region is intermediate between that of Frances and Boulder. The summer climate is delightful. It is warm in the sun during the day, but there is almost always a breeze, and it is always cool at night. In the winter, the snowfall is heavy, and there are strong winds which are particularly bad during the fall and early winter.

The altitude is too high and the nights are too cool for extensive agriculture, even if the topography and soil were favorable, but garden vegetables and grasses grow very well.

SOIL

The soil over the greater part of the area is thin and lacks fertility, although grasses and forests grow fairly extensively on most of the north and east slopes.

On the moraines, in some valley bottoms, and where the monzonites and latites have been thoroughly disintegrated, the soil is much richer than elsewhere and it seems to be of a very good quality.

In many places, rock in place comes clear to the surface of the ground, and there is neither soil nor mantle rock present.

VEGETATION AND TIMBER

The vegetation over much of the region, as is indicated by the preceding paragraphs, is scanty. Where the slopes are sufficiently gentle to allow the accumulation of soil, grasses grow well, and such slopes are grazed by cattle or sheep.

Good timber is scarce. There is considerable between Sunset and Sunnyside, and quite a good deal of pine is scattered over some of the higher slopes, but there is not enough to supply the demand in case of extensive mining operations. There is not enough to make large scale lumbering worth while, although there is sufficient timber to supply the present local demand.

Some rather large areas should be re-forested, in order to prevent, or at least reduce, the dangers of soil removal in times of flood. Most of the timber on the ground now is pine, although spruce and aspen are of common occurrence.

INDUSTRIES

Mining and grazing are the chief industries.

MINING

The mining will be discussed more in detail later on, but it should be stated that ever since the first prospectors entered the district, mining has been the most important industry. It is responsible for the building of the Denver, Boulder and Western railroad, for the location of the town of Ward, and for most of the cultural development of the area. At one time when the production of the region immediately about Ward was at its height, more than 2,100 people got their mail at the Ward post office, and other settlements and towns were at one time or another very prosperous. At present the mining industry is at low ebb. Most of the best ground has been worked out down through the zone of secondary enrichment. The ore now available, while large in amount, is of low grade, and it offers many obstacles to successful economical treatment. When an efficient, economical method for treating the low-grade sulphide ores has been devised, it is safe to say that mining and milling will again come into their own, in this region.

GRAZING

Cattle, sheep and horses graze in this region during the summer, and horses run out all winter long in the vicinity of Gold Lake, where the grass is heavy and where there is reasonably good protection from the cold winds.

The grass seems to be exceptionally good for sheep and cattle, and both do splendidly on the summer range. Since nearly all of the region is within the boundaries of the Colorado National Forest Reserve, the number of animals allowed to graze is limited, and the preservation of the grasses on the range is thus assured.

CHAPTER III

GENERAL GEOLOGY

OUTLINE OF THE AREAL GEOLOGY

All of the rocks of this region, except the alluvial and glacial deposits, are either igneous or metamorphic. There are no unmetamorphosed sediments nearer than the foothills formations that lie several miles to the east.

Pre-Cambrian schists, gneisses, granites and quartz diorites constitute about two-thirds of the out-cropping rocks of the area. Small batholiths, stocks and dikes of acidic, and intermediate Tertiary (?) intrusives cover most of the rest of the area. There are a few small intrusions of basic rocks.

ALLUVIUM

Nearly everywhere along the creeks there are small deposits of alluvium. These deposits are increasing in amount at present, because of the inability of the larger streams to carry away the material that is brought in by small tributaries, or carried in by slides, slope wash, etc. Most of the debris left along the stream beds is very coarse.

In the heads of some of the valleys there are patches of alluvium, large enough, and rich enough, to be valuable for agriculture. These are shown on the geologic map by the symbol Qal.

MORAINES

In the northwest corner of the area there are large glacial deposits. The glaciers came from the west and brought great amounts of debris of all sizes from large boulders to fine rock flour. The deposits are left in well-developed lateral moraines which are found near Duck Lake and in California Gulch southwest of Ward; and in ground moraines of irregular form and surface relief that occur west of Ward.

The moraines are typical, both as to form and composition, but, as has happened in most of the mountainous mining regions of Colorado, their origin has not been recognized by the prospector, and in the Ward region there has been a good deal of useless prospecting in the glacial debris. Claims have been located, shafts sunk and tunnels driven because of the finding of indications of mineralization in the moraines. Of course, the mineralized boulders may have been carried several miles by glaciers.

Some perfectly legitimate prospecting may have been done in the morains if outcropping veins have been followed up to the edges of the glacial deposits, but there is little evidence that this has happened in the region near Ward. Most of the prospect holes, so far, located in the moraines have been of the "hit or miss" variety and it is probably unnecessary to say that so far they have without exception "missed" the veins.

SCHISTS

The highly metamorphosed gneisses and schists have not been mapped separately in the Ward district. To do so would require a large amount of detailed work that would be out of harmony with the purpose of the report. Intense folding and crumpling have made the relationships between the two groups most complex, and in many places it is impossible to determine where one leaves off and the other begins.

Structure.—The structure of the gneiss and schist series is complicated, and no single group of measurements can be accepted as of average value in determining the dip and strike of the schistose layers. In general the dips are high, ranging from 40° to 63°, with 45° as perhaps the nearest approach to an average reading. The direction of dip is generally northeast.

GRANITE AND QUARTZ DIORITE GNEISS

Closely associated with the schists are many masses of granite, and quartz diorite gneiss. The rocks exhibit all stages of metamorphism from the slightly metamorphosed condition to completely banded and highly crumpled gneisses. In some cases the degrees of metamorphism are regarded as indications of the relative ages of the rocks, the more highly metamorphosed ones being, supposedly, the older.

Since the granites and quartz diorites occur, usually, in masses of small extent and since, in many cases, it is impossible to entirely differentiate them from the older schists, they have been mapped with the pre-Cambrian metamorphics, although they may be, in part, of more recent age.

GRANITES

In the central and northern parts of the Ward district there are granites which are possibly much younger than the rocks just described. These granites are comparatively little metamorphosed. But it is not unusual to find small masses of gneiss or schist enclosed in the granite, as if caught up when the granite was intruded into the older rocks.

The borders of the granite areas are not as distinct, in all cases, as the boundaries on the map might lead one to believe. In many places the exact contact is indistinct and irregular and the boundary lines are, therefore, more or less arbitrarily drawn.

PEGMATITE

Pegmatite dikes are found scattered all over the areas occupied by the metamorphic rocks and the granite and quartz diorites. That they are of various ages, some very old, is shown by the variable amount of alteration in dikes of different regions. In the gneiss and schist areas some of the dikes have been broken apart, and moulded into elongated lens-shaped masses by the forces that altered the country rocks. Other dikes in the same areas show little or no evidence of metamorphism.

Most of the dikes are small, with widths varying in different dikes from a few inches to two or three feet, and with lengths of from a few feet to several hundred yards. Since most of them are so small and unimportant they have not been shown on the geologic map.

TERTIARY (?) INTRUSIONS

There are a great many Tertiary intrusions in the Ward district, and they occupy in the aggregate a rather large area. One monzonite porphyry batholith has an area of more than two square miles. Another trachyte intrusion has a surface exposure of more than one square mile. These with ten other smaller intrusions have a total combined area of about seven square miles. In addition to these, there are more than 130 dikes which vary greatly in width and length.

All of the larger intrusions, in whatever form they may be, are important factors in the development of the topography of the region. Nearly every prominent peak or sharp ridge is made up of intrusive rock which is more resistant to erosion than the surrounding country rock. Burnt and Bald mountains, and Sugarloaf Mountain that lies just east of Bald Mountain, although outside of the area covered by this report, are good examples of the effects of the intrusions on the topography.

Composition.—With the exception of a small number of basic dikes, the intrusives of this region represent a very complex acidic and intermediate series of rocks. In several instances there are well-represented transitions from the rocks near the center of a small batholith outward to the border. A full study of these rocks would be a very interesting piece of work for a petrographer, but it would require several hundred thin sections and a very large amount of time. As the work now stands more than 200 thin sections were examined under the microscope and many interesting results were obtained, but the petrographic work could have been greatly enlarged upon if it had seemed desirable to do so.

The preponderance of acidic and intermediate rocks over the basic intrusions is very noticeable. The only representatives of the latter are two small masses of olivine basalt and five small dikes of diabase.

Age.—So far as the field evidence goes there is no way of determining the general age of the intrusions. They are referred, however, to the Tertiary period, because this was the time when the great volcanic disturbances were most extensive in the Front Range region.[1]

[1]Cross, W., U. S. Geol. Survey Monograph 27, p. 312, 1896. Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), pp. 10 and 13, 1915.

CHAPTER IV

GENERAL GEOLOGY—Continued

PRE-CAMBRIAN GNEISS, SCHIST AND GRANITE

THE IDAHO SPRINGS FORMATION

There are four important varieties of schist in the Ward district; namely, garnetiferous quartz-mica schist, sillimanite schist, quartz-mica schist and hornblende schist. All probably are phases of the Idaho Springs formation.[1]

Name.—This term was first used by Ball to designate "a series of interbedded metamorphic rocks, presumably of sedimentary origin, which are typically exposed in the vicinity of Idaho Springs," Colorado. The same name has been used by Bastin[2] and Hill in describing rocks of the same characteristics that occur in parts of Gilpin, Clear Creek and Boulder counties.

Age.—The Idaho Springs formation is believed to be of pre-Cambrian age, and its highly metamorphosed condition led Bastin[3] to regard it "as much older than the slightly metamorphosed pre-Cambrian quartzites of certain parts of the (Front) range, which have been provisionally classed by Van Hise[4] and others as Algonkian.

Extent.—This formation covers approximately the south half and part of the east portion of the area of the Ward district. It is not entirely continuous but is nearly so. It undoubtedly extends all the way along from Ward to Idaho Springs, east of the crest of the Front Range. The width of the formation is very variable, in the Ward district it ranges from less than 1 to more than 6 miles.

GARNETIFEROUS QUARTZ-MICA SCHIST

This is the most common schist in the region. It occurs extensively along the south side of the district, and is somewhat less abundant in the other parts of the metamorphic area.

Composition.—Quartz, biotite and garnet are the important constituent minerals. The garnets range in diameter from 2 mm. to 10 mm., and they make up very varying amounts of the whole rock. Most of them are badly fractured, and in many cases they have been changed by movements into more or less lens-shaped aggregates. Quartz makes up roughly from one-third to one-half of the whole rock. It is much more abundant in the schists of the

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[1]Ball, S. H., General geology [of the Georgetown quadrangle, Colo.]: U. S. Geol. Survey Prof. Paper 63, p. 37, 1908.

[2]Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colorado: U. S. Geol. Survey, Prof. Paper 94, p. 26, 1917.

[3]Bastin, E. S., and Hill, J. M., op. cit., p. 30.

[4]Van Hise, C. R., and Leith, C. K., Pre-Cambrian Geology of North America: U. S. Geol. Survey Bull. 360, p. 827, 1909.

northeastern part of the district than in those of the southwest part. It is colorless, or white because of fracturing. Biotite is next in importance to the quartz. Where there are few or no garnets present the biotite is likely to be fresh, but where it is associated with garnets, it is usually altered. Chlorite and iron oxides are the common alteration products. Sillimanite appears, in many cases, as small fibrous looking crystals, which weather white. These crystals add to the readiness with which the rock cleaves. Orthoclase or microcline are subordinate constituents.

Associations.—This schist grades so gradually into gneissoid granite that it is in many places quite impossible to tell where one rock ends and the other begins.

It is also closely associated with the other schists hereafter described.

SILLIMANITE SCHIST

The chief differences between this schist and the one just described are in the larger amounts of sillimanite, and the smallei amounts of quartz present, in the sillimanite schist.

Composition.—Muscovite is an important constituent of the sillimanite schist, and orthoclase is more abundant than in the garnetiferous quartz-mica schist. Sillimanite, while probably subordinate in amount to the quartz, is by far the most conspicuous mineral in the rock. It occurs as radiating feathery appearing crystals or fibrous grains. Its color is grayish brown when fresh, but grayish white when weathered, and since most of the surface rocks are weathered the effect of the sillimanite is to give the schist, in which it occurs, a white or gray appearance. The sillimanite seems to have been formed, largely, along shearing planes in the schist. Garnet may or may not be present, but if present, it is always in a subordinate amount. Biotite occurs in small amounts.

Occurrence.—Sillimanite schist is found in the Idaho Springs formation, chiefly south and east of Sunset and near Sunnyside.

QUARTZ-MICA SCHIST

In several local areas, but particularly in the northeastern part of the district, there is a quartz-mica schist which is markedly different from all the other schists in the area.

Composition.—It is a fine even grained rock, made up of flakes of biotite and grains of quartz, each mineral grain being about 2 mm. in diameter.

Structure.—Foliation is not so pronounced in this rock as in the other schists, although the flat surfaces of the biotite flakes are in a roughly parallel position. The mica grains are considerably mixed with the quartz, and the result is a peculiar ''pepper and salt'' effect in the color and general appearance of the rock.

Occurrence.—This rock is not of wide spread occurrence, and it is only regarded as a peculiar and interesting, but relatively unimportant member of the metamorphic complex.

HORNBLENDE SCHIST

This is the least common of all the schists in the Ward district, but it is found in several localities, and is particularly noticeable near Gold Lake, south of the Morning Star mine in Spring Gulch, and in the Ruby mine at Sunnyside. It is very heavy and tough. The color is black or dark gray.

Composition.—It is composed almost entirely of hornblende with only very small amounts of feldspar and quartz. South of the Morning Star mine, the schist has more quartz, and is coarser than are most of the other rocks that have been included under the same name. When weathered the color usually becomes green.

Structure.—The hornblende occurs in stout interlocking prismatic grains, and as a result of this occurrence the schist is rarely well foliated. It does not break much more readily in one direction than in another.

Origin.—It is possible that this schist is of igneous, rather than sedimentary origin, and if so, it does not properly belong with the Idaho Springs formation. The foliation planes of the hornblende schist do not correspond in attitude with those of the other schists. Furthermore, much of the hornblende schist seems to occur in small masses in the granite. It is possible that the rock represents small ancient intrusions of hornblende diorite or gabbro that have since their formation been much metamorphosed.

GRANITIC GNEISS

Occurrence.—Granite gneiss or gneissoid granite, as it might equally well be called, is the most abundant rock in the Ward district. It occurs in practically every part of the area where schists are found, and it is also found, although much less abundantly, in the areas that have been mapped as granite. In neither case has it been differentiated from the other rocks on the map.

In the schist areas the gneiss is likely to grade almost insensibly into schist. In the granite areas the boundaries are in most places fairly distinct.

With the possible exception of hornblende schist, the gneiss is unquestionably younger than the schists with which it associates. It is certainly older than the granites, and is probably about the same age as the quartz diorite gneiss which will be described later.

Structure.—There is a great difference in the development of the gneissic structure in the different rocks of the area. When the rocks are fine and even textured, and when they contain biotite, the banding is usually uniform and well developed. In the gneisses which have very small amounts of biotite the gneissic structure is indistinct. In those rocks that have a very large amount of biotite, that mineral is likely to be found segregated more or less completely into lenses which interlock rather loosely with lenses of quartz and feldspar. These lenses average about an inch in thickness. They are two or three times as long and wide as they are thick. This peculiar segregated structure of the minerals leads to a rather mottled or blotched appearance of the rock.

Composition.—The gneissoid granites contain about 50 per cent of feldspar, mainly microcline, 25 per cent of quartz and about the same amount of biotite. Minor minerals are sillimanite, which occurs in considerable quantities in some of the rocks, magnetite and acid plagioclase. Microcline, the most abundant feldspar, is usually white or flesh colored, and it occurs in grains as much as 20 millimeters in length. More often, however, the grains are much smaller.

QUARTZ DIORITE GNEISS

Occurrence.—This rock is believed to be only a phase of metamorphosed granite, and the occurrence is essentially the same as that of the granite gneiss. All of the quartz diorite gneiss outcrops, however, have a small surface area. The most typical example of this rock is found near the Giles mill at the junction of Peck and Spring gulches.

Composition.—The chief differences between the quartz diorite gneiss and the granite gneiss are in the composition of the plagioclase feldspars and in the amount of quartz present in the two rocks. The typical quartz diorite gneiss has much less quartz and much more plagioclase, but there are all gradations from one rock to the other.

Biotite makes up fully 25 per cent of all the quartz diorites. It may occur in even larger amounts. Microcline and an intermediate sodic-calcic feldspar, probably labradorite, are present in varying amounts, but together they constitute about 50 per cent of the rock. Quartz, which is usually glassy, is the next most important mineral. Sillimanite and magnetite may occur in small amounts. The latter is found only in microscopic grains, and it is probably an alteration product from biotite.

When weathered the feldspars kaolinize, the biotite disintegrates, forming chlorite, iron oxides and epidote, and the rock soon becomes streaked with iron rust.

Structure and Color.—Most of the quartz diorite gneiss is rather perfectly and uniformly banded, due to the presence of so much biotite and to the even and rather fine texture of the rock. The prevailing color of the rock is dark gray. Most of the biotite is fresh, and its luster is bright. The feldspars are predominantly blue-gray when fresh and white when weathered. The whole rock, because of its color and structure, presents a most striking and attractive appearance.

GRANITE

Occurrence.—Except possibly for the Tertiary intrusions the granites are the most widespread and important rocks in the northern half of the Ward region. They occur mainly in stocks and bosses throughout the area, the smaller intrusions being in the southern half and the larger ones farther north.

Varieties.—There are four more or less easily recognized varieties of granite in this region. The first is a medium to coarse textured somewhat porphyritic biotite granite, which probably corresponds to the Silver Plume granite[1] described by Ball from the Georgetown Quadrangle.

The second variety is a much finer textured rock rich in biotite. The third is a very coarse grained or porphyritic massive granite composed chiefly of quartz and feldspar, and the fourth is pegmatite, which occurs in dozens of dikes and veins cutting all rocks older than the Tertiary intrusives.

Age.—As is stated in the preceding chapter, the age of the granites is, for lack of better evidence, regarded as pre-Cambrian. In general they appear to be much younger than the gneisses and schists, but in some cases it is difficult to separate the granites from the gneisses. The varying degrees of metamorphism of these granites that are on the borderline, suggest that they are of more than one age, but there is no other evidence available on this point.

COARSE-TEXTURED BIOTITE GRANITE

This is by far the most common of the granites mentioned above. It occurs in practically all of the granite areas and is the typical massive granite of the region.

Description.—The color is usually light gray or pale pink, the latter color predominating. Porphyritic texture is very common. The phenocrysts are chiefly microcline.

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[1]Spurr, J. E., Garrey, G. H., and Ball, S. H., Geology of the Georgetown Quadrangle, Colo., U. S. Geol. Survey Prof. Paper 63, pp. 58-60, 1908.

Composition.—The minerals present consist chiefly of microcline, orthoclase, biotite, considerable quartz and a small amount of acid plagioclase. Accessory minerals are occasional grains of hornblende and apatite in very small amounts. Pyrite is of very common occurrence near quartz veins of which there are many cutting the granite.

The rock is fine textured with most of the grains averaging less than 3 mm. in diameter. However, some of the feldspars are 10 or 15 mm. in length.

The color is usually dark gray. The biotite is rather evenly distributed through the rock, and it presents a distinct granular appearance. The rock is seldom found fresh, but is streaked or stained with iron due to rapid weathering.

FINE GRAINED BIOTITE GRANITE

This granite is much less important, and more restricted in occurrence than the one just described. It occurs almost entirely in small masses in the schist and gneiss areas, and probably represents small intrusions in those rocks. It is in some places, but not everywhere, gneissoid.

Composition.—Biotite constitutes about one-tenth of the rock. Quartz occurs in somewhat larger amounts, and microcline is the most abundant mineral of all. The usual accessory minerals occur in small amounts.

PORPHYRITIC GRANITE

This rock, which occurs most extensively in the northern part of the area, between Lefthand creek and Spring Gulch and north of Peck Gulch is quite likely a phase of the coarse biotite granite described above. It is composed almost entirely of quartz and microcline, both of which occur in rather large grains. The microcline grains are in many cases an inch or more long and give the rock a distinctly porphyritic appearance.

The color of the microcline is white or pale pink. The quartz is colorless, the general color of the rock is a light pink or gray.

Composition.—Iron oxides, both hematite and limonite, are found sparingly between the grains of quartz and feldspar. Biotite, hornblende and muscovite are almost never found.

PEGMATITE

There are a great many pegmatite dikes and veins that cut the gneiss, schist and granite in all parts of the area. The dikes vary greatly in length, width and importance. The largest one is the great Livingston dike which is in the northeast corner of the area. It is between 200 and 300 feet in width.

The larger dikes are, without exception, very coarse grained. The small ones vary in texture from an aplite to a medium textured pegmatite. Some have local masses of graphic granite.

Composition.—Microcline, orthoclase, quartz, muscovite and biotite are the most important minerals and are named in the order of their importance. Muscovite does not occur anywhere within the area in large enough amounts to be of commercial value. Muscovite and biotite do not occur in the same dikes. In many cases massive quartz and feldspar are the only important minerals present.

On the whole these dikes are remarkably free from the accessory minerals that so often occur in pegmatite. Pyrite and fluorite are the only such minerals that are found in any considerable quantity. The former is of widespread occurrence. The latter occurs in small amounts in two dikes east of Ward.

Age.—Although many of the dikes cut the metamorphic rocks they show little or no evidence of metamorphism. It is probable, however, that some of the small gneissoid granites in the schist and gneiss areas, particularly those gneissoid granites that are poor in mica, were once dikes of pegmatite which have been so thoroughly metamorphosed as to nearly destroy their identity. The borders of such masses are so mingled with the country rock that their exact limits are in doubt, but in general these masses are lens shaped, or roughly rounded.

Effect on Topography.—The larger dikes of pegmatite form the backbones of ridges, in which they occur, and they are always important factors in the development of the topography.

Many of the larger dikes have great amounts of massive quartz in the center. This is scattered over the ground as the dike weathers, and because of resistance to chemical weathering it soon forms a protective covering over the dike and its immediate surroundings. In course of time the area so covered is left in the form of a ridge or hill by the agents that wear down the land surface.

Origin.—There are believed to be two modes of origin of the pegmatite. Some of the large dikes are evidently intrusions, and very old ones, for they are cut by Tertiary intrusions. The small veins and dikes, which are in most cases very irregular in width and length, are the result of solution and recrystallization along ancient joints and in fracture planes of the country rock. These are much more commonly found in the granite than in the gneiss and schist areas.

CHAPTER V

GENERAL GEOLOGY—Continued

TERTIARY (?) IGNEOUS ROCKS

GENERAL RELATIONS AND OCCURRENCE

There are more than 130 separate intrusions within a surface area of 22 square miles in the Ward region. These are divided into 14 varieties of rocks, most of which are acidic or intermediate in composition and aphanitic or porphyritic in texture.

Forms.—The forms of the intrusions are: Dikes which vary greatly in width and which range from a few feet to more than two miles in length, and stocks which are very irregular in outline and cover areas that differ in size from a few square yards up to more than two square miles.

The largest stock is monzonite porphyry. It extends from Fourmile creek between Sunset and Copper Rock northeast and north to Lefthand creek and on to include Burnt Mountain, which lies north of Spring Gulch. This stock is very irregular in outline as is indicated by the geologic map. Most of the others are more nearly circular in form.

Origin.—The forms of the intrusions suggest that they spring from a common magma. That this magma is monzonitic in composition is indicated by the following facts: First, there are no dikes cutting any of the stocks and practically none that cut other dikes. Second, nearly all of the stocks are monzonite porphyry, and where they occur there are few monzonite dikes near, but many others of slightly different composition radiate out from the regions of the stocks indicating magmatic differentiation and intrusion. Third, in the region west of the monzonite stocks there are many quartz monzonite dikes. It seems entirely probable, therefore, that at least the monzonite, latite, diorite, andesite and dacite intrusions, as well as the few basalts and diabases may have sprung from a common magma, and since some of the felsites are dacitic and latitic in composition, and others which are true rhyolites are in direct contact with monzonite stocks, it is probable that they too may have come, through magmatic differentiation, from the monzonitic magma.

Age.—As is stated in Chapter III, these rocks are regarded as of Tertiary age. The references given at the end of the third chapter may be supplemented by the following to indicate the age of similar rocks farther south[1] and east.[2]

Fenneman noted the fact that intrusions cut Pennsylvanian and Upper Cretaceous sediments near Boulder, and it is now known that some of these intrusions are almost identical with those in the Ward region.

Cross[3] has stated that the andesitic dikes from volcanic rocks of the Front Range first appear in the Denver formation, which is of early Tertiary age. The volcanic rocks of the Ward region are similar in composition, and it is believed of the same age as those referred to by Cross west of Denver. Hence, they are probably of early Tertiary age.

Descriptions.—The following descriptions will give the main facts concerning the composition, texture and occurrence of the Tertiary (?) igneous rocks of the region. Detailed exhaustive microscopic descriptions have with one exception been avoided.

The general order of the descriptions is based on the percentage of silica in the rocks. It is theoretical only, however, and depends entirely on microscopic determinations, for no chemical analyses have been made.

FELSITE

Name.—The term felsite is used to include a large number of light colored fine-grained or partly glassy rocks, which consist chiefly of potash feldspar and quartz, with small amounts of biotite or hornblende.

Occurrence.—Twenty-six dikes have been mapped as felsite. They are found chiefly in and near Ward and on the east side of the area.

One felsite dike is a mile or more long. Most of them are only a few hundred feet long and less than 100 feet wide.

Composition and Color.—Most of the rocks are nearly white when fresh. After weathering the colors are gray, greenish gray and white. Dendrites and concentric rings of brown iron oxides are of common occurrence in the weathered rock. Kaolin is an important end product in the weathering.

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[1] Bastin, E. S., and Hill, James M., Economic Geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colorado. U. S. Geol. Survey Prof. Paper 94, 1919.

[2] Fenneman, N. M. Geology of the Boulder District, Colorado: U. S. Geol. Survey Bull. 265, pp. 35-40, 1905.

[3] Cross, Whitman, Geology of the Denver Basin in Colo.; U. S. Geol. Survey Mon 27, pp. 34-209, 1896.

Often a platy parting is found in the rock due probably to peculiarities in cooling.

The important minerals are: Orthoclase and microcline, a good deal of quartz and small amounts of biotite or hornblende. Plagioclase feldspar is found in some of the specimens and the felsites, grade, therefore, into dacites and quartz latites. Pyrite and iron oxides occur in varying amounts. Many important ore deposits occur on the borders of felsite dikes.

Texture.—Most of the felsites are very dense and fine grained. In many specimens there is much glass, which indicates very rapid cooling. Usually those of the whitest color are the finest grained, while those that have greenish gray colors are coarser.

Phenocrysts of biotite are quite common. Occasional quartz crystals are found. Orthoclase also occurs as phenocrysts in some of the dikes. Muscovite is found in distinguishable grains in some cases. Few of the phenocrysts are large and none of the felsites is extremely porphyritic. They are to be classed, therefore, as partially glassy and very fine grained, or as medium grained aphanitic rocks with occasional small phenocrysts.

QUARTZ MONZONITE PORPHYRY

Name.—The name quartz monzonite porphyry is here applied to a large number of rocks which are composed of about equal amounts of orthoclase and plagioclase, a smaller amount of quartz, either biotite or hornblende and small amounts of accessory, or secondary minerals, and which have phenocrysts occupying at least as large space as the groundmass.

Occurrence.—There are five prominent types or varieties of this rock, four of which are found near important mines. It has seemed best to give to each variety the name of the mine or region where it is typically exposed and to describe each separately.

The following varieties will, therefore, be described in order:

Modoc quartz monzonite porphyry.

Utica quartz monzonite porphyry.

Brainerd quartz monzonite porphyry.

White Raven quartz monzonite porphyry.

Mt. Alto quartz monzonite porphyry.

MODOC QUARTZ MONZONITE PORPHYRY

Occurrence.—This rock occurs in a single dike, which is found in the Modoc mine about half a mile due north of Ward. The dike extends east for about a mile. It is found just north of the Telegraph mine buildings and along the north side of Spring Gulch. The dike varies from 20 to nearly 100 feet in width. It does not make a prominent ridge, but weathers, in most places, as fast as the country rock.

Texture.—The texture of this rock is even and fine grained with many white feldspar and greenish black hornblende phenocrysts. A few phenocrysts of quartz are also present. The feldspar crystals are, as a rule, not more than 4 millimeters long and half as wide. The most common size is about 2 millimeters in diameter. Hornblende grains occur up to 5 millimeters in length, but most of them are not half so long, and they are very narrow.

Color.—Fresh specimens are hard to get. When weathered the color is a greenish gray, due to the alteration of the ferromagnesian minerals. The white feldspars kaolinize and turn slightly yellow. Green or yellowish green epidote also appears. The effects of weathering are to give the rock a greenish gray tone and also to emphasize its granular texture.

Composition.—A study of thin sections gives the following mineral constituents: Orthoclase and albite, in about equal amounts; biotite, quartz, hornblende, epidote, zoisite, sericite and kaolin. The last four named are secondary minerals, which are alteration products of first four, except quartz. Apatite and magnetite also occur as accessory minerals.

The feldspars occur both as phenocrysts and in the groundmass. In most of the specimens studied the phenocrysts were so kaolinized that their outlines were indistinct. Quartz makes up about one-tenth of the groundmass. It rarely occurs in phenocrysts. Biotite and hornblende have been much altered and little of this is left. Apatite is quite plentiful. Magnetite is found in small amounts in both euhedral and subhedral grains. Epidote and zoisite occur in medium sized subhedrons, and as jagged shreds in the groundmass. Sericite occurs in thin plates on some of the feldspar phenocrysts.

UTICA QUARTZ MONZONITE PORPHYRY

Occurrence.—There is also only one dike of this rock. It extends for about half a mile southeasterly from the Utica mine, and is 30 or 40 feet wide.

Texture.—At first glance this rock appears to be of fine, even grained texture. The phenocrysts are small and harmonize so well with the color of the groundmass that they are not at all conspicuous.

Color.—The color of fresh specimens is gray. When weathered it is a rusty or mottled gray. There is much fresh biotite present, which, with the white feldspar and gray groundmass gives a "pepper and salt" appearance to the rock. The biotite grains are particularly prominent in weathered specimens.

Composition.—In hand specimens, biotite and orthoclase are the only minerals that can be identified. Under the microscope orthoclase, plagioclase, biotite and quartz are the principal minerals. The first two occur in nearly equal amounts. Quartz is found sparingly as small phenocrysts and abundantly in the groundmass. An occasional grain of hornblende is seen. The feldspars are much kaolinized. Magnetite occurs as small interstitial grains.

BRAINERD QUARTZ MONZONITE PORPHYRY

Occurrence.—There are two large dikes of this rock on the north side of the valley near the mouth of the Brainerd tunnel which is on Lefthand Creek about a mile east of Ward. Another dike occurs farther north in Tuscarara Gulch.

Texture.—The texture is rather coarsely granular. Biotite, hornblende and orthoclase can be distinguished in the hand specimen. Feldspar crystals up to 5 or 6 millimeters in diameter occur in abundance and give the rock a somewhat porphyritic appearance. Biotite crystals in perfect hexagonal form are plentiful.

Color.—This rock has a very attractive soft gray color, which in some cases has a slightly pink tone, due to the large number of orthoclase phenocrysts. The general appearance is much like that of a very fine, even grained quartz poor light gray granite. When weathered the color is brownish gray.

Composition.—In the hand specimen, feldspars often more or less kaolinized, bright biotite crystals and fine needle-like grains of hornblende are easily recognized.

In thin sections, orthoclase, plagioclase, quartz, hornblende, biotite, apatite and iron ore are seen. Plagioclase with low extinction angles is rather more abundant than orthoclase. Biotite occurs in larger amounts than hornblende. Quartz is seldom phenocrystic, but there is much in the groundmass. Apatite and iron ore are found only in very small amounts.

So far as the writer could learn no important ore bodies are located on dikes of this rock.

WHITE RAVEN QUARTZ MONZONITE PORPHYRY

Occurrence.—There are 22 dikes of this rock in the Ward region. Nearly all of them are found between Sunset and Sunnyside and northward in a belt less than two miles wide to Ward. There are more dikes of this rock near Puzzler and in the lower part of California Gulch than in any other part of the area.

Most of the dikes are small, but three are each a mile or more in length, and several are more than 100 feet in average width.

Economic Conditions.—In many places the contacts of this porphyry and the country rocks are highly mineralized. The White Raven mine, Black Jack, Cross, Graybird and Philadelphia, all in California Gulch, and many other small properties in that region undoubtedly owe their silver, gold and other mineral deposits to the intrusion of this rock.

Texture and Color.—In all places where it was examined the rock was a typical porphyry. It is often called "bird's-eye porphyry" by the miners of the districts in which it occurs.

White plagioclase feldspar makes prominent phenocrysts, which are in sharp contrast to the gray or greenish gray fine-grained groundmass. In some cases the groundmass is partly glassy and very dense, and the color is decidedly green.

Composition.—Specimens from the same dikes and from different dikes vary considerably in composition. Phenocrysts of quartz are found in the rock of one part of a dike while they may be entirely absent from another part. Where it is abundant, there is on the average one good sized grain of quartz for each square centimeter of surface area. In most specimens examined, however, there was much less. A lime-soda plagioclase feldspar makes up practically all of the other phenocrysts. Multiple twinning can be seen with the unaided eye in many of these grains. The large feldspars have been much kaolinized.

Microscopic examination shows that the mineral constituents are: Orthoclase, plagioclase and quartz; the secondary minerals, epidote, chlorite, kaolinite and sericite; and the accessories, apatite, magnetite and pyrite. The exact determination of the plagioclase feldspars in this section is impossible on account of the kaolinite and sericite that have formed on the parent feldspar grains. However, chips broken from the freshest phenocrysts and placed upon the stage of the microscope and measured for the maximum extinction angles from the trace of the albite twinning indicate that the plagioclase is andesine. Ferromagnesian minerals, probably mostly hornblende, have been largely or entirely replaced by chlorite, epidote and zoisite. The greenish color of much of the rock is due to the abundance of chlorite. Quartz is present both as phenocrysts and in the groundmass. In the latter condition it encloses many minute orthoclase crystals. Apatite is quite abundant. It occurs as minute needle-like crystals. Magnetite appears as small grains, and it also surrounds those minerals which have been formed through the alteration of the ferromagnesian minerals. Pyrite anhedrons, small but rather plentiful, occur with chlorite.

MOUNT ALTO QUARTZ MONZONITE PORPHYRY

Occurrence.—This rock is found in a single dike about one-fourth of a mile north of Mt. Alto Park, and about one mile east of Gold Hill Station.

It is of no economic importance as far as is known, but it is an extremely interesting rock to the petrographer on account of its similarity to the great stock of monzonite porphyry that lies a short distance to the north.

Texture.—The texture is coarsely porphyritic. Single crystals of orthoclase two inches long are not uncommon and there are many from one-half inch to one inch in length. Quartz is also phenocrystic, although there is more in the groundmass.

Color.—The color is prevailingly gray or brownish gray, although the white or pale flesh-colored orthoclase phenocrysts may give slightly different shades. Much fresh biotite in the groundmass, and as small phenocrysts combined with the quartz and feldspar, both of which are commonly quite fresh, give the rock a speckled appearance.

Composition.—The minerals just named in the preceding paragraph are the only ones that can be recognized without the aid of a microscope.

A detailed microscopic examination of thin sections from this rock was made by Mr. Donald C. Kemp, and his description, slightly modified by the writer follows:

In the thin-sections of this rock, examination under the microscope discloses titanite, magnetite, apatite, hornblende, biotite, feldspar and quartz; also chlorite and a carbonate.

The titanite occurs as anhedrons and euhedrons. The latter are of two types: (a) Long lath-shaped crystals, which in some cases show twinning, and (b) minute grains, having a rhombic outline. It is fairly plentiful in the rock, equalling if not exceeding the quartz grains in amount. The largest crystals occur with magnetite; many of these contain inclusions of apatite. Magnetite is plentifully scattered throughout the section, and occurs, (a) as comparatively large anhedral masses 0.5

mm. or less in diameter, generally in patches or groups, (b) as smaller euhedrons sparsely distributed, and (c) as minute, pepper-like sprinklings, or "reaction-rims" surrounding biotite and hornblende. These minerals also enclose magnetite grains. Minute crystals of apatite, both in slender needlelike forms, and in short stout prisms are found as inclusions in most of the larger titanite crystals.

Hornblende, which originally occurred as small, well-developed phenocrysts has been almost completely replaced. Of the mineral itself but one or two small fragments were noted in the slide. The crystal cavities however, have been refilled by magnetite, chlorite, and a carbonate, probably of magnesium and calcium. The borders of these pseudomorphs as a rule are surrounded by rims of secondary magnetite. Biotite, sparsely distributed, appears as medium-sized flakes, all of which contain inclusions. These are, for the most part magnetite, with one exception, viz., that of a relatively large, rounded feldspar grain. An instance was noted also, where a feldspar phenocryst included a partially chloritized biotite flake. These relationships indicate that the crystallization of biotite and feldspar was in part at least, synchronous. In general the biotite shows less alteration than does the hornblende, although the outlines of the flakes are ragged, indicating that alteration has set in.

The feldspars are orthoclase and plagioclase. The former occurs as large ragged euhedrons and subhedrons which show fracturing. The surfaces as a whole appear fresh, but along the fracture-lines sericitic material appears, and slight kaolinization has developed. Inclusions of magnetite are common, and in one case, above mentioned, a tablet of biotite appears. The orthoclase except in one instance, is not twinned. In this case, however, the trace of the twinning plane is parallel to the trace of the principal cleavage. The cleavage remains in the position on both sides of this trace. This is a characteristic of Manebach types. Phenocrysts of about half the size of those just described, and of more regular outline are common. Kaolinization is quite noticeable in the centers of these. Plagioclase, in well distributed small and medium-sized phenocrysts; and in large localized patches composed of interlocked lath-shaped grains, occurs about equally with the orthoclase. Twinning after the Carlsbad, albite, and Manebach laws is common, and sometimes all three systems appear in the same mass. In general, however, the first two only occur. Kaolinization in the plagioclase has not developed to the extent shown in the orthoclase. Extinction angles, in sections normal to the albite twinning, measured from the trace of the twinning plane, vary from 8° or 9° to as high as 17° in one or two cases. No very satisfactory determination of the feldspar could be made in this slide, because of the manner in which most of the crystals are cut. But where Carlsbad twinning is present there is a sharp contrast in interference colors between crossed nicols, in the 45° position. This evidence, together with that of the extinction angles, places the plagioclase in the andesine group; and the zonal banding shows a gradation in composition from the borders toward the centers of the crystals; the centers being more basic. Quartz occurs in small rounded grains few in number, and scattered. These all show resorption. The phenocrystic quartz content would probably be less than 3 per cent of the entire rock.

The ground-mass, which constitutes about half of the rock, is composed of much altered orthoclase, and possibly quartz in micropoikilitic texture.

QUARTZ LATITE PORPHYRY

Name.—Quartz latite porphyry is the term applied to rocks of the same composition as quartz monzonite porphyry, but whose groundmass is largely glassy.

Occurrence.—It is interesting to note that two of the three quartz latite porphyries of the region are found on the borders of quartz monzonite porphyry dikes, while the third is very closely associated, if not actually connected, with its granular equivalent.

The first of these rocks occurs in the White Raven mine near the contact of the large quartz monzonite porphyry dike and the granite country rock. The rocks are mapped together with the name of the latter porphyry.

Another quartz latite porphyry is found on the borders of the Brainerd quartz monzonite porphyry in Tuscarora Gulch. It is also mapped as quartz monzonite porphyry.

About one mile east of Sunnyside, on the north side of Fourmile Creek, there are three dikes close together, and all of the same rock. The eastern one of the three can be traced almost to the large branching quartz monzonite porphyry dike which is found slightly farther east and northeast. There is every reason to believe that they are all parts of the same intrusion. The three dikes have, however, been shown on the map under their proper names.

Texture.—All of the rocks are distinctly porphyritic. Few phenocrysts are more than 5 millimeters in diameter. In the hand specimens, the groundmass in all cases appears very dense. Under the microscope it is found to be almost entirely glassy, but it includes some very small feldspar grains. The groundmass and phenocrysts occupy nearly equal areas.

Color.—The two rocks first mentioned above under "occurrence" are gray. Those east of Sunnyside are a very light brown, and are much streaked with iron rust.

Composition.—In so far as the composition can be determined it agrees almost exactly with that of the White Raven and Brainerd quartz monzonite porphyries, with which these rocks are respectively associated. Orthoclase, intermediate plagioclase, quartz and biotite, and the common secondary minerals derived from the alteration of these are the important recognizable minerals. The White Raven quartz latite porphyry is highly impregnated with galena which is silver bearing.

MICA DACITE PORPHYRY

Name.—A fine-grained porphyritic rock, composed of chiefly quartz and plagioclase with subordinate amounts of orthoclase, and one or more of the minerals biotite, hornblende and pyroxene, is called dacite. In the Ward district the rocks of this general composition have biotite in large amounts and are, therefore, mica dacite porphyries.

Occurrence.—There are 11 dikes in the Ward region, and all but one are north of Lefthand creek. One large dike runs north and south from one hill to the other across Lefthand Canyon, just east of Puzzler. The others lie mainly in a belt about one and a half miles wide, from the Lois mine on the west nearly to the east border of the area.

Texture and Color.—There is a rather remarkable similarity in the appearance of the rocks in these dikes. When fresh, the color is gray or greenish gray. The groundmass is very fine grained, and, in some cases from the borders of the dikes, it is glassy. There are many prominent phenocrysts of feldspar, quartz and biotite. Usually the feldspar crystals are rectangular in outline. They are six or eight millimeters in length and two-thirds as broad. In some specimens the quartz phenocrysts are as large and quite as numerous as the feldspars, but in the average specimen they are fewer in number and slightly smaller. In most of the rocks studied much black, very lustrous biotite is present in hexagonal crystals. The freshly broken surface of average specimens shows a rather coarsely porphyritic rock whose phenocrysts are fresh and of glassy luster. These stand out in strong contrast to the dense gray or greenish gray groundmass. When weathered the color is greenish gray, dull gray or brown.

Composition.—The composition, as shown in the hand specimen, is indicated in the preceding paragraph. Many thin sections were studied under the microscope, and the minerals determined are: Plagioclase, quartz, orthoclase, biotite, magnetite, apatite, epidote, sericite, chlorite, kaolinite. In a thin section of the dike rock that runs east from the Lois mine, garnet and zoisite were also found.

Very little orthoclase occurs as phenocrysts, but there is considerable in the groundmass. It is fresh in some specimens and coated with kaolinite or sericite in others. The extinction angles in the plagioclases measured from the trace of albite twinning averaged between 0 and 3½ degrees. Therefore the plagioclase is believed to be a rather basic andesine. Quartz is abundant as phenocrysts and also in the groundmass. In the latter it is micrographic, enclosing minute tablets of feldspar. Biotite is found in larger amounts as phenocrysts, than in the groundmass, but is present in both conditions. Apatite is abundant in long needle-like crystals, and is sparingly present in short prisms. Magnetite is not plentiful. When present it is in euhedral crystals. In the Lois mine dacite there are minute garnets in the groundmass which are apparently dodecahedral in form. They are surrounded with a matrix of epidote and zoisite and are clearly of secondary origin. Epidote, zoisite and chlorite are present in approximately equal amounts. They have been formed through the alteration of feldspars and ferromagnesian minerals. Chlorite gives the groundmass of some rocks its green color. In some sections kaolinite and sericite are abundant. In others they are entirely absent.

In weathering, both biotite and feldspar crystals disintegrate rapidly, leaving little pits, while the quartz stands out prominently as knobs on the surface of the rocks.

TRACHYTE

Name.—Trachyte is the name applied to a fine-grained rock of the general composition of a syenite. It contains chiefly orthoclase feldspar and one or more of the ferromagnesian minerals, biotite, hornblende or augite. The two soda-lime feldspars, albite and oligoclase, are generally present in small amounts, as are of course the common ascessories, titanite and zircon and sometimes quartz in very small amounts.

Occurrence.—This rock is popularly known as the "Sunset trachyte," because of its occurrence in a large stock, and in dikes near that village. The main part of the trachyte stock is on Bald Mountain, about a mile and a half west of Sugarloaf Mountain. The large dikes extend out to the north from the stock. One of them crosses Fourmile Canyon and continues for more than half a mile beyond. Three other dikes of trachyte are found near those already mentioned. Before the railroad between Boulder and Sunset was junked, this rock was shipped in car load lots to Boulder where it was crushed and used to surface streets. Its platy jointing made it very suitable for this purpose.

Description.—It was impossible to secure fresh specimens of trachyte, therefore the appearance of the unweathered rock is not known with certainty. It is probably a light gray rock with pale pink, flesh colored or white phenocrysts of orthoclase. The weathered rock ranges in color from a light brown through buff to red and pinkish gray. Kaolinization is pronounced, and there are numerous pits where there were at some time ferromagnesian minerals. Manganese stains are very common.

Wherever it is found the rock breaks into sharp-edged plates, which are usually not more than two or three inches in thickness. The texture is usually decidedly porphyritic.

The phenocrysts seldom exceed 3 millimeters in diameter. They are chiefly glassy orthoclase, but hornblende, or at least outlines of what is believed to have been hornblende, occurs in small amounts.

Composition.—Orthoclase is the most important primary mineral in the rock. It has been replaced by sericite and kaolinite to a very large extent in the specimens that were examined. A small amount of soda-lime feldspar probably oligoclase is also present. Considerable iron and chlorite are believed to be derived from the decomposition of ferromagnesian minerals, and small amounts of titanite and zircon complete the list of recognizable minerals in the thin sections that were examined.

[1]Breed made both microscopic and chemical analyses of this rock and records apatite, and probably augite in addition to the minerals given above. His chemical analysis is given in the accompanying reference.

There are few, if any, important ore deposits connected with the trachyte intrusions.

MONZONITE PORPHYRY

Name.—Monzonite is the name commonly applied to rocks intermediate in composition between syenite and diorite or between diorite and gabbro, in which orthoclase and plagioclase occur in nearly equal amounts, and in which one or more of the ferromagnesian minerals is present. If much more orthoclase than plagioclase is present the rock inclines toward syenite, if the reverse is true, to a gabbro.

According to this usage, the rocks in the Ward region, which have the mineral composition indicated above, and in which the groundmass is microlitic and the texture distinctly porphyritic, are called monzonite porphyries.

Occurrence.—This rock has the greatest areal distribution of any of the post-Cambrian intrusives in the region. It forms a very large irregular stock which extends from the south side of Fourmile Creek nearly to Gold Lake. It also is found in 18 dikes.

As is stated in the first part of this chapter, it is believed that the monzonite magma is the parent of most of the intrusive rocks of the region, and this opinion will probably be substantiated by a

[1]Breed, R. S., The Sunset Trachyte, from near Sunset, Boulder County, Colorado. Colorado Scientific Society Proceedings vol. 6, pp. 216-230, 1899.

detailed study of the geologic map, on which the relations of the great monzonite stock to the other intrusive rocks is well shown.

Description.—There is a wide variation in the appearance of the rocks classed as monzonite porphyry. Most of them are coarsely porphyritic, with orthoclase and hornblende predominating. Others have fewer and smaller phenocrysts, with hornblende in long slender needles the dominant mineral. Still others are essentially even grained, but have some feldspar phenocrysts which are so small or so nearly the color of the groundmass as to be very inconspicuous.

When fresh the rock is rather dark gray in color, but it weathers rapidly, and the color changes to some shade of brown or greenish gray. The pink, flesh colored or white feldspar crystals, and the black hornblende or biotite relieve the rather monotonous gray or brown that would otherwise be pronounced. The feldspar phenocrysts, however, kaolinize as weathering goes on and turn yellow or brown, and the ferromagnesian minerals also break down so that after prolonged weathering the prevailing color is a light brown, sometimes with green tone, which is characteristic of the monzonite porphyry areas as a whole.

Composition.—Orthoclase and sanadine constitute most of the feldspar phenocrysts. Many orthoclase crystals, perfect in crystal form, or twinned, and more than an inch in length have been found where the monzonite has been disintegrated through the agents of atmospheric weathering. Orthoclase also occurs sparingly in the groundmass. Plagioclase, mostly andesine, is the most important mineral in the groundmass. It also may occur as phenocrysts, which are smaller than the orthoclases. The proportion of orthoclase and plagioclase varies greatly in different parts of the same stock. As a rule plagioclase is found in greater amounts. In some places it is impossible to differentiate between monzonite porphyry and diorite porphyry. Hornblende is the most important ferromagnesian mineral. It occurs both as fine, long needle-like crystals, and as medium sized stout phenocrysts. It is present also in the groundmass. Biotite is rarely phenocrystic, but is present in the groundmass. Epidote invariably accompanies hornblende and biotite. Zircon is found in some sections as inclusions in the hornblende. Titanite is abundant in the groundmass as is magnetite. Sericite, kaolin, chlorite and calcite are plentiful in the thin sections of weathered rocks.

LATITE PORPHYRY

Name.—Latite is a monzonite in composition, but with a groundmass that is largely glassy. Latite porphyry, therefore, is, as the name implies, essentially like the monzonite porphyry just described except that it is finer textured and has much glass in the groundmass.

Occurrence.—There are 9 latite porphyry dikes which are scattered widely over the Ward region. Some are found near Copper Rock, others near Tuscarora Gulch, and others north of Sunnyside, as well as in intermediate areas. Practically all of the latites are mineralized at least on their borders. Pyrite is found in nearly all of these rocks, and the occurrence of more or less gold with the pyrite is not uncommon. Because of the pronounced mineralization, particularly on the borders of latite intrusions and granite, there has been much prospecting in such regions, and every latite dike has been well exposed.

Several masses of latite porphyry are found on the borders of monzonite porphyry dikes or stocks. They have been mapped with the monzonite. Others occur on the borders of diorite porphyry, and have been mapped with the diorite.

Description.—In the whole Ward region no other series of dike rocks, which can be classified under a single group name, exhibits so many variations in color, texture and condition of weathering as do the latite porphyries. No two look alike. In most cases they do not resemble any other rocks in the region, although some are much like andesites, and others might be mistaken for some of the felsites. All have two common characteristics, a dense or glassy matrix and many phenocrysts. Here the similarity ends. Some have many small phenocrysts, others have few and large ones. Gray and brown colors, or tones intermediate between these are most common. In most of the hand-specimens taken from the dikes, the phenocrysts are feldspar. In some, hornblende is prominent, in two biotite is very common, and in one all three minerals are abundant.

Nearly all of the latites are bady weathered. It is probable that where fresh they are of medium gray color, but after weathering the color is likely to be one of those mentioned in the preceding paragraph.

Composition.—The latite porphyries have essentially the same composition as the monzonites just described. Most of them are so badly weathered that it is impossible to determine the original mineral composition. Plagioclase seems to be more abundant in the groundmass than orthoclase, and it is also equally important in phenocrysts. Hornblende was probably the most common ferromagnesian mineral, but in most of the specimens it has been badly altered. Biotite is rare in most of the thin sections examined. In at least two, however, it is abundant as phenocrysts. Epidote, chlorite, kaolinite, magnetite and titanite are of very common occurrence. The green minerals, epidote and chlorite, have much to do with the color of the weathered rocks. Pyrite is very abundant in some of the dikes.

DIORITE PORPHYRY

Name.—This name is given to a rock intermediate in its silica content, which is holocrystalline and porphyritic, and which contains chiefly an intermediate plagioclase feldspar and one or more of the ferromagnesian minerals.

Occurrence.—The diorite porphyry of the Ward region is almost certainly a differentiation product of monzonite. It is found in six different intrusions, two of which are small stocks and the rest are dikes. Two dikes are quite large. The diorite occurs chiefly north and south of Lefthand Creek, one or two miles east and southeast of Ward. One large dike crosses the old Denver, Boulder and Western railroad grade, about one mile northwest of Sugarloaf Mountain. North of Lefthand Canyon and just east of Tuscarora Gulch there is a stock of what should properly be called diorite porphyry. This connects with the monzonite porphyry stock of Burnt Mountain by a narrow neck of the latter rock. Within the borders of the stock are good examples of the closely related rocks, monzonite, latite and diorite porphyry. The prevailing rock is, however, the latter.

Description.—In general appearance the diorite porphyries are much like the monzonites, except that they are somewhat coarser grained. They are all porphyritic. All are brown or gray in color and nearly all show abundant plagioclase and biotite phenocrysts. When weathered the color of the surface of the rocks is brown or reddish, often the latter, due to the liberation of iron oxides. The rock joints and breaks into thin, nearly flat sharp-edged plates which lie in many places on steep hillsides and protect the underlying rocks from rapid disintegration.

Composition.—Under the microscope the following minerals were recognized: Plagioclase, biotite, a little orthoclase, apatite, titanite and calcite. All of the feldspars are badly weathered, but most of them seem to belong to the group basic andesine. Some of them seem to be andesine on the borders and a more basic feldspar probably labradorite in the center.

Phenocrysts make up more than one-half of the average rock. There are apparently two periods of crystallization of the phenocrysts. During the later period more, but smaller, grains were formed.

Biotite is brown in color. It occurs in many irregular grains, almost always bordered by magnetite. In the hand specimens, thick grains of biotite, which happen to be oriented in the right direction, much resemble hornblende when seen on their edge. Apatite is found as long slender grains. It is closely associated with calcite. Titanite is sparingly present. Hornblende is found in small quantities in some specimens. There are no important ore deposits known on the diorite dikes in this region, and there is very little mineralization of the rocks. There are some prospect holes, long since abandoned near the contacts of this rock and granite.

ANDESITE AND ANDESITE PORPHYRY

Name.—Andesite is the name given to fine-grained rocks which have the composition of diorites. Such rocks contain large amounts of intermediate or basic plagioclase feldspar and one or more ferromagnesian minerals, with (usually) smaller amounts of orthoclase and other accessory minerals. The rocks may or may not be porphyritic, but in the Ward region, practically all are.

Occurrence.—All of the andesites in this region occur in dikes. There are no stocks. Fifteen dikes, which include the various varieties of andesite, have been mapped. The most important group of dikes is found south of Copper Rock on the north side of Sugarloaf Mountain. Others are scattered widely over the whole region. Several dikes are half a mile or more in length and from a few feet to more than 100 feet in width, but most of them are smaller.

Many prospect holes have been dug on the borders of the andesite intrusions on account of their extensive mineralization, but so far as could be determined no large and rich bodies of ore have been found.

Description.—Most of the fresh andesites are gray. Some are very dark, others are light. Many are brownish or greenish gray when slightly weathered, due to the liberation of iron or to the formation of epidote or chlorite from the ferromagnesian minerals. Thoroughly weathered surfaces are, in most cases, some shade of brown.

The groundmass of most of the rocks is very fine grained. Grains of feldspar, and biotite, hornblende, or augite often occur in sufficient size to give the rock a distinctly porphyritic appearance. Most of the feldspar outlines are rectangular. When hornblende occurs as phenocrysts it is usually in needle-like grains from one-fourth to one-half an inch in length. Where augite is phenocrystic the grains are usually short and stout. If broken they show rectangular outlines. A large proportion of the biotite grains that are large enough to be regarded as phenocrysts are really very small, possibly averaging 2 millimeters in diameter. Their hexagonal crystal form may be easily seen under a pocket magnifying glass. The rocks containing hornblende or augite phenocrysts are, as a rule, much more weathered than are those which contain biotite.

Some of the andesite porphyries can not be distinguished in the hand specimens from diorite porphyry. In fact the same masses of rock in some cases, are dioritic in the center and andesitic on the borders. Andesites and latites also may look very much alike, and it is impossible to separate them except under the microscope.

Composition.—This has in part been indicated in the preceding paragraphs. All the slides that were studied, showed orthoclase, plagioclase, biotite and titanite. Hornblende was present in nearly all cases, and a pyroxene, which is believed to be augite, was found in several sections. In the weathered specimens the feldspars were more or less kaolinized, and red and black iron ores, epidote, chlorite and calcite occurred in abundance, as alteration products of the ferromagnesian minerals. A little primary quartz is present in some specimens, and there is some which is probably secondary. Most of the titanite is fresh or very little altered. Some large zircon grains were found, and apatite inclusions in feldspar were of frequent occurrence.

There are few orthoclase or microcline phenocrysts, but considerable orthoclase is in the groundmass. Most of the plagioclase is acidic andesine, but some labradorite is present. Many plagioclases show zonal banding and are obviously more basic in the center than on the edges. In some specimens hornblende phenocrysts far exceed the feldspars, but in the majority of cases, feldspars are the most numerous.

OLIVINE BASALT

Name.—Olivine basalt is the name applied to a fine grained rock of the composition of a gabbro. That is, one which contains chiefly a basic feldspar, pyroxene and olivine.

Occurrence.—There are two small bosses of this rock near the Mountain View and White Pine mines in Chipmunk Gulch, about one mile north and a little east of Ward. Neither boss has a surface area of more than a few hundred square feet. No important ore deposits are known to occur here.

Description.—This rock is a very fine textured, dark gray basalt, of high specific gravity. In the hand specimens, many minute lath-shaped grains of gray feldspar, and larger grains of green olivine can be seen. While the texture is, as a rule, fine and even, it varies from place to place, and near the borders of one of the intrusions it is vesicular. The vesicles have been filled with amygdules of secondary white quartz. The rock weathers to a dark brown color. Weathered surfaces are much pitted, and are streaked with red or brown iron oxides. No regular system of jointing could be found.

Composition.—Microscopic study of thin sections shows that basic, undetermined plagioclase is the most abundant mineral present. This feldspar shows no polysynthetic twinning, and as no chemical analysis of the rock was made its composition is not definitely known. Augite and olivine are also present in large amounts. Considerable black iron ore and calcite are found in weathered specimens.

DIABASE

Name.—This rock was named hypersthene diabase by Professor Crawford in his descriptions of the rocks of the Sugarloaf district.[1] Since the publication of his report on that area, Professor Crawford has studied this rock further, under the microscope, and has advised the writer that he has some doubt as to his original identification of the mineral called "hypersthene." He, therefore, believes it better to call the rock simply diabase.

Diabase is the term used to define a basic rock of the composition of the gabbro family, but intermediate in texture between the granitoid (holocrystalline) gabbro and the felsitoid (lens grained) basalt. It has also another textural significance, in that the older lath-shaped feldspars are separated by younger irregular grains of pyroxene. If the pyroxene grains actually enclose the feldspars the texture is called "ophitic."

Occurrence.—There are 5 dikes of this rock, all in the northeast corner of the area. The largest dike is about 60 feet wide and extends northwesterly for more than a mile from the east border of

[1]Crawford, R. D., Geology and Petrography of the Sugarloaf District: University of Colorado Studies. Vol. 6, No. 2, p. 115, 1909.

the region mapped. It is the same dike which cuts through the Sugarloaf district, and its course can be followed for 10 miles or more. This dike is much more resistant to the agents of erosion than the country rock which it cuts, and it, therefore, makes a conspicuous ridge throughout its whole extent in the Ward region.

The other dikes are not so large nor are they so conspicuous, but they are easily recognized, and can be followed by their topographic forms. No important ore bodies have been found on these dikes.

Description.—For a full description, including microscopic analysis of this rock, the reader is referred to Professor Crawford's report[1] mentioned above.

The diabase is heavy, hard and very tough. Fresh pieces can be broken only with difficulty.

The color is black, gray or dark greenish gray. The latter color predominates. When weathered the color is brown or brownish gray.

In the small dikes and along the borders of the large ones the texture is fine grained, but near the center of the large dike it is porphyritic or in some cases entirely holocrystalline. In the course-grained rocks greenish gray feldspar predominates, but a black fibrous looking pyroxene can also be seen. It is evident that the feldspar is responsible for the common greenish-gray color of the rock.

Most of the dikes show highly developed cubical jointing.

Composition.—Under the microscope four important minerals are seen: A basic plagioclase feldspar which shows much polysynthetic and occasional Carlsbad twinning, augite, hypersthene (?) and black iron ore. Calcite and sericite, which are alteration products of the feldspar, quartz, which occurs in small amounts on the borders of some of the pyroxenes, serpentine, which is also an alteration product of the pyroxene and iron oxide, are the important secondary minerals.

Age.—The evidence of the relative ages of this and the other intrusive rocks in the region is not conclusive, for contacts are much obscured in some cases. It is known however that the diabase is younger than the metamorphics, granite and pegmatite. It appears to be younger than one mica dacite and one felsite dike which it intersects. It seems to be older than and cut off by a stock of monzonite porphyry, but it may have come from the monzonite magma through magmatic differentiation.

[1]Op. Cit. pp. 115-118.

CHAPTER VI

ECONOMIC GEOLOGY

ORE DEPOSITS

GENERAL DISCUSSION

When this report was first contemplated the writer expected to make a full examination of the mines of the Ward Region in order that he might study thoroughly the ore deposits. It has been impossible to make such an examination and study on account of the small number of mines that have been in operation at any time since this work was started.

Practically all of the mines that have been opened since 1911 have been studied, however, and the following notes are based in part on specific data procured from such study, and in part on more general information secured from many sources.

GEOGRAPHIC SITUATION

The Ward region is near the northeast end of the great mineralized zone which extends for about 250 miles from Montezuma County in southwestern Colorado, northeastward to the central part of Boulder County. This zone is between 100 and 125 miles wide. It contains practically all of the noted mining regions of the state, among which may be noted, Nederland, Blackhawk, Central City, Georgetown, Empire, Montezuma, Fairplay, Alma, Telluride, Silverton and Rico. Cripple Creek and Silver Cliff and intermediate mining regions lie in a shorter subsidiary belt of the same general trend.

There have been reports prepared by the United States Geological Survey or by the Colorado Geological Survey on nearly all of these areas.

GEOLOGIC CONDITIONS

STRUCTURE

Strike.—With the exception of some of the deposits near Sunset and Copper Rock, nearly all of the ore in the Ward region occurs in veins which strike roughly east and west. In some cases the strike is northwest. The latter is true of veins in California and Puzzler gulches south of Ward.

Dip.—Nearly all of the veins dip at rather high angles to the north. Angles of 60° are not uncommon. Angles of less than 45° are infrequent. Sharp changes in dip are very common.

FORMS OF THE ORE DEPOSITS

Most of the ore deposits are in fissures, and are known as fissure veins. Some deposits are found directly on the contacts of igneous intrusions and country rock and may be classed as contact deposits. It is probable, however, that these are actually fissure veins whose position is dependent upon the formation of fissures subsequent to the intrusions.

In the White Raven mine much of the ore occurs in shoots. In the shoots between the surface and depths of 500 or 600 feet there are many large vugs. Similar shoots of less importance have been encountered in other mines.

Nearly all of the veins are single and straight, without branches or faults. Some, however, are branching.

VEIN FORMATION

County Rock.—The best-developed and richest veins are in granite or gneiss. The Idaho Springs formation seems to have been incompetent to preserve fractures and fissures caused by crustal movements, to the same extent as the granites. The result is that well defined veins in the granites and gneisses often play out in part at least when followed into the schists.

The mineralization in the granite veins is also much greater as a rule than in the highly metamorphosed rocks. This is due, the writer believes, not only to the conditions mentioned in the preceding paragraph, but to the further fact that in the schists because of their structure, conditions would be more favorable for dispersion of mineralized solutions, hence, there would be less likelihood for concentrated deposits.

Relations to Igneous Intrusions.—There is an undoubted relationship between the ore deposits and the Tertiary (?) intrusive rocks. Close questioning of the prospectors who were the first in the district revealed the fact that they "invariably looked for porphyry dikes" when prospecting for new ore bodies. More than half of all of the ore deposits of the whole region are on or near the contacts of dikes.

The richest deposits seem to be closely associated with felsite, dacite, quartz monzonite and latite or quartz latite dikes. These are the ones that were, in all probability, richest in mineralizers at the time of their intrusion.

Origin of the Veins.—That the veins are not all, possibly not the majority, contemporaneous with the intrusions, is shown by the fact that in many cases veins are found within the intrusion, and by the further fact that brecciation in the intrusions and vein filling some distance from the walls has been noted in several instances.

There were, at least, two periods of movement. The first was of large extent and preceded most of the Tertiary vulcanism. The position of the dikes was largely determined by the formation of fissures at this time. The second period of movement with consequent fissuring closely followed the main igneous activity and gave rise to many of the veins that are now found. Because of the limited number of veins that could be examined it is impossible to state whether or not there was a second period of vulcanism following mineralization of the fissures, but it is probable that there was, and that some of the veins have been cut by dikes.

The concentration of the ore deposits near the intrusions, but not necessarily as contact deposits, is probably due to the fact that hot solutions were most abundant and most active near the intrusions, and to the further fact that, in addition to the fissuring caused by crustal movements which preceded igneous activity, there were undoubtedly many fissures in the country rock caused by the intrusions themselves.

Such fractures would be most numerous near the surface of the ground, and would be fewer in number farther down. The land surface at the time of the Tertiary (?) intrusions was much above the present one, hence fissures formed in that way may have largely disappeared through erosion.

The size of the veins is very variable. Some workable deposits are only 6 inches wide. The average width of the veins in the whole region is from 2 to 4 feet. In the Columbia, Niwot, Baxter, Utica, Dew Drop and others, ore bodies from 6 to 8 feet wide are not uncommon. The White Raven vein is 14 feet wide in some places.

Faults that have displaced parts of the veins are not uncommon. The writer has had opportunity to examine faults in the Dew Drop. Newmarket, Humboldt and Nelson, and many others are reported. Nearly all have small displacements, and the faulted ends of veins have been picked up in most cases without much difficulty.

ORES

Gold, silver, lead, copper, zinc, tungsten in the order named are the important ores. Only the first three have been produced, in large quantities, but the others are known to exist in various parts of the region.

GOLD ORES

Occurrence.—Gold has been found in four forms in the Ward region. Some of the first strikes of gold were made in placer deposits. The gold was washed down from the lodes or veins in which it originally occurred and deposited in sand and gravel along the various streams. The placer deposits were never very important and have long ago been worked out. Most of the gold has been found in quartz veins with pyrite or chalcopyrite or both. In such occurrence the gold in the free state is intimately associated with the iron or copper iron sulphide. When it occurs with chalcopyrite the deposits are likely to be richer than in those with pyrite alone. Chalcopyrite usually is less abundant than pyrite, but in some cases it is much more abundant.

Gangue minerals are chiefly quartz, sericite and fluorite. Quartz is invariably present in the large fissure veins. It may be either massive and white or crystalline and colorless. The former variety is much more common except in drusy cavities in veins above the ground water table.

Sericite is of common occurrence in many of the vein walls due to the action of mineralized solutions which filled the veins. This action was undoubtedly effective in widening the original fissures and in increasing to a pronounced degree the size of the mineralized bodies.

Unimportant, but nearly universally present, minerals in most of the larger mines are molybdenite and wolframite. Molybdenite is found sparingly in many veins. It usually occurs as thin black facings which look much like graphite but are blue gray rather than black. In some veins it is present in small flakes.

Wolframite is found in nearly all of the mines of the Ward district. It was not found by the writer in the mines near Sunset. In the Niwot, Newmarket, Humboldt, Nelson and other mines near Ward, and especially in the regions west and south of Gold Lake, it is particularly abundant.

Gold ores also occur with galena and sphalerite ores. Some gold has been mined from veins which contain chiefly galena, silver, and sphalerite. In these veins gold may occur both in its native state and as an alloy with silver. It is not high-grade gold ore, however, and the veins are not mined for their gold content. Only the White Raven mine and others on the same vein and certain others north of Sunnyside have ores of this type.

Calcite and barite are the two most common gangue minerals. Tennantite is present in the White Raven mine in small quantities at depths of approximately 600 to 1,000 feet below the surface of the ground.

Telluride gold ores occur in some mines, particularly those on the east side of the Ward region. Rich telluride ore is reported from the Morning Star mine in Spring Gulch.

ENRICHMENT

Secondary enrichment of the pyritic gold ores above the permanent ground water table and extending slightly below that surface has been of utmost importance in the development of the gold mines of the region, because it is in this oxidized zone that all the rich, ''free milling'' gold ores have been found.

The oxidized and enriched zone is clearly defined in all the mines which have been started at the surface and which have penetrated well into the ground-water zone. Near the surface the vein minerals are either oxidized or coated with iron oxides. Limonite is the most common mineral. It is rusty yellow or brown in color, and as it has been widely distributed by water, it discolors all substances in and near the veins, with which it comes in contact.

The gangue quartz is stained and loosened by the solution of the associated pyrite. It is often honey combed and is called by the miners ''rotten quartz.'' Drusy cavities lined with small quartz crystals, and stained with iron oxides, are apparently favorable situations for free gold, and it is a well-known fact that from such cavities extremely high values in gold have been taken.

The reasons for the gold enrichment in the pyritic veins are two: First, some of the gold was dissolved and redeposited. Chlorine water is an active solvent of gold, and if the chloride solutions containing gold come in contact with iron (ferrous) sulphate the gold would be precipitated. Ferrous sulphate would undoubtedly be present in large quantities due to the oxidation of pyrite. The source of the chlorine is uncertain. It is, however, present in small amounts in some of the mine waters, and it is assumed that it has been an active chemical agent in the oxidized zone. That enrichment of this sort occurred, is indicated by the large amounts of free gold in certain "bonanzas" found near the surface of the ground. Such rich deposits could not easily be explained by mechanical concentration of the gold through long continued weathering. Solution and redeposition of gold is also indicated by the large size of many flakes and pieces of free gold that have been found in the enriched zone. The writer has seen some such grains that were one-fourth of an inch in diameter. In the veins well below the ground-water level nearly all of the gold is in microscopic grains.

The other process of gold enrichment was undoubtedly a residual one. Through long periods of time the quartz-pyrite veins were subjected to the attack of all the chemical agents in the air and in surface waters. The fractures in the veins at and near the surface of the ground were widened and the chemical activities were thus made to progress through the veins until largely through oxidation and carbonation processes the sulphides and other vein minerals except gold and quartz were removed or greatly altered. Gold would be left as a residuum, and in certain cases would be mechanically concentrated by the movement of solutions through cavities. Naturally, in such cases the gold would be caught and held in pockets and constricted openings of other sorts.

The depth of gold enrichment by the processes just indicated is dependent upon the permanent level of the ground water. Climatic conditions, topography and the texture of, and fractures in the rocks largely control this level. Fluctuations also are caused by mining operations which may drain temporarily or permanently certain regions, but these would be of too recent occurrence to have any important effect on the enrichment of ores. The ground-water table in the Ward region is from 50 to 200 feet below the surface of the ground. It is rarely, however, so deep as 200 feet.

VALUES

Nearly all the valuable gold ores have come from quartz and pyrite, or chalcopyrite veins. The values have varied greatly in different mines. Some very rich pockets of ore have been found in the oxidized portions of the veins and rich solid sulphide ore running from $100.00 to $300.00 a ton was by no means uncommon. The average value of the smelting ore produced in the region up to 1900 was between $60.00 and $70.00 a ton. Milling ore values ran from $10.00 to $15.00 a ton.

Below the ground-water level the values have greatly decreased. There are many thousand tons of ore now blocked out which will run between $6.00 and $12.00 a ton in gold. The average value of this ore is about $10.00 a ton in gold and from $4.00 to $10.00 in copper and silver combined, depending upon the market prices of those metals.

SILVER ORES

Silver is found in some amounts in nearly all of the gold veins. It is particularly abundant in the galena-sphalerite veins, but is usually present in the pyrite veins as well, where it is probably an alloy with the gold.

The proportionate amounts of silver and gold in pyrite veins are indicated by a group of twenty-four assays made from pyrite ores that were taken from all parts of the Ward region. These assays gave an average of .86 ounces of gold and 8.70 ounces of silver per ton of ore, or almost exactly ten times as much silver as gold by weight.

Mineral resources for the years 1910, 1911 and 1912 give a total production for the Ward district of 3,181 ounces of gold and 30,145 ounces of silver, which checks closely the ratio figures given above. This was before the White Raven mine was well developed, and the production was almost entirely from pyrite and chalcopyrite ores.

Mint reports for three representative years, 1887 to 1889 inclusive, when silver was "high," gave the following production values for a group of six mines. The mines were: B. & M., Boston, Colorado, Columbia, Morning Star, Puzzler.

The total values in gold and silver were: Gold, $168,774.80, and silver, $38,395.78.

The silver values, like the gold, are usually greatest in the veins that contain the most chalcopyrite. In the oxidized zone silver values are somewhat lower than in the same veins below the ground water surface. This fact would indicate that the primary silver in the veins is taken into solution to some extent by the chemicals of the air and of surface waters, and is carried away.

The greatest values in silver ore were found in the lead vein of the White Raven and neighboring mines. Since the White Raven was the only mine of this type that was carefully examined by the writer, the discussion of this type of ore will be deferred until the description of that mine is reached.

LEAD ORES

The only lead ore that has been mined in any considerable quantity in the Ward region is from the White Raven mine, therefore the occurrence of this ore will be included in the description of that mine.

Some very good-looking galena, which carries negligible values in gold and silver, was found on a dump (said to be the Gold Drop dump) about three-fourths of a mile northwest of Sunnyside. The shaft was full of water and the vein could not be examined. Considerable quartz and pyrite are on the dump. The country rock is mica schist.

COPPER ORES

Both chalcopyrite and chalcocite are important as ores of copper in the Ward region. Tennantite is found in the White Raven mine associated with galena, but it is not in large enough amounts to be classed as an ore.

Chalcopyrite is the most important copper mineral in this region. It is found in all parts of the area, but is particularly abundant in the mines south and west of Sunset and in the Dew Drop and many other mines near Ward. It is also found at Copper Rock where azurite and malachite have been derived from it through oxidation and carbonation.

From the Sunset region, chalcopyrite has been shipped to smelters, as an ore of copper, in which the gold and silver values have been secondary. Chalcopyrite contains 34.5 per cent copper. Some small shipments of ore from the mines near Sunset have run 20 per cent copper, which indicates the high percentage of chalcopyrite in the veins. Some of these veins are filled almost entirely with massive copper-bearing pyrite which can be mined in the nearly pure state.

The recoverable copper in the gold and silver ores shipped from pyrite and copper-bearing pyrite veins, and taken from below the ground water level averages between 1 per cent and 2 per cent for the whole region.

ZINC ORES

Zinc is not an important ore in the Ward region. It is found in commercial quantities only in the White Raven, Cross and Black Jack mines, all of which are on the same vein. Very little zinc has ever been saved from the White Raven ores. It will be discussed under the description of that mine.

TUNGSTEN ORES

Wolframite is widely scattered through the veins of the Ward district proper. It is not found far south of Ward, which is rather surprising as one would expect to find it in increasing quantities as the Nederland-Lakewood tungsten belt is approached.

Wherever wolframite occurs it is intimately associated with quartz and pyrite, and chalcopyrite is also likely to be present. Although wolframite is found in practically every mine near the town of Ward it has not been mined for the tungsten content from any of these mines except the Nelson. In 1915 and 1916, when the demand for tungsten for war purposes was at its height, certain ore bodies in the Nelson mine were opened with the intention of saving both tungsten and gold values. Wolframite is found in this mine in the 60 and 150-foot levels. A fault with nearly a north strike has cut both of these veins and no tungsten has been found west of it. The wolframite occurs only in pockets, and it is so irregular in amount and so thoroughly intergrown with pyrite that it is not believed to be commercially valuable.

Near Gold Lake there are several tungsten claims. The late Johnnie Knight owned the Connoton claims which are situated about one mile west of Gold Lake.

The Connoton vein is on the contact of mica dacite porphyry and granite. It dips 55° N. 10° W. A drift has been run along the vein for one hundred and fifty feet. Wolframite occurs with quartz and pyrite in the vein, which is from four inches to one foot wide. About ten tons of ore have been shipped from this mine which ran 6 per cent WO_3. It contained so much pyrite, however, that it could not be marketed.

An analysis of the wolframite from this mine[1] follows: WO_3 71.27, FeO 20.01, MnO 7.15, CaO 1.58. This analysis was erroneously reported from "Johnnie Ward's mine, instead of Johnnie Knights'."

During the recent tungsten boom, other properties were developed for wolframite, between Gold Lake and Spring Gulch. The ore and its associated minerals are practically the same as in Johnnie Knights' claims. The properties will be described under mines.

MINING INDUSTRY

GENERAL DISCUSSION

The mining industry in the Ward region has been declining for many years. The decline began with the panic of 1893. While mining has not steadily declined since that date, it is safe

[1]George, R. D., The Main Tungsten Area of Boulder County, Colorado; Colorado Geological Survey, First Report, p. 42, 1908.

to say that it has never recovered from the depression in the price of silver of that time.

About 1899 the annual production of the Ward district alone was $200,000. The annual production for the years 1910 to 1915 inclusive was $41,276 from an average number of nine mines. In 1916 the production was more than $130,000, due largely to the greatly increased output of the White Raven mine, which has been the largest producing mine, from the standpoint of value of the ores, since 1913.

About 1890 more than 2,100 persons got their mail at the Ward post office. At the present time, as this bulletin goes to press, December, 1920, there are not 200 people living in the whole area included in this report.

The decrease in mining in this region may be ascribed to three causes: First: The low price of silver which has affected the industry since 1893. Although the price of silver increased greatly during the war and following its close, mining costs also increased proportionately, and as the price of gold was fixed, it was not profitable to open mines that had long been unused.

Second: As so often happens in declining mining districts, litigation over the ownership of claims has prevented some mines from being worked.

Third, and by far the most important of all: Practically all of the rich pyritic ore deposits have been worked out in the oxidized zone. The ores below the ground-water table are of too low tenure, and the treatment costs are too high to allow profitable mining of the gold and silver ores in pyrite and chalcopyrite veins under existing economic conditions. It is safe to say that with the present fixed value of gold, greatly renewed activity in the mining of the Ward region will appear; only, after improved methods of ore extraction plus lower costs of such concentration and extraction have been developed.

MINES

GENERAL STATEMENT

There are about two hundred mines in this region that have produced some ore. Most of these are very small. It is believed that only about fifty have produced more than $5,000 in gross value during their entire history.

Even had it been possible to personally examine every vein opened by the two hundred odd mines of the region, a description of each mine would be of doubtful value in this report, for in most cases the descriptions would be of necessity largely stereotyped in form and would simply amount to a catalogue of the mines of the region.

As has been stated in the preceding pages, it was not possible to examine most of the mines, because they were not being worked and were full of water. Therefore, for this reason and the one suggested in the last paragraph, no attempt will be made to describe each individual mine. But a list of the most important mines will be given, and the reader will be referred to the Mining Reporter, vol. 40, pp. 18-20, 49-50, 65-66, 78-79, 94-95, 1899, for further information; and to the topographic map which accompanies this report for the locations of the various mines.

Certain mines, concerning which definite data were obtained, and which are representative of certain types of ores or of important localities are hereafter described in considerable detail.

IMPORTANT MINES OF THE WARD REGION

(It has been impossible to get complete data regarding the production of all the mines of this region. Some mines that should be included in this list may have been omitted. Mines that have produced more than $100,000 in combined ore values are starred):

Adit
*Baxter
*B. & M.
*Big Five
Boston
Cardiff
*Celestial
*Celestial Extension
Centennial
Chathem
Colorado
*Columbia
Copper Glance
Dew Drop
Dolly Varden
Forest Queen
Giles
Gold Queen
Gov. Routt
Homestake
Humboldt
Idaho
Innspruck
*Madaline
Maid of Erin
Milwaukee
*Morning and Evening Star
Nelson
Newmarket
Orphan Boy
Pennsylvania
Philadelphia
Puzzler
*Ruby
Skandia
Stoughton
*Sullivan No. 5
Texas
*U. P. Group
*Utica
*Ward Rose
*White Raven
Wirth

DESCRIPTIONS OF MINES

RUBY MINE

Location.—The Ruby mine is situated at Sunnyside on Fourmile Creek, about three miles due west of Sunset. Three claims are owned by the Ruby Mining and Milling Company. They are the Little Annie, Iron Cross and Ruby. All are patented. All have well-defined veins.

Geology.—The country rock is coarse grained gneissoid granite. It has been cut by a dark gray felsite dike which strikes nearly east and west. The dike forms the hanging wall of the Ruby vein. The vein is well defined and has been opened on the 100 and 240 foot levels. It is a typical quartz vein which carries pyrite and chalcopyrite with values in both gold and silver. The strongly mineralized portion of the vein is from six to eighteen inches wide, and from this streak smelting ore is mined which runs from $60.00 to $90.00 a ton. Associated with it is from 2 to 4 feet of mill dirt, which is simply more or less mineralized vein material. This carries values of from $2.00 to $14.00 a ton.

Development.—The development consists of a shaft 274 feet long, drifts on the vein of about 1,000 feet, and stopes between certain drifts, 75 feet high and 200 feet long.

Equipment.—The mine is well equipped with shaft house, steam hoist and all necessary buildings and mining machinery.

A small concentrating mill with stamps, classifiers, Card tables and Frue vanners has been operated to treat the milling ore from the Ruby and the Milwaukee mines. Only the low-grade concentrating ores have been so treated.

Production.—The total production from this mine is said to be $120,000.

WHITE RAVEN MINE

Location.—The White Raven property is situated on the north side of California Gulch at an elevation of 8,800 feet, about three-fourths of a mile south of Ward.

Geology.—The country rock is mainly coarse gray granite, but there is some schist. A large monzonite porphyry dike, in places 50 feet wide and about 1 mile long, cuts the granite and forms the hanging wall of the White Raven vein. The dike strikes nearly east and west and dips at angles between 45 and 80 degrees to the north.

Veins.—The vein was formed after the intrusion of the dike. A fracture roughly parallel to the dike and in most places on the contact between the dike and the country rock was made by earth movements. Brecciation of the dike and country rock was extensively developed, and the fracturing and brecciation of the rock was followed by vein filling.

The vein thickens and thins out between the walls from 2 or 3 feet to 14 feet. Small fractures branch out from the major ones and thus increase the opportunities for mineralization between the main vein walls. The main vein strikes nearly east and west and dips on the average 60° North. Between depths of 400 and 600 feet below the surface the dip flattens to 45°.

Shoots.—Much of the ore and most of the richest ore in the mine occurs in shoots which are roughly cylindrical forms in the vein, of large vertical but small lateral extent. Two ore shoots on the tunnel level run together on the next level, 100 feet below, and this is a rather common condition in other cases. On the fifth level of the mine a very large shoot was found. It was 30 feet wide and at least 200 feet long. Running out from these shoots for some distance on either side the ore in the vein is likely to be very rich.

Vugs.—Vugs or "bug holes," as they are called by the miners, are of very common occurrence in the White Raven mine. Wherever there is much brecciation in the vein vugs occur, and in the ore shoots, especially above the 500-foot level, many vugs into which a man could easily crawl are found. The vugs are almost invariably lined with very rich silver lead ore which occurs as galena crystals covered with wire silver.

Ores.—The ores are lead and silver with a little zinc, copper and gold. Lead occurs as galena, usually in large well-formed crystals. Silver is in two forms. It is included in the galena, probably as native silver, often alloyed with gold, and it is also extensively found in the vugs and upper portions of the vein as coatings on the galena in the form of wire silver. In many places the wires of native silver are so close together that they form a thick net over the underlying galena. The length and the diameter of the wires vary greatly. Many wires half an inch long, and with a diameter larger than a coarse hair have been found.

Zinc is not abundant in the mine, but sphalerite ore has been mined in some of the shoots above the 500-foot level, which ran 30 per cent zinc.

Gray copper, tennantite, is found sparingly in the lower levels of the mine. Scarcely any was found between the surface and the 700-foot level, but between the 700-foot level and the 1,170-foot level it has been found in small amounts scattered through the vein. It is apparently increasing in amount with greater depth.

Gold occurs at all levels. It is alloyed with silver and is intimately associated with galena. It is not an important ore compared with lead or silver. Most of the gold has been found near the surface.

Gangue Minerals.—Calcite and barite are the only two important gangue minerals. Pyrite is present in parts of the vein in well-scattered grains, but it is in too small amounts to be at all important. Calcite is found wherever the vein is mineralized. Barite is most abundant in some large vugs and in cavities where free crystallization of ores and gangue was possible.

Order of Crystallization.—The minerals, galena, primary silver and gold were deposited contemporaneously with calcite. Later more calcite was formed, also some barite, and last of all native silver was deposited. When sphalerite occurs it is with the galena. In some cases the order of formation of the minerals, due to enrichment was evidently lead, silver and gold, calcite, silver, calcite and silver.

Ore Values.—In different levels the values are very different. Practically all of the gold has come from the vein east of the shaft at the tunnel level. The total value of gold recovered has been about $20,000. The highest silver values have been above the seventh level. Much silver lead ore has run 10 to 15 per cent lead and 120 to 180 ounces of silver per ton. Some single 20-ton narrow gauge car loads of ore have netted more than $5,000. With the present 25-ton mill it is stated that it is not uncommon to have clean ups at the end of the day worth $5,000. Zinc ore shipments selected have run 30 per cent metallic zinc, and many selected lots of galena ore have carried as much as 66 per cent lead. The average tenure of shipping ore has been 100 ounces of silver and 10 per cent lead to the ton.

Development.—The White Raven property includes the White Raven, and White Raven Extension claims. The owners of these claims also control the Black Jack, Cross and Gray Bird claims which lie just west of the White Raven claims and which are on the White Raven vein.

Some development work, both by tunnels and shafts, has been done on all of these claims, but most of it has been confined to the White Raven Extension.

On this claim a cross-cut tunnel has been run in 400 feet to cut the vein. At the tunnel level a drift extends 1,000 feet east. A shaft extends up to the surface, and the main shaft which goes down on the vein was begun at this level. The hoist is inside the mine. The tunnel level is about 200 feet below the surface of the ground.

A shaft has been sunk below the tunnel level for a distance of 800 feet measured on the dip of the vein which averages about 60° North. Drifts have been run as follows (the levels are numbered, beginning with the first below the main tunnel):

Level 1	46 feet west from the shaft
Level 2	76 feet west from the shaft
Level 3	54 feet west from the shaft
Level 4	85 feet west from the shaft
Level 5	185 feet west from the shaft
Level 6	246 feet west from the shaft
Level 7	220 feet west from the shaft
Level 8	275 feet west from the shaft
Level 9	275 feet west from the shaft
Level 10	285 feet west from the shaft

All of these have been run out to the apparent limit of the ore bodies, but the vein continues west. In addition, a drift was run 125 feet beyond the ore on the ninth level and drifts were run about 700 feet east of the shaft on the third and sixth levels. The variation of the strongly mineralized portion of the vein is indicated by the amount of drifting to the west at the various levels. On the eighth level a new winze was started which has now been carried down 270 feet measured on the dip.

Equipment.—The White Raven mine has first-class equipment, which consists of the necessary living quarters and mine buildings and a full electric equipment of mining machinery. The hoists are electric and are housed within the mine. The mill will be described in a later section.

Production.—The mine was not extensively developed until 1913. Since that time it has produced about $800,000 worth of ore, chiefly lead and silver. About 1,000 ounces of gold valued at $20,000 has been mined, and the values of zinc and copper have been still smaller.

BIG FIVE MINES

Without attempting to describe the properties in detail, attention is called to the group of mines now owned by the Big Five Mining and Milling Company of Denver.

This company is the largest property owner at the present time in the Ward region. It owns 42 claims, including 8 mill sites. Nearly all of the claims are in a group, which extends from the Columbia vein on Niwot Hill across California Gulch, where the mill and main mine buildings of the Big Five Company are located, on to the south for some distance to include most of the claims in the old mining camp known as Frances. The six Columbia claims and the Queen, Helen C, Gold Crown, Adit, and Dew Drop are some of the important ones in this group.

The Adit tunnel, which starts at the Big Five mill in California Gulch, runs west 4,000 feet to cut the Gold Crown Extension, Dew Drop and intervening veins. It branches at the Helen C claim, and a cross cut extends north 3,000 feet to the Niwot winze on the Columbia vein. Drifts then run 2,000 feet east and 800 feet west on this vein, so that the total development at the Adit tunnel level is nearly 10,000 feet.

In addition to these workings there is a raise from the Adit tunnel to the Dew Drop tunnel level of 300 feet, and the Niwot winze is sunk below the Adit tunnel to a depth of 450 feet on the dip of the vein which is 45° North.

The Dew Drop vein has been opened on its tunnel level for 1,000 feet and some stoping has been done. The ore is a heavy chalcopyrite-quartz gold ore which assays about $10.00 a ton in gold. Very large quantities have been blocked out.

The Niwot shaft is cut by the Adit tunnel at a depth of slightly less than 500 feet. Extending out from the Niwot winze, below the Adit tunnel are drifts as follows:

At 100 feet	east 100 feet
At 200 feet	east and west together 100 feet
At 300 feet	east 150 feet
At 400 feet	east 200 feet and west 100 feet
At 450 feet	east 40 feet and west 60 feet

By means of the Adit tunnel a large amount of ground has been opened and partially developed.

The equipment of this company is complete and modern. The main tunnel is well built and designed to handle a large tonnage from the veins which it cuts.

A 50-ton concentrating mill has at various times been operated by the Big Five Company. It consists of crushers, roll mill and Wilfley tables.

The total production of the properties now owned by the Big Five Company is about $6,000,000. Much of it was obtained from the Niwot and Columbia mines before the present company was organized.

NIWOT AND COLUMBIA MINES

Big Five Mines

It has not been possible to examine these properties in detail, but it would not be proper to prepare a report on the Ward district without some reference to these mines which have been the greatest producers of gold in the entire region.

Location.—The mines are situated near the top of Niwot hill about half a mile west of Ward on the very remarkable Columbia vein which extends eastward from the top of Niwot hill for more than a mile. On this vein are the Niwot, Columbia, Madaline, Sullivan No. 5, Baxter, Boston and Utica mines, all of which have been large producers.

Geology.—The vein is on and near the contact of a white felsite porphyry dike and granite. In places the granite is gneissoid and occasional areas of schist are also found. The vein is large and continuous. In places it is 12 or 14 feet wide. The vein minerals are quartz and pyrite, which carry in the oxidized zone, much free gold and considerable silver. Below the ground-water level the gold is combined with the other vein minerals.

Development.—Part of the development of the Niwot is included in the preceding discussion of the Big Five mines. It has an inclined shaft 950 feet long which reaches a vertical depth of 800 feet. Drifts at regular levels and considerable stoping have thoroughly opened the vein. The Columbia shaft is about 400 feet long on the incline and drifts total about 1,000 feet.

Production.—These two mines have produced nearly half of the values from the whole Ward region. The portions of the vein near the surface are now largely worked out, but there is still much ore at lower depths.

Equipment.—No buildings are left on the Niwot ground, but the winze is worked from the Adit tunnel. There is a shaft house and hoisting machinery at the Columbia mine, but air for drilling, etc., is furnished from the Big Five power house in California Gulch.

NELSON MINE

Location.—This mine is a short distance east of the Newmarket and Humboldt, and near the Colorado and Gold Queen on the hill north of Ward.

History.—It was one of the first mines to be located in the Ward district and it has been worked intermittently ever since, but between 1902 and 1915 little mining was done.

Geology.—The geology of the region is very simple. The rock is mica schist with some gneissoid granite, which probably represents granite intrusions into the schist before the metamorphism. There are Tertiary dike rocks in or very near the mine. The dip of the schistose planes is practically the same as that of the vein, namely 65° to 75° N. 15° E.

The vein is a fissure in the schist. It strikes N. 75° West. The walls are well defined and are ordinarily from 3 to 5 feet apart. The gangue is largely quartz and sericite.

Ore.—The ore is quite typical of that of the Ward region. It is a gold ore, in pyrite. Chalcopyrite and wolframite are irregularly associated with the pyrite. Wolframite is largely confined to the east end of the vein on the 60 and 150-foot levels. Practically no tungsten has been found below the 150-foot level.

The gold ore occurs largely in pockets in the vein. The mineralized portion of the vein entirely pinches out in some places and widens to 18 or 20 inches in other places.

Faults.—A fault, which strikes nearly north and south and dips at a high angle to the east, cuts all the veins a short distance west of the shaft. The west end of the vein has been moved to the north eight feet horizontally by the fault. Practically all gold and silver and tungsten values disappear west of the fault, which indicate that the fault preceded ore formation, and that the mineralized solutions were diverted by the fault plane.

Production.—Ore values of about $75,000 in gold and silver have been produced altogether. More than half of this amount came from pockets near the surface of the ground, for this mine, like most of the others in the Ward region, has produced more and richer ores from the oxidized zone than below the ground-water level. All of the ore mined has been smelting ore which, when well sorted, ran from $20.00 to $80.00 a ton in gold. The small size, and the irregularities of the vein, together with the low gold content below the ground-water level do not make this mine an attractive proposition for future development.

Development.—The development is as follows: One inclined shaft 450 feet long on the dip of the vein. Drifts on the vein at 60, 150, 250 and 450 feet. Total drifting 800 feet. A small amount of stoping above the 150-foot level.

Equipment.—The Nelson is equipped with a good shaft house and shop, and a steam hoist, with the regular necessary mining tools and other machinery.

MORNING AND EVENING STAR MINE

(This statement is based upon notes kindly furnished by R. D. George, who examined the mine in 1911.)

Location.—The property consists of three claims, The Morning Star, Evening Star and Emelina, which are situated in Spring Gulch about one mile east of Ward.

Geology.—The rock in the vicinity of the mine is mainly gneiss and granite. Some blocks of schist are encountered but they are not large in proportion to the whole volume of the country rock along the veins. Felsite porphyry dikes are found in the mine.

Veins.—There is no obvious relationship between the veins and the felsite porphyry dikes of the region, although in some places veins follow or cut the dikes. The veins are strong and continuous. The walls stand up well and need comparatively little timbering. Two well-defined veins are found, namely, the Morning Star and the Evening Star. The Emelina is a faulted portion of the Morning Star vein. Several subordinate veins have been encountered. The strike of the veins is nearly east and west.

Ore.—The usual quartz veins of the Ward region, which carry pyrite and some chalcopyrite with gold values, are typical of this mine. The smelting ore shipped from these veins has been of high grade.

In addition to the ordinary sulphide ore, on the 300-foot level, a rich body of telluride, native gold and sulphide ore was struck. Some of this ore ran 54 ounces to the ton.

The ore is more continuous and much less ''pockety'' in this mine than in many others, and the reserves are believed to be large.

Development.—The total amount of development done, in shafts, tunnels and drifts is about 6,000 feet. There are two shafts, one 300 feet and the other 210 feet deep. Continuous stopes of considerable length from the 200-foot level to the surface indicate the continuity of the ore bodies.

Production.—The total production of this mine is about $600,000. Smelting ore values run up to $90.00 a ton. Mill dirt carries values of from $3.50 to $14.00.

Equipment.—The mine is equipped with fairly modern machinery, including a hoist good for 500 feet, three boilers, one 100, one 50 and one 30 horse-power, two engines of 30 and 15 horse-power respectively, and a Norfolk compressor.

There is a 10-stamp concentrating mill on the property, which is equipped with amalgamation plates, Blake Crusher, 2 Wilfley tables and one Frue vanner.

ALASKA (BRAINERD) TUNNEL

The portal of this tunnel is at Camp Talcott, on Lefthand Creek, about one and one-third miles southeast of Ward.

On account of the large amount of water in the mines on Utica hill, and because of the strong possibility of cutting valuable veins, it was decided to start a tunnel on Lefthand Creek, which would, when completed, drain the mining region east of Ward.

The linear distance from the tunnel site to the center of Utica hill is about 3,200 feet. The vertical difference in elevation is almost exactly 1,000 feet. The tunnel has been driven about 2,500 feet and is, therefore, still 700 feet from its goal. Shafts were sunk on Utica hill more rapidly than was expected and the B. and M., the deepest mine in the region, is now not more than 200 feet above the tunnel level.

No important veins were encountered, and because of this fact, and due to the decline of mining in the Ward region, work on the tunnel was long ago discontinued.

NATIONAL TUNGSTEN COMPANY CLAIMS

Location.—About half way from Gold Lake, south to Spring Gulch, a group of claims has been developed for their wolframite content. The claims are: Midnight, Last Chance, Jumbo, Jumbo Extension, Pugh, Josephine, Annie S., Jay Bird, and a mill site at the foot of the hill in Spring Gulch.

Geology.—The rocks in the region are granite, and mica dacite porphyry dikes. The dikes seem to have no relationship to the occurrence of the tungsten.

When the claims were visited two veins had been prospected. Wolframite occurred in both, in small amounts. The veins are fissures in the granite. Quartz is the important gangue. Pyrite is not abundant.

The width of the veins varies from 1 to 3 feet. The tungstic oxide content of samples taken across the veins in different places ranges from 2 to 10 per cent. A small concentrating mill with electric power and equipped with crushers, a ball mill, jigs, Wilfley and Card tables was erected to handle the ores, but so far as can be learned little ore was actually treated, due to the decline in the price of tungsten soon after the mill was completed.

CONCENTRATION AND EXTRACTION OF ORES

HISTORICAL OUTLINE

The processes and problems of ore treatment have become increasingly complicated and difficult as greater depths in the mines have been reached, and as costs of labor, transportation and supplies have increased.

In the early 60's and for a number of years thereafter nearly all of the ore produced in the Ward region, was free milling in nature. That is, it came from veins near the surface of the ground, in which most of the sulphides had been oxidized, and the gold was left in a free state in cavities of the veins. All that was necessary, then, in order to save the gold was to break up the ore by stamps which weighed from 650 to 1,000 pounds each, wash the powdered material over amalgamation plates, and the quicksilver caught the gold.

When the veins were mined to a greater depth, massive sulphide ores were encountered. These ores could not be concentrated and the gold obtained by the simple stamp mill, amalgamation method. But with the introduction of smelting methods, it became a common practice to sort the ore and send high-grade sulphides to smelters which were operating at Blackhawk and Denver. This method is still in use.

However, only the ores of relatively high value could stand the mining, transportation and smelter charges and yield a profit. Much valuable ore of lower grade was wasted. It could be only thrown out on the dump, or left in the stopes of the mines. To make greater savings, therefore, concentrating mills were developed. At first stamps were used to break up the ore and gangue minerals, but modern processes have discarded stamps and substituted jaw crushers, and roll mills, or in some cases ball mills. After being crushed the ore is broken up in one of these type of mills. Then it is carried by water over Wilfley and Card tables, and in most cases, Frue vanners, or some other form of blanket tables or "rag plants."

After the crushed material leaves the roll or ball mills or stamps as the case may be, the processes of concentration are based on the fact that the sulphide minerals that carried the precious metals, and also those metals in the free state have a much higher specific gravity than quartz and the rock-making minerals of the country rock. Therefore, when the ore is properly crushed so as to separate it from its gangue and the crushed material is passed over properly constructed and operated tables, the ore and the other minerals are separated.

Jigs are now being employed in some mills. They take some of the classified material that comes from the crushers, and other material that has passed through coarse rolls or ball mills.

Concentrates made by these gravity processes on jigs, tables and vanners are shipped to the smelters as are the high-grade ores.

Later, cyanide plants were introduced. Smelting charges were high, as were transportation costs. It became known that cyanide solutions would dissolve gold, and therefore, in some cases, in conjunction with the gravity processes just described, and in some cases independently, cyanidation treatment was used. This, too, however, is not inexpensive, and difficulties are involved in properly agitating the ore in the solutions so that all the gold may be attacked and eventually dissolved by the cyanide solution.

These processes with many modifications have been tried in the Ward region. None have solved the problem of extracting at a profit, the values from the solid sulphide ores mined well down below the ground-water surface, when such values have been less than $18.00 or $20.00 to the ton of ore.

There are thousands and probably millions of tons of sulphide ore in the Ward region which carry values in gold and silver of from $6.00 to $15.00 to the ton. Eventually they will be mined and milled at a profit.

LIST OF MILLS

The following list includes all the mills that are known to the writer to have been operated in the Ward region. Only one, the White Raven, is at present in operation, and it is the only one that will be described in detail. Those starred are now dismantled.

Name	Location	Type of Ore	Process
Bean Brothers	Spring Gulch	Tungsten	Roasting
*B. & M.	Utica Hill	Gold-sulphide ore	Concentration
Big Five	California Gulch	"	"
Conqueror	Foot of Ward Hill	"	Concentration, Amalgamation
*Giles	Mouth Peck Gulch	"	"
Golden Slipper	Puzzler	"	Cyanidation
*Humboldt	North of Ward ½ Mi.	"	Concentration
Lois	West of Ward 1 Mi.	"	"
Lulu B (Utica Hill)	Utica Hill	"	Cyanidation
Modoc	Duck Lake	"	Concentration
Morning and Evening Star	Spring Gulch	"	"
New Market	Ward	"	"
*Niwot	Niwot Hill	"	Free milling (Amalgamation)
National Tungsten Company	Spring Gulch	Tungsten	Concentration
Ruby	Sunnyside	Gold-sulphide ore	Amalgamation
*Stoughton	Ward	"	"
*Telegraph	North of Ward 1 Mi.	"	Concentration
*Utica	Ward	"	"
White Raven	California Gulch	Lead-silver	Concentration and Flotation

WHITE RAVEN MILL

The only mill at present operating in the Ward region is the White Raven.

This mill was completed and put into operation in September, 1919, and has been running ever since with (until August, 1920) two shifts a day.

The mill is a combined mechanical concentration and flotation plant. Its capacity is 25 tons of ore a day. It was built primarily in order that the dump might be milled, but since the railroad between Boulder and Ward has been junked it has been, and will in the future be used to concentrate all but the richest ore that is mined.

The milling methods are simple but effective. The ore is crushed by a Blake jaw crusher, elevated and classified. Everything less than one-fourth of an inch in diameter goes to a Richards jig, over that size to the large Improved Standard Roll mill. From the rolls the coarse ore goes to the jig and the fine to a Wilfley table. Overflows from the jig and seconds from the Wilfley go to a fine Standard roll, then to a Card table. The overflows from the Wilfley and Card tables go to a Barr flotation cell in which practically all of the remaining values are recovered.

Nearly all of the fine wire silver is caught on the Wilfley table. There are only small amounts of gold and zinc and only traces of copper in the ore. Pyrite is absent, and the concentration problems are, therefore, not difficult.

Two men on a shift run the mill. The cost is $2.00 a ton. It is stated that over 95 per cent of the assay values of the ore are saved.

The jig concentrates, and those from the tables and flotation cells are dried and shipped by truck to Boulder, where they are sampled separately and sold.

PRODUCTION

It has been impossible to get accurate figures of the production of the mines of the whole Ward region.

The U. S. mint reports and the U. S. Geological Survey Mineral Resources, give Boulder County production for certain years by districts. Nearly all of the Ward region is included in the Ward district, but the mines near Sunset are included in the Sugarloaf district.

According to the reports mentioned in the preceding paragraph, Boulder County produced in the years 1885 to 1903 inclusive, gold and silver valued at $8,321,418, and the Ward region produced slightly less than 24 per cent of this amount, or almost exactly $2,000,000.00.

Between 1904 and 1915, inclusive, Boulder County produced, according to Mineral Resources, $2,906,184 in gold, silver, lead and copper. Of this amount the Ward district produced almost exactly 20 per cent, or $581,236.

Since 1915 the production of the Ward region has been approximately $600,000. This gives a total production since 1885 (disregarding lead and copper before 1904) of $3,181,236, for all the mines in this region. Definite figures of production before that year are lacking, but probably greater mineral values were produced before than have been produced since that date.

Another set of estimates has been made from all available sources but largely by a group of men who have been long connected with the mining industry in the Ward region. Some data have been taken from the Mining Reporter for 1899. Nearly all the estimates were checked by at least two men and they are believed to be reliable.

The total ore value of the 30 largest producers in the region has been thus estimated at $7,799,000. No mine whose estimated production is less than $5,000 has been included in this list. There are a larger number of small mines that have produced some ore and the total value of all the ore produced in the Ward region up to the present time is conservatively estimated to be $9,000,000. By many this is regarded as 25 per cent too low.

FUTURE PRODUCTION

The future production of the Ward region is most uncertain, but it is the writer's opinion that this region is by no means "worked out."

PYRITE ORES

It is known that great bodies of low-grade sulphide ores are blocked out in the Dew Drop, Columbia, Utica, B. & M., Stoughton and many other mines, whose veins are both large and continuous. The total amount of such ore is not known, but it probably runs into the millions of tons.

ORE WITH DEPTH

Some doubt has been expressed by various miners and prospectors as to the continuance of the ore bodies with increasing depths below the surface of the ground. It is, of course, evident that enriched ore bodies of the nature of those in this region will disappear with depth, but there is nothing in the geology of the region to indicate that the primary minerals of gold, silver, lead and copper may not be found at much greater depths than have yet been reached.

MORE PROSPECTING

More prospecting should be done along the monzonite porphyry dikes, especially those that are near the foot of Saw Mill hill and in California Gulch, for it is very probable that other ore deposits, similar to those of the White Raven mine exist, and may be found by careful prospecting.

BETTER METHODS OF CONCENTRATING ORE

Until improved methods of concentrating the low-grade gold and silver ores are devised these mines must remain closed, but such methods certainly will be eventually developed. Flotation already seems to be pointing the way toward the desired processes of concentration. If it proves to be as successful as imperfectly completed experiments would indicate that it may be, it will do much to solve the present problems, and this or some other process will bring the Ward region into a new period of production and prosperity.

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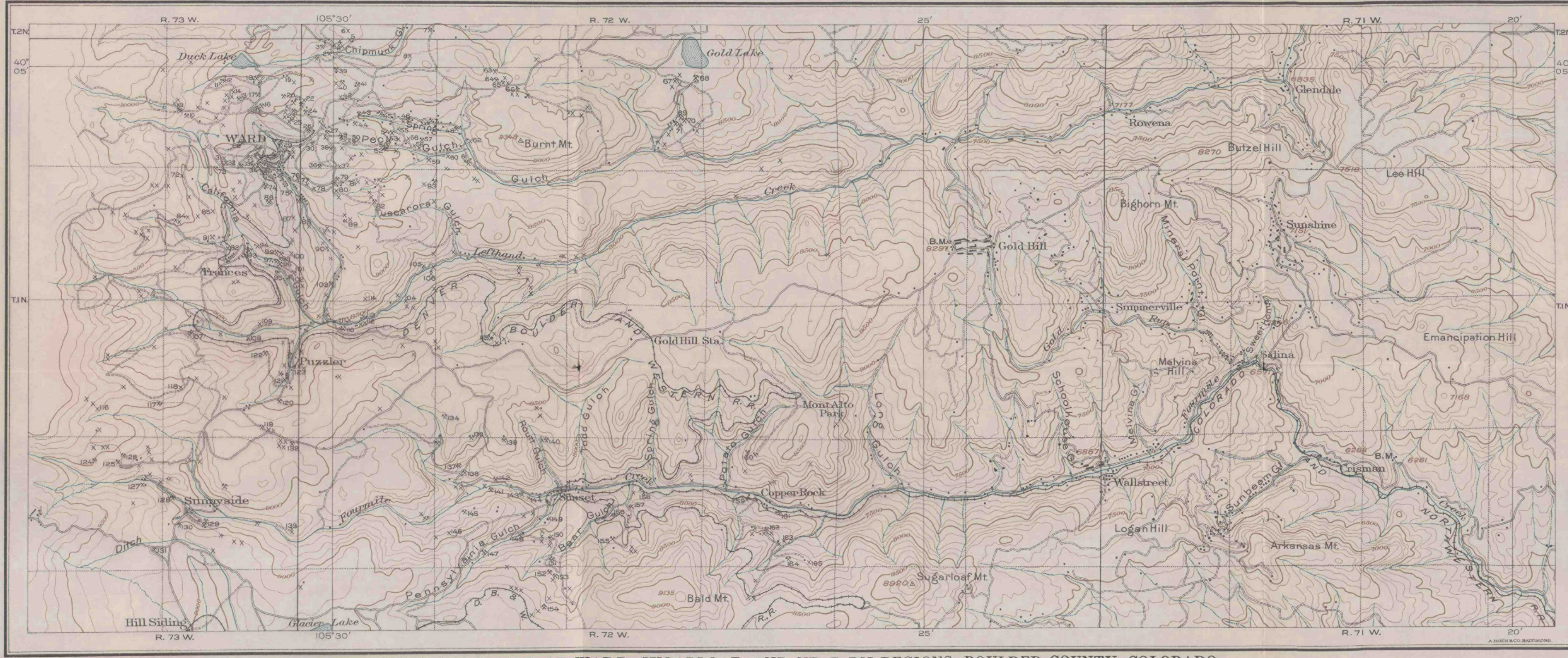

Topography east of 150°30' by U. S. Geological Survey and originally published on the scale of 1:62500
Surveyed in 1902
Topography west of 105°30' by P. G. Worcester
Surveyed in 1910-11
The culture of the U. S. Geological Survey map of the west two-thirds of R. 72 W. has been modified by P. G. Worcester

TOPOGRAPHIC MAP OF WARD, SUGARLOAF, AND NEAR-BY REGIONS, BOULDER COUNTY, COLORADO

Scale $\frac{1}{62500}$ or approximately $1\frac{1}{2}$ inches to 1 mile

2 Miles

3 Kilometers

Contour interval 100 feet

Datum is mean sea level

MINES

1 Sound Currency
2 Sound Currency
3 White Pine
4 Diagonal
5 Mountain View
6 Mountain View
7 Orinoco
8 Bertha
9 Lois
10 Sunny View
11 Cardiff
12 Gold Coin
13 Boulder County
14 Lake Shore
15 Pride of Ward
16 Gold Crystal
17 Humboldt Ext.
18 Modoc
19 Honest John
20 Grand View Sh.
21 Texas Sh.
22 Texas Tun.
23 Grand View Tun.
24 Humboldt
25 Comstock
26 New Market
27 Golden Queen
28 Stoughton
29 American
30 Bluebird
31 Niwot
32 Madeline
33 Columbia
34 Sullivan (No. 5)
35 Baxter
36 B. and M.
37 Oldenburg
38 Colorado
39 Pride of the West
40 Red Cloud
41 Forest Queen
42 Telegraph
43 Telephone
44 Kansas City
45 Celestial
46 Celestial Ext.
47 Morning Star
48 Emilina
49 Chatham
50 Nelson
51 Lake City
52 Denver
53 Jolly Tar
54 Silver Dollar
55 George Washington
56 Calambia
57 Innspruck
58 Norwegian
59 Scharnitz
60 Giles
61 Little Giant
62
63 Mountain Queen
64 Camera
65 Klondike
66 Connoton
67 Sulphide
68 Plymouth Rock
69 Last Chance Tun.
70 Last Chance Sh.
71 Midnight Tun.
72 Nimbus
73 Baltimore
74 U. P. Sh.
75 U. P. Tun.
76 Buston
77 Utica (Lower)
78 Utica (Upper)
79 Lulu B.
80 Oklahoma
81 Superior
82 Idaho
83 Polar Star
84 High Line
85 Gold Chief
86 Gold King
87
88
89
90 Tarbox
91 Dew Drop
92 New California
93 Adit
94 Cornicopia
95 Philadelphia
96 Cross Tun.
97 Cross Sh.
98 Gray Bird
99 Black Jack
100 Village Bell
101 White Raven
102 White Raven Ext.
103 Empire No. 3
104 Moltke
105 Brainard Tun.
106 Bismark
107 Bloomer Tun.
108 Parole
109 Golden Slipper
110 Yellow Aster
111 Col. Dick
112 Leviathan Group
113 Northwestern
114 Ward
115 Holt
116 Gold Drop
117 Copper King
118 Red Lion
119 Ward Rose Sh.
120 Ward Rose Tun.
121 Johannsburg
122 Protection
123 Puzzler
124 Emma Daniels
125 Milwaukee
126 Atlantic
127 Pennsylvania Gr.
128 Silent Friend
129 Ruby
130 Morning Glory
131 Black Diamond
132 Homestake
133 Cumberland
134
135 Moonlight
136 Star
137 Bluebell Sh.
138 Bluebell Tun.
139 Scandia
140 Gov. Routt
141 Centennial Tun.
142 Copper Glance
143 Continental
144
145 Centennial Sh.
146 Mammoth
147 Dolly Varden
148 Bismark
149 Free Coinage Tun.
150 Free Coinage Sh.
151 Canton Tun.
152 Canton Sh.
153 Golden Chest
154 Culebra
155 Lee S. Sh.
156 Lee S. Tun.
157 Meadow Lark Sh.
158 Meadow Lark Tun.
159 Shelton Tun.
160 Don D.
161 Orphan Boy
162 Orphan Boy
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164 Sunrise
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