STATE OF COLORADO

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES

SPECIAL PUBLICATION 2

GEOTHERMAL RESOURCES OF COLORADO

BY

RICHARD HOWARD PEARL

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

1972

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ABSTRACT

The United States is facing a serious energy crisis. It is estimated that the electrical requirements of the United States will reach 5.8×10^{12} kwh by 1990. It is also estimated that the energy requirements of Colorado will grow from 11,743 Gwh in 1970 to 58,221 Gwh Gwh in 1990. Most of the future electrical power will come from conventional generating plants, however a large share will have to come from other sources such as nuclear and geothermal generating plants.

Geothermal resources--the natural heat of the earth's interior--has been increasingly used since the start of the century to generate electricity. The present worldwide geothermal generating capacity has reached nearly 900,000 kw and will probably increase 10 fold in the near future.

The quantity of heat above surface temperature stored in the outer 62 miles (100 km) of the earth's crust is equivalent to 2×10^{22} kwh, or the heat content of 3×10^{18} short tons of coal. The flow of heat from the earth's interior, measured at the surface, occurs at the rate of 1.5×10^{-6} cal/cm^2/sec. While most of the heat energy in the crust is too diffuse to be considered a potential resource, significant concentrations of geothermal energy do occur in local "hot spots". Many of the anomalous high heat flow areas occur in regions that have experienced late Tertiary and Quaternary volcanism and mountain building. The deeper parts of many sedimentary basins also contain some local "hot spots". Associated thermal springs commonly issue from faults along the margins of the volcanic areas, however some of them may be related to volcanism that occurred miles away.

Exploration for a commercial geothermal reservoir is similar to that for metalliferous mineral and hydrocarbon deposits, and involves common geological, geophysical, and geochemical techniques.

The geothermal resources of Colorado are indicated by 113 thermal springs and wells having a temperature in excess of 21°C (70°F). . While these thermal springs and wells are located throughout the western half of Colorado, most of them are located in the southern Rocky Mountains of southwestern Colorado.

In 1965 Lewis (1966) measured the temperature, discharge, and specific conductance of 35 of these 113 thermal springs. From 1968-1970 Mallory and Barnett (1972) sampled and chemically analyzed 21 thermal springs and wells. Thus a total of 41 thermal springs and wells have been remeasured since 1965. The chemical analyses, temperature, and discharge of these 41 selected thermal springs and wells is presented. The temperature of the waters varies from a low of 21°C at Eldorado Springs to a high of 84°C at Hortense Hot Spring. The waters of the 41 thermal springs and wells issue from rocks ranging in age from Precambrian to Tertiary, of various composition, and under all types of geologic conditions. A brief description of the geologic conditions of the area immediately surrounding the 41 springs and wells is presented.

The 16 published surface or near surface measurements of the flow of heat from the interior of the earth in Colorado have been compiled and are given. The measurements vary from a low of 1.4 H.F.U. at Yellow Creek in the northwest part of the state to a high of 3.7 H.F.U. at Ouray, Colorado in the San Juan Mountains.

ACKNOWLEDGMENTS

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GEOTHERMAL RESOURCES

INTRODUCTION

From earliest recorded times man has noticed surface manifestations of heat coming from the depths of the earth, such as geysers, hot springs or steam, and has attempted to put this heat to beneficial use. In Colorado these waters have been used for bathing, medicinal and agricultural purposes over the last 100 years. In recent times, wells have been drilled in close proximity to some of these features in an effort to tap this heat. In an increasing number of cases in various parts of the world, these efforts have met with success. The steam and/or hot water obtained from the wells have been utilized for agricultural purposes, to generate electricity, to heat buildings and for recreational purposes. Research and development are now being pursued to desalinate geothermal fluids for fresh water and mineral extraction.

Geothermal resources, the natural heat, steam and hot waters of the earth's interior, can be utilized to generate useful forms of energy. With the worldwide increased usage of electricity more and more attempts have been made to use geothermal energy to generate electricity. The first geothermal generating plant was constructed at Larderello, Italy in 1904. In 1958 electrical power from geothermal heat was generated commercially at Wairakei, New Zealand. In 1960 at The Geysers, California, the first commercial steam generating plant in the United States went into operation. It is anticipated that by 1974 The Geysers will have a total generating capacity of over 500,000 kw (Bruce, 1971; and Grose, 1971).

At the present time, worldwide geothermal generating capacity has reached nearly 900,000 kw and probably can be increased at least ten fold under current economic conditions (Grose, 1971).

With the use of electricity doubling every ten years, the United States is facing a serious energy crisis. It has been estimated by the Upper Colorado Staff and Work Group Chairmen (1971) that the electrical requirements of the United States will increase from 1.53×10^{12} Kwh in 1970 to 3.1×10^{12} Kwh in 1980 and 5.8×10^{12} Kwh in 1990. The Public Service Company of Colorado has made projections for Colorado's future power needs through the year 1990, with the historic demands they are:

(J. W. Martin, personal communication, 1972)

1960	5,559 Gwh
1970	11,743 Gwh
1980	28,480 Gwh
1990	58,221 Gwh

As in the past, most of the future electrical energy will be generated by conventional coal, oil and gas fired plants and hydrolectrical plants. However, with the increased demand, declining fossil fuel reserves, and environmental concerns, major new sources of electrical power, such as nuclear and geothermal, will have to be considered. Technological developments in the last few years has made electricity generated from these sources competitive in cost with electricity generated from the other sources (Horvath, J. C. and Chaffin, R. L., p. 30).

GEOTHERMAL ENERGY

The earth as a whole, is a tremendous reservoir of thermal energy; however, most of this heat is too deeply buried or too diffuse to be considered as an energy source (White, 1965). The quantity of heat, above surface temperature, stored in the outer 100 kilometers (km, 62 miles) is equivalent to approximately 2×10^{22} kwh or the heat content of 3×10^{18} short tons of coal (White, 1965). The flow of heat from the interior of the earth measured at the surface, occurs at an average rate of 1.5×10^{-6} cal/cm^2/sec. (1.5 heat flow units, HFU).

While most of the heat in the earth's crust is too diffuse to be considered as a potential energy resource, economically significant concentrations of geothermal energy do occur in local "hot spots" where high temperatures (66°C to 343°C) are found in porous rocks containing water and/or steam (Godwin and others, 1971). These anomalous high heat flow areas are generally found in regions of recent volcanism and mountain building and in the deeper parts of many sedimentary basins. In these areas, the flow of heat may be many times the average; for example, the Imperial Valley of California has a heat flow of 3.0 HFU (Von Herzen, 1963) and the Fire Hole Geyser Basin of Yellowstone Park has a heat flow of 67 HFU (White, 1970). The highest measured heat flow in Colorado, 3.1 HFU, was measured at Ouray, Colorado (E. Decker, 1972, personal communication).

The normal geothermal gradient in the crust of the earth (rate of temperature increase with depth) will vary from about 1°Celcius (centigrade) per 100 feet (Bowen, 1972) to 1°Celcius per 160 feet (White, 1965) (plate 1). In geothermal areas the gradient is often several times the "normal" rate. For example, at the Geysers area in California, steam at temperatures of about 240°C is reached at 3,000 to 4,000 feet. This is a geothermal gradient of 6 to 8°C per 100 feet, or 6 to 8 times the world normal (Bowen, 1972).

White, 1965 and Grose, 1971 pointed out that a geothermal reservoir, to have any potential for exploitation, must meet the following requirements: (1) Relatively high temperatures; (2) Reservoir volume of several tens of cubic kilometers; (3) Reservoir at depths shallow enough for economic drilling; (4) Permeability of rock great enough to allow the water or steam to flow continuously at high rate and to allow recharge; (5) Trapping mechanism such as a low permeability caprock or a hydrostatic trap; (6) Reservoir fluids that do not contain undesirable amounts of dissolved solids such as salt, silica, calcite, arsenic and boron; and (7) A geothermal energy source large enough to maintain energy supplies for 20-30 year electrical generation plant life.

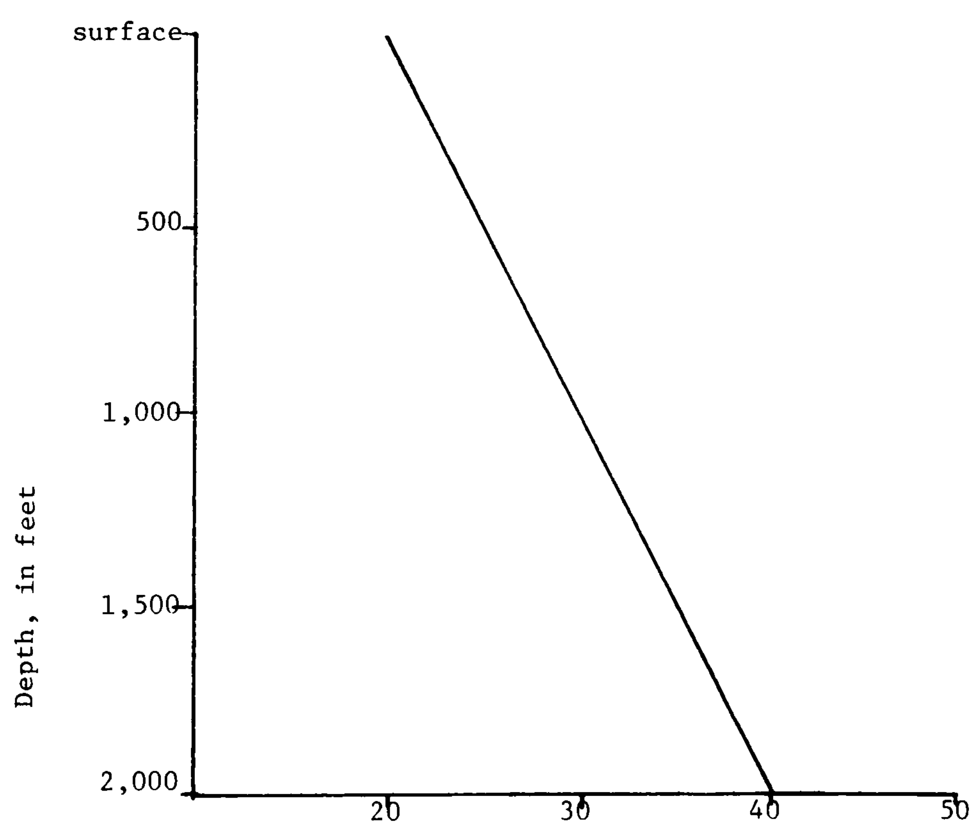

Plate 1. Normal geothermal gradient

White (1965) classified areas having above average geothermal gradients into three types: (1) Areas in which the geothermal gradient is significantly higher than "normal" but where notable hydrothermal activity is absent; (2) Areas of hot springs; and (3) Areas that have little or no surface thermal expression but have high temperature fluids retained beneath low permeability caprocks. White (1965) felt that because of their ease of identification, types 2 and 3 offer the greatest immediate possibilities for economic development.

The heat energy in a geothermal reservoir consists of the heat stored in the rocks, water, and/or steam filling the pores and fractures in the rock (Godwin and others, 1971). Brines, water and steam are the principal agents by which most of the heat is either transferred to depths shallow enough to be reached by drilling or allowed to escape at the surface in the form of springs and fumaroles (Godwin and others, 1971).

Either dry or wet steam may be found when exploratory wells are drilled to tap a geothermal heat source. In rare cases, such as in the Larderello area of Italy and The Geysers area of California, dry steam, unaccompanied by liquid water, is found. Dry steam reservoirs are characterized by the purity of the steam, temperatures that range from 230^{o}C to 250^{o}C, and reservoir pressures that are subnormal, ie 32 to 35 kg/cm^2 (White, Muffler, and Treusdell, 1971). The usual case however is to find a reservoir of superheated water whose composition ranges from pure water to brine. The temperature of the water usually ranges from 66^{o}C to 360^{o}C and the reservoir pressures are normal to slightly higher than normal hydrostatic (Godwin and others, 1971; White, Muffler, and Truesdell, 1971). When a wet steam reservoir is tapped, due to the rapid drop in reservoir pressure caused by the well bore, some of the superheated water flashes into steam and moves up the well bore. The water not flashed into steam is carried up the well bore along with the rapidly expanding and moving steam. The steam and water then are frequently separated at the well head by a simple centrifugal separator (Goldsmith, 1971).

GEOLOGIC OCCURRENCE OF GEOTHERMAL ENERGY SOURCE

The large geothermal provinces of the world are found in areas that had late Tertiary and Quaternary tectonism and volcanic activity (Grose, 1971; and Waring, 1965). In analyzing the occurrence of the geothermal provinces of the world, Grose, 1971, noted three general environments or associations in which thermal springs occur: they are volcanic and petrologic associations and tectonic environments. Grose (1971) noted that most of the thermal springs occur in volcanic districts which have had volcanic activity in the immediate area. While most of the springs emerge from faults along margins of the calderas or from within the volcano-tectonic graben, some of the springs may be related to volcanism that occurred several miles away. Grose (1971) further noted that in many geothermal areas the (geothermal) reservoirs appear to be more commonly associated with acidic volcanic rocks rather than the more basic types. However, if the rocks are relatively porous and permeable, then the reservoir rocks can be practically any type or age. A sealing cap rock of low permeability and low thermal conductivity is usually essential to maintain a large and deep geothermal energy source. Plate 2 is a generalized illustration depicting the above conditions.

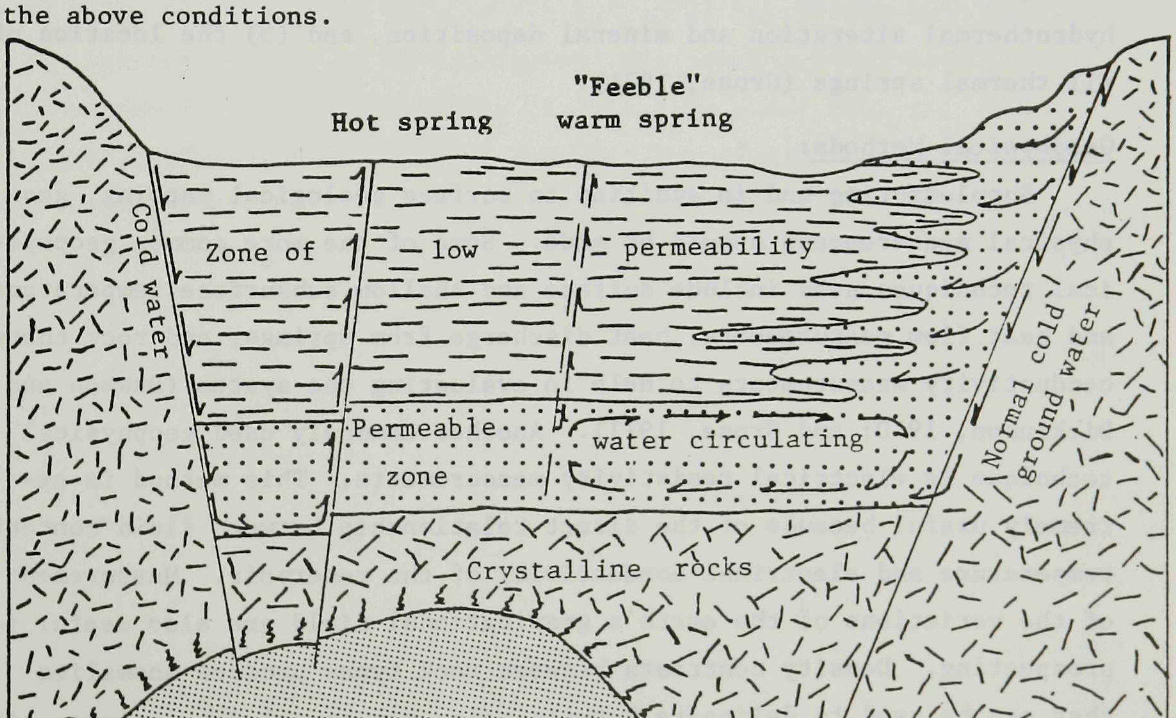

Plate 2. Generalized illustration of geothermal systems. (Modified from U.S. Geological Survey, 1969)

EXPLORATION FOR A GEOTHERMAL RESERVOIR

Exploration for a geothermal reservoir containing commercial quantities of steam and hot water involves an integrated and coordinated program applying many geological, geophysical and geochemical techniques (Grose, 1971; Koenig, 1970). The exploration approach is basically similar to that for metalliferous mineral deposits and oil and gas prospects (Grose, 1971). At the present time exploration efforts are primarily directed to areas of surface heat leakage--such as thermal springs and fumaroles (Grose, 1971). The more commonly applied exploration methods employed are geologic mapping, accompanied by gravimetry and by geochemical surveys (Koenig, 1970; and Horvath, 1971).

Geological Methods:

Surface geological mapping is of prime importance in the exploration for a geothermal energy source. All conventional geologic mapping methods are used, including photogeological and remote sensing techniques to obtain data concerning (1) types and extent of structural features, (2) lithology and extent of porous and permeable beds, (3) the distribution and age of all volcanic rocks in the area, (4) the nature and extent of hydrothermal alteration and mineral deposition, and (5) the location of all thermal springs (Grose, 1971).

Geophysical Methods:

Supplementing and in addition to surface geological mapping, geophysical measurements should be made. Some of the more common geophysical techniques used include surface and shallow subsurface temperature and heat flow measurements, heat discharge from springs, and rock thermal conductivity measurements to help in evaluating the system (Dawson and Dickinson, 1970; and Grose, 1971). Another commonly used geophysical technique is electrical resistivity measurements. This method is extremely useful because of the direct relationship between fluid content, temperature and electrical conductivity of the reservoir. Measurement of the variations of the earth's gravitational field are also useful in prospecting. Density contrasts between rock types produce anomalies that can be used to delineate between major structural depressions, structural highs, and buried volcanic or intrusive rocks, all of which may help in locating a local heat source. Passive monitoring of seismic noise may prove practical in areas of high thermal activity.

Geochemical Methods:

Examination of the geochemical character of thermal springs affords a rapid, preliminary evaluation of the thermal area. Work by White (1965, 1970) has shown that in most cases high-temperature hot-water systems have chloride contents greater than 50 ppm, whereas vapor dominated systems have chloride contents less than 20 ppm. Subsurface temperatures greater than 180°C are implied by deposits of sinter around hot springs and the presence of natural geysers; travertine deposits usually indicate lower temperatures. The dissolved mineral content of thermal waters useful in predicting reservoir temperatures are: silica (probably the best indicator), sodium/potassium ratio; calcium and bicarbonate content; magnesium/calcium, chloride ratios. Papers by White, 1970; Fournier and Truesdell, 1970; Fournier and Rowe, 1966 discuss this matter in considerable detail.

GEOTHERMAL RESOURCES OF COLORADO

INTRODUCTION

The geothermal resources of Colorado are expressed in over 100 thermal springs and wells having a temperature in excess of 21°C (70°F). These springs are located throughout the western half of the state with most of them located in the southern Rocky Mountains in the southwestern part of Colorado (Plate 4).

The first complete inventory of the thermal springs and wells of Colorado was made by R. D. George and others (1920). At that time measurements were made of the temperature, discharge volume and chemical quality for approximately 254 springs and wells. Of the 254 springs and wells investigated, 113 exhibited temperatures in excess of 21°C and are classified as thermal springs.

Prior to 1920 numerous authors studied individual or groups of springs in the state. For a complete list of these authors the reader is referred to the reference section at the end of the paper.

Stearns and others (1937) have described the physical properties of numerous thermal springs in Colorado. Drawing upon previous work, Waring (1965) listed the discharge and temperature of 44 thermal springs in Colorado. In 1966 Lewis revisited 35 of the larger thermal springs measured by previous workers and measured their temperature, discharge, and specific conductance. Starting in 1968, Mallory and Barnett (1972) chemically sampled several new springs and wells, and resampled many of the thermal springs sampled by George and others in 1920.

METHODS OF PRESENTATION OF DATA

The physical properties, such as chemical data, temperature, and discharge, of 41 select springs and wells as reported by George and others, 1920; Waring, 1965; Lewis, 1966; and Mallory and Barnett, 1972, are listed in tables 1, 2 and 3 at the end of the paper. These 41 springs and wells were selected for inclusion in this report as they were the ones resampled and reanalyzed by Lewis (1966) and Mallory and Barnett (1972). The location of the wells and springs are shown on plate 4. The locations of the thermal waters in relation to the surrounding geology are shown on plate 6-11. The wells and springs are located to the closest ¼,¼ section if known. Many of the agencies in the state concerned with ground water follow the well and spring numbering system used by the U. S. Geological Survey, Water Resources Division. Because the system indicates the location in an abbreviated form, it is used in this paper to supplement the previously used consecutive numbering system. For a complete description of the numbering system, the reader is referred to plate 3 near the end of the paper.

USES OF THERMAL WATERS IN COLORADO

Except in a few instances the thermal waters of Colorado are relatively unused. The greatest use of the water is for recreational purposes at such locations as Glenwood Springs and Steamboat Springs. Minor amounts of thermal water are being used for space heating, and domestic and miscellaneous agricultural purposes.

GEOLOGY OF THERMAL AREAS

The thermal springs and wells of Colorado are found throughout the western part of the state in association with: (1) rocks of varying age and type, (2) primarily mountainous area, and not sedimentary basins, (3) faults primarily of late Cenozoic age, and (4) the Rio Grande Rift Zone of south-central Colorado.

SOURCE OF HEAT

George and others (1920) noted that ground-water being heated only by the normal geothermal gradient ($1^{o}C/100'$) to reach the surface with a temperature of $38^{o}C$ would needed to have gone to a depth of 12,500 feet. Those authors believed that it is extremely improbable that most waters could go to such depths under normal conditions. Various explanations have been given for the possible source of the heat for thermal springs, such as chemical activity in the breakdown of metallic sulphides, earth movements, disintegration of radioactive substances, and volcanic magmatic masses at shallow depths. It is believed by most workers that the first three methods might produce heating on a restricted scale but for any large scale development of thermal springs a larger heat source is needed such as a magma mass.

Waring (1965, p. 4) noted that on a world wide basis the most notable feature of thermal springs is their close association with the main belts and areas of volcanoes. This is certainly the case in Colorado where most of the thermal springs are in close proximity to areas of Cenozoic volcanism. Waring (1965, p. 4) also noted that thermal springs are found in areas where there has been geologically recent structural deformation. In many regions of western Colorado, thermal springs are found along or close to fault zones near the edge of mountain fronts.

HEAT FLOW MEASUREMENTS

Sixteen surface or near surface measurements of the flow of heat from the earth's interior have been made in Colorado. As described earlier, the heat from the interior of the earth, as measured at the surface, occurs at an average rate of 1.5×10^{-6} cal/cm^2/sec., or 1.5 heat flow units (H.F.U.). Any measurement in excess of 1.5 H.F.U. usually indicates a geographically restricted heat source at fairly shallow depths. Heat flow measurements should be an intergal part of a geothermal exploration program.

Table 6, at the end of the paper, lists the heat flow measurements in Colorado. Plate 5 shows the location of the measurements. The heat flow values range from a low of 1.4 H.F.U. at Yellow Creek in the Piceance Creek Basin to a high of 3.4 H.F.U. at Ouray, Colorado.

DESCRIPTION OF SELECT THERMAL SPRINGS AND WELLS IN COLORADO

Since 1966, 41 of the 113 thermal springs and wells in Colorado have been resampled and chemically reanalyzed by Lewis (1966), and Mallory and Barnett (1972). The following description of the geographical, geological, and physical properties of these 41 select thermal springs and wells is taken, in part, from the papers by George and others (1920), Lewis (1966), and Mallory and Barnett (1972). The springs and wells are discussed in the numerical sequence as they appear on plates 6-11 at the end of the paper.

Northwest Colorado and Glenwood Springs Area (plate 6)

1. Juniper Hot Springs, Moffat County. These springs which are located approximately 71 miles west of Steamboat Springs along the Yampa River are located in the flood plain of the river. The waters issue from shales and sandstones of Cretaceous age with a temperature of 39°C and a discharge of 50 gpm (gallons per minute).

2. Routt Hot Springs, Routt County. These springs, which have no commercial development associated with them, are located along Hot Springs Creek approximately 7 miles north of Steamboat Springs. According to Lewis (1966, p. 51), the waters issue from Tertiary age basaltic rocks with a temperature of 64°C common throughout the 12 to 20 springs. The springs have a total discharge of approximately 100 gpm.

3. Steamboat Springs, Routt County. In this group of springs there are 15 large and a reported 120 small thermal springs, which are located on the Yampa River at the foot of the Park Range. The springs occur near the contact between the Precambrian rocks which form the core of the Park Range and the overlying sedimentary rocks of Mesozoic age. Capping the Park range, east of Steamboat Springs, are Tertiary age extrusive rocks. Most of the smaller springs have a temperature of 24°C, while the large Bath House Spring has a temperature of 39°C. The springs have a total discharge of 2,000 gpm.

7. Dotsero Hot Springs, Garfield County. These unused springs are located along a fault zone separating the Precambrian age rocks from the Pennsylvanian age formations near where U. S. 6 and 24 cross the Colorado River approximately 4 miles west of Dotsero, Colorado along

the north bank of the Colorado River. The springs have a discharge of approximately 520 gpm with a temperature of 32°C.

8. Glenwood Springs, Garfield County. These springs, which are the largest group of hot springs in Colorado, are located in and downstream from the city of Glenwood Springs along the Colorado River, on the south flank of the White River Uplift. These springs are also some of the most highly mineralized springs in the State, containing dissolved solids in excess of 20,000 mg/l. There are numerous hot springs located all along the Colorado River for several miles down stream from the city of Glenwood Springs. The springs issue from several different formations. The large ones near the canyon mouth issue from the Mississippian Leadville Formation, while the springs downstream either issue from alluvium or Pennsylvanian red beds. There is some difference in opinion as to the yield of the springs. George (1920, p. 211) estimated the discharge of the largest spring at 400 gallons per minute. Lewis (1966, p. 34) estimated the discharge of the same spring to be 2,500 gpm, based on the elapsed time to fill the swimming pool. Lewis measured the temperature of this spring at 52°C.

Upper Colorado River and Front Range Area (plate 7)

4. Hot Sulphur Springs, Grand County. This group of springs, which comprise the eastern most thermal springs in the Colorado River drainage basin, have a total discharge of 90 gpm, with a representative temperature of 45°C. The thermal waters are probably migrating upward from depth along a large thrust fault that cuts the area. The springs issue from the Cretaceous age Dakota sandstone. Tertiary age lava flows are found for several miles on either side of Hot Sulphur Springs.

5. Eldorado Springs, Boulder County. Eldorado Springs are located approximately 25 miles northwest of Denver, near the contact of the late Paleozoic and younger sedimentary rocks and the Precambrian metamorphic rocks. According to C.R. Robinson (per. comm.) the springs issue from the Lyons sandstone. The discharge of the springs varies from 10-15 gpm to a combined total of 160 gpm with a temperature of 28°C. The source of the heat for the thermal waters probably is coming from the magma mass that supplied the Tertiary intrusives found along the Front Range from Golden,

Colorado to the vicinity of Boulder, Colorado.

6. Idaho Springs, Clear Creek County. These springs are located 34 miles due west of Denver on Fork Creek, a tributary of Clear Creek at the city of Idaho Springs. The springs are situated in an area of Precambrian metamorphic rocks intruded by a syenite prophyry in the center of a very highly mineralized mining district. Throughout the last 70 years commercial development has occurred around these springs. At present, a hotel located at the site offers therapeutic services. The flow of the spring at the hotel was estimated by Lewis to be 50 gpm. The temperature of the springs varies from a low of 39°C to a high of 50°C.

Aspen and South Park Area (plate 8)

9. Penny Hot Springs (Avalanche Hot Springs) Pitkin County. This unused group of springs is located along the banks of the Crystal River 12 miles south of Carbondale on State Highway 133. The largest spring in the group has a discharge of 300 gpm and a temperature of 51°C. The geology of the area consists of Permo-Pennsylvanian red beds which have been intruded by a Tertiary age rock body of diorite. The source of the heat is probably from the diorite rock body. The springs issue from the intrusive rock, red beds, and the alluvium of the river.

10. Rhodes' Hot Springs, Park County. These undeveloped hot springs are located approximately four miles south of Fairplay, Colorado on the east side of the Mosquito Range. The springs issue from alluvium along Four Mile Creek, a tributary of the South Platte River. The springs have a temperature of 26°C and a discharge of 250 gpm.

11. Hartsel Hot Springs, Park County. Hartsel Hot Springs are located adjacent to U. S. Highway 24 approximately 60 miles west of Colorado Springs near the southern end of South Park, in and around the town of Hartsel. The southern end of South Park is an area that experienced multiple middle to late Tertiary lava flows. The springs are near the contact of the Precambrian rocks and the overlying Mesozoic age sedimentary formations. The springs have a reported discharge of 3-8 gpm and a temperature of 31°C-57°C.

12. Conundrum Hot Springs, Pitkin County. These relatively unused hot springs are located along the banks of Conundrum Creek, approximately 10 miles south of Aspen, Colorado in the Maroon Bells-Snowmass Wilderness area. The springs are used by hikers into the Wilderness area. The two large springs and four smaller ones have a total discharge of 130 gpm with a maximum temperature of 38°C.

Upper Arkansas River and Gunnison Area (plate 9)

13. Cement Creek Spring, Gunnison County. This spring is approximately 10 miles southeast of Crested Butte, Colorado. The spring issues from an unidentified limestone formation a short distance from a body of Precambrian granite. Its flow was estimated by George and others (1920) to be 40 gpm. Lewis (1966, p. 85) reported the total discharge to be 340 gpm. It is not known if Lewis included the discharge of the Ranger's Spring in his total. Ranger's Spring is about 2½ miles below Cement Creek Spring and according to George and others (p. 207) it had a discharge of 300 gpm. This discharge, when added to the Cement Creek Spring, would give a total discharge of 340 gpm. The temperature of the Cement Creek Spring reported by various authors is approximately 26°C.

14. Cottonwood Hot Springs (Buena Vista Hot Springs), Chaffee County. These springs are located along State Highway 306, six miles west of Buena Vista on Cottonwood Creek. The springs are near the contact of the Precambrian granite and the Tertiary monzonite intrusive of the Collegate Range. The discharge of the springs has been estimated to be between 100 gpm and 150 gpm. with the temperature varying between 49°C and 62°C. The water was used in 1966 (Lewis, p. 60) for bathing at a new resort built in the area.

15. Mount Princeton Hot Springs (Chalk Creek Hot Springs), Chaffee County. Mount Princeton Hot Springs are located along State Highway 162 on the north bank of Chalk Creek, 25 miles northwest of Salida, Colorado. The geologic conditions at these springs is quite similar to the Cottonwood Hot Springs area with the heating of the water probably coming from the Tertiary monzonite intrusion which forms the collegiate Range. These hot springs have a total discharge between 250-400 gpm

and a temperature range of 48°C-57°C. The thermal water has limited local use.

16. Hortense Hot Springs (Part of the Mount Princeton Hot Springs group of other investigators), Chaffee County. This spring, which is the hottest in the State of Colorado, is located approximately one mile west of the Mount Princeton Hot Springs. Its geologic conditions are similar to the Mount Princeton Hot Springs. The discharge of the spring is estimated to be between 22-33 gpm and its temperature ranges from 74°C-84°C. The water is used for swimming pools and space heating at two youth camps.

17. Waunita Hot Springs, Gunnison County. Located about 28 miles east of Gunnison, Colorado on Hot Springs Creek are two groups of springs about ½ mile apart. A resort has developed around the upper springs with the water being used to heat a swimming pool. The lower group of springs are unused. The springs issue from a sandstone formation which overlies Precambrian granite. Tertiary age lava flows are present on Tomichi Dome; about two miles south of the hot springs. Both groups of springs have a total discharge of 1,000 gpm with the hottest spring having a temperature of approximately 70°C.

18. Poncha Springs, Chaffee County. These springs are located on Poncha Mountain six miles southwest of Salida, Colorado. There are approximately 40 individual springs in this group. The discharge of the various individual springs varies from a low of 2 gpm to 15 gpm or more. The combined discharge of all the springs has been reported at 135 gpm and the temperatures varies between 55°C and 69°C. Some of the water is used for bathing at the site but the greatest amount of water is piped the six miles to Salida and used in the city's swimming pool. Tertiary lava flows varying in composition from rhyolite to andesite overlie faulted Precambrian age rocks within a few miles of the springs. The springs occur at the fault contact of the Precambrian and Tertiary formations.

19. Wellsville Warm Spring, Fremont County. These springs are located five miles southeast of Salida, Colorado on the north bank of the Arkansas River. In 1966 the water was being used to raise tropical plants and fish for commercial markets in Colorado Springs and Pueblo. The thermal water comes from a tunnel driven into Mississippian age formation.

The discharge of the springs has been reported at being between 150-200 gpm with a temperature of $33^{o}C$-$34^{o}C$.

26. Valley View Hot Springs (Orient Hot Springs), Saguache County. This spring is located approximately 10 miles southeast of Villa Grove in the north end of the San Luis Valley. In 1966 the water was unused. Chronic (1972) describes the area surrounding the spring as being highly mineralized, with the springs being in close proximity to a fault bordering the east margin of the San Luis Valley. The springs issue from the mountain side just above the upper limit of the alluvial material that fills the valley. There are six separate springs in this group having a total discharge of approximately 275 gpm, and a representative temperature of $36^{o}C$.

27. Mineral Hot Springs (Chamberlain Hot Springs), Saguache County. This spring is located approximately 7 miles southwest of Valley View Hot Springs, and approximately 46 miles north of Alamosa Colorado in the northern part of the San Luis Valley on Colorado Highway 17. George and others (1920) stated that there were about 30 separate openings in two groups whose flow ranged from a fraction of a gallon per minute up to 10 gpm. Water temperatures between $58^{o}C$ and $62^{o}C$ were measured in the springs in 1968. The water is coming from the Quaternary alluvium that fills the valley. Lewis (1966) noted that Precambrian age granitic rocks are exposed three miles to the west. Numerous Tertiary Lava flows occur throughout the subsurface in the valley and are exposed in the mountains to the west. The heat source that supplied the lava for the flows is probably the heat source for the waters of the springs.

28. Cebolla Hot Springs (Powderhorn Hot Springs), Gunnison County. This spring is located on Cebolla Creek about 16 miles south of the Gunnison River, southwest of Gunnison, Colorado. George and others, in 1920 described about 20 separate springs in this group whose temperatures ranged from $9^{o}C$ to $46^{o}C$ and whose discharge varied from one or two gpm to 15 or 20 gpm. The New Bath House Spring (no. 182 of George and others) according to Lewis (1966) had a discharge of 20 gpm and a temperature of $38^{o}C$. The springs issue from Precambrian granites, schists and gneisses which are cut by dikes. The group of springs is located along the northern

side of the San Juan Volcanic area (plate 4) in an area of intensive volcanic activity throughout Cenozoic time. The heat for the water is presumably related to this activity.

Lower Arkansas River and Pagosa Springs--Wagon Wheel Gap Area (plate 10)

20. Fremont Natatorium, Fremont County. This artesian well is located on the northeast edge of Canon City at the intersection of Central Street and Doffer Avenue (Mallory and Barnett, 1972). The well which is reported as being 1,655 feet deep and flowing between 125-150 gpm with a temperature of 36°C is probably tapping the Dakota Formation.

21. Canon City Hot Springs, Fremont County. This spring is located on the south side of the Arkansas River at the southwest end of Riverside Drive (Mallory and Barnett, 1972) a few miles from the eastern end of the Royal Gorge. George and others (1920, p. 205) felt that the water must be coming from the Precambrian granites at depth. This spring has a very low discharge and in 1920 the water had to be pumped from the spring. At that time the water had a temperature of 38°C but in 1969 its temperature was 20°C.

22. Artesian Well, Fremont County. This well is located 0.5 miles southwest of the intersection of U. S. Highway 50 and State Highway 115 on the east side of the road (Mallory and Barnett, 1972). The water in this well's temperature was measured by Mallory and Barnett, (1972) in 1969 at 27°C. The water is unused at the present time. The depth of the well is unknown but it probably taps the Dakota Formation, the principal aquifer in the region.

23. Artesian Well (Watson Artesian Well), Pueblo County. This well is approximately 1,000 feet northeast of the Don K Ranch, at the upper end of the South Red Creek Road. Like the previous well, the depth of this well is unknown, but it is probably deriving its water from the Dakota Formation. Discharge of the well was reported at 200 gpm in 1920, in 1969 the temperature of the water was 28°C.

24. Artesian Well, (Clarke's Magnetic Mineral Spring?) Pueblo County. This well is located at the northeast corner of Clark and B Street in Pueblo, Colorado. There is some question if this is the same well reported by George and others (1920, p. 190) at this same location. George and others (1920) reported its depth at 1,425 feet and temperature at 25°C.

25. Artesian Well, Pueblo County. This well, located on the east side of the Pueblo Municipal Airport north of U. S. 50 and Baxter Road, was located and sampled by Mallory and Barnett in 1969. They did not measure its discharge but they did measure a temperature of 28°C. The depth of the well is unknown but the water is probably coming from the Dakota Formation.

35. Antelope Warm Spring, Mineral County. This spring is located just to the north off the Spring Creek Pass Road, 13 miles southwest of Creede, Colorado. It is located in the San Juan volcanic area, an area that experienced very active volcanic activity throughout Cenozoic time. The intense volcanic activity has produced the numerous springs located throughout the San Juan Mountains today. The discharge of Antelope Warm Spring is reported at 10 gpm and a temperature of 32°C.

36. Wagon Wheel Gap Hot Springs, Mineral County. These four hot springs and two cold springs are located along Goose Creek about one mile from the town of Wagon Wheel Gap and seven miles southeast of Creede, Colorado. George and others (1920, p. 239) described the bedrock geology of the area as consisting of granites cut by numerous dikes and locally capped by Tertiary lava flows. The largest of the springs, Boiling Spring, has a discharge of 50 gpm and a temperature of 58°C.

37. Shaw's Spring (Del Norte) Rio Grande County. This spring, which is 25 feet northeast of the swimming pool, and the associated development, is located about six miles north of Del Norte, Colorado, in the west central portion of the San Luis Valley. The spring issues from Tertiary age sandstone a short distance from the outcrops of an igneous rock body. The spring has a discharge of approximately 10-12 gpm and a temperature of 30°C.

41. Pagosa Springs, Archuleta County. Pagosa Springs are located on U. S. Highway 160, 57 miles east of Durango, Colorado. Big Pagosa Spring is reported to have a discharge of 700 gpm with a temperature of 60°C. The waters from these springs are used in the town for commercial and recreational purposes as well as to heat sidewalks and driveways for melting of snow in the winter (Lewis, 1966, p. 45). The waters issue from fractures and joints in the Cretaceous Mancos shale, but are undoubtly

related to the cooling of the igneous magma mass that supplied the Tertiary lava flows found throughout the immediate area.

Southwestern Colorado Area (plate 11)

29. Orvis Hot Spring (Ridgway Hot Spring), Ouray County. This relatively undeveloped group of springs is located about 1½-2 miles south of Ridgway, Colorado on the north side of the San Juan Mountains (plate 4). George and others (1920) reported that the Ridgway Hot Spring issued from alluvium of the Uncompahgre River about 300 yards from the river. The flow of the springs was estimated by them to be 15 gpm. Lewis (1966) reported the discharge of the spring to be 20 gpm with a temperature of 54°C.

30. Ouray Hot Spring, Ouray County. The springs occur at numerous points throughout the town of Ouray. Lewis (1966, p. 43) noted that the discharge of the springs varies from seeps to a reported 358 gpm, with the total discharge of all springs to be 800 gpm. Lewis also noted that the temperatures of the springs ranged from 60°C to a reported 82°C. The hottest spring that George and others reported was the Pavilion Spring (no. 386) which had a temperature of 70°C. It is assumed that this is the spring that Lewis selected for his representative spring of the area. The water is used commercially to heat the swimming pool in the city. The geology of the immediate area around Ouray is quite complex. Ouray, which was the center of a large, very rich mining district during the last century, is located in the San Juan Volcanic area and the San Juan Mountains. The surrounding area is covered with numerous lava flows of Tertiary age and is cut by numerous faults.

31. Lemon Hot Spring (Geyser Warm Spring), San Miguel County. This spring is located across the San Miguel River from the town of Placerville, on State Highway 145 in southwest Colorado. This spring, like so many others in the southwestern part of the state is related to the late Cenozoic volcanism that occurred in the area. The yields of these springs are not exceptionally large, nor are they on the average very hot. The springs do indicate the presence of a heat source that extends over a large area. Lemon Hot Spring issues from Triassic red beds on the northern end of a large north-south fault (Bush, and others, 1956). Placerville,

like many towns around the flanks of the San Juan Mountains was the center of a mining district, with numerous mines in the vicinity. As to be expected the areas is cut by a high number of large faults. The spring has a temperature of 34°C and a discharge of 8 gpm.

32. Dunton Hot Spring, Dolores County. The spring is located just to the south of the town of Dunton, Colorado on the west side of the San Juan Mountains (plate 4). Due to the inaccessability of the area, the waters are relatively undeveloped. The formations cropping out amoung the spring are the Jurassic Morrison Formation and Triassic red beds with the spring water issuing from a large north-south fault (Bush and Bromfield, 1966). The spring has a discharge of 20 gpm and a temperature of 42°C.

33. Geyser Spring, Dolores County. This undeveloped spring with a discharge of 20 gpm and a temperature of 30°C is located just over two miles southwest of Dunton, Colorado on Geyser Creek. The waters, which are migrating upward along a large northeast-southwest trending fault, issue from Triassic age red beds (Bush and Bromfield, 1966).

34. Iron Spring, Dolores County. This spring is supposedly located 3/4 miles north of Rico, in southwestern Colorado (Plate 4). There is some question regarding the exact location of this spring. George and others (1920, p. 232) described five springs in the vicinity of Rico. Of these only one (no. 191) was a thermal spring. This spring was described as being in a tunnel driven into Permian age rocks 3/4 mile north of Rico. Lewis (1966) located and sampled a spring in this vicinity that had about the same temperature and discharge as noted by George and others. Lewis, in reporting the latitude and longitude of this spring, was apparently in error because no mention of any spring is made on either the topographic map or the geologic map of the area at the location he gave. Recent geologic mapping by Pratt and others (1969) does not show any spring or any Permian age formations 3/4 miles north of Rico. However, this does not mean that George and others errored in the general location of this spring because the recent geologic mapping may have reinterpreted the age of the formations. To the north and northeast of Rico are numerous faults and mines associated with the faults on both

sides of the east-west Rico Dome. The spring, if present, is probably associated with one of these features. Even with the obvious short comings in the location, it was decided to include this spring in the report as it is believed by the writer that the spring does exist.

38. Pinkerton Hot Springs, La Plata County. This group of springs is located on U. S. Highway 550, approximately 13 miles north of Durango, Colorado. These springs, which are on the south flank of the San Juan Mountains, issue from sandstone of Permo-Penn. age. Precambrian age granites are exposed a few miles to the north. The springs have a reported total discharge of 75 gpm and a representative temperature of $30^{\circ}C$.

39. Tripp Hot Springs, La Plata County.
40. Trimble Hot Springs, La Plata County.

These two groups of springs will be discussed together as they occur in close proximity to each other and their geology is the same.

The springs are located adjacent to U. S. Highway 550, approximately ten miles north of Durango. The springs issue from Permo-Penn. red beds but the water and the heating action is related to the nearby San Juan Mountains and their related volcanic lava flows. As stated before, these mountains were the site of numerous outpourings of lava throughout Tertiary time and the heating of the spring water is presumably related to residual heat from this period.

The springs are relatively undeveloped. The reported discharge of the Tripp Hot Springs is up to 60 gpm with a temperature of $32^{\circ}C$, while the reported discharge of the Trimble Hot Springs is up to 200 gpm with a maximum reported temperature of $51^{\circ}C$.

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* Describes individual or groups of springs.

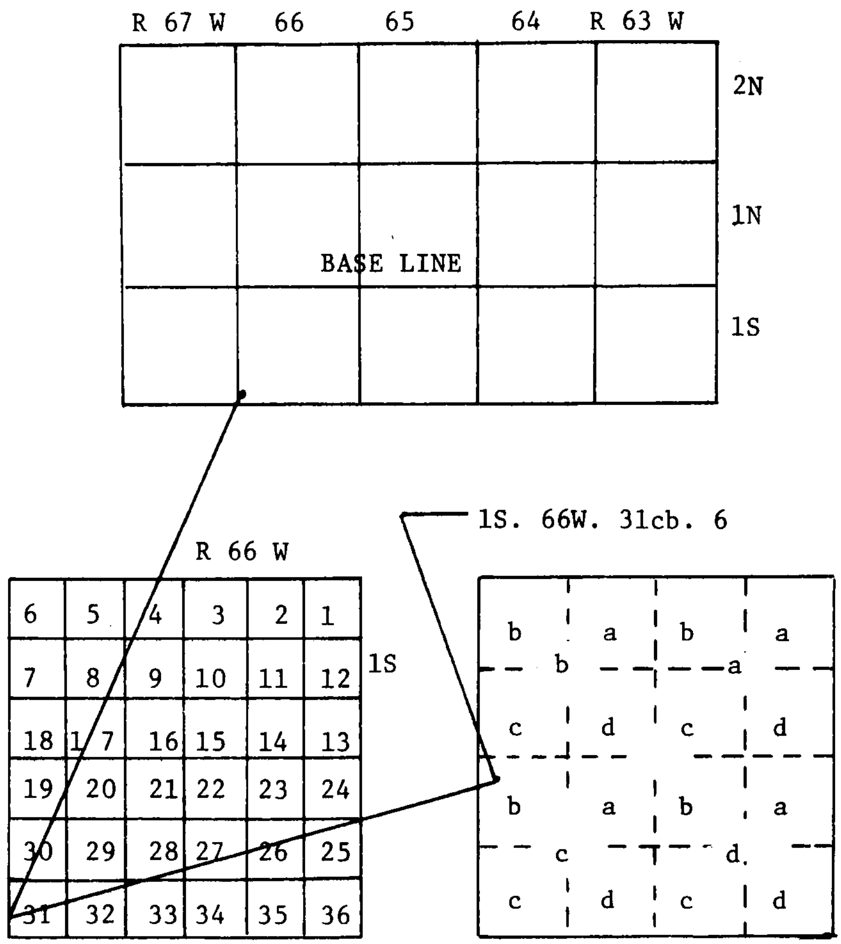

Plate 3. Well-numbering system used in Colorado

The well-numbering system used in Colorado is based on the U.S. Bureau of Land Management system of land subdivision, and shows the location of the spring by township, range, section, and position within the section. In Colorado, all lands are referenced to the 6th. Principal Meridian and New Mexico Meridian. The first two segments of the number designate the township and range. The third number designates the section. The letters following the section number locate the well within the section. The first letter denotes the quarter section, the second the quarter-quarter section. The letters are assigned within the section in a counter-clockwise direction beginning with a in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. In the above example the spring is located in the NW¼, SW¼, Sec. 31, T. 1 S., R. 66 W. 6th. Principal Meridian.

Table 1. Physical Properties of Thermal Springs and Wells in Colorado

No.	Name	T	R	Sec.	P.M.	Latitude	Longitude	Reference *	Temp. °C	Discharge (gpm) **	Specific Conductance (Micromhos)	Year Sampled ***	Remarks
1	Juniper Hot Springs	6N	94W	16cd	6	40°28'02"	107°57'11"	a97;b1	39	25-35	----	1911-12	
a								c19C9	38	50	2,100	1965	
2	Routt Hot Springs	7N	84W	18dc	6	40°33'35"	106°51'00"	a215;b2	64	-100	----	1911-12	
a								c9B4	64	100E	1,000	1965	15-20 Springs.
3	Steamboat Springs	6N	84W	8	6			a212;b2a	40	250-300E	----	1911-12	
a								c2A2	39	2,000T	1,850	1965	15 large,120 small springs.
4	Hot Sulphur Springs	1N	78W	3dc	6	40°04'32'	106°06'38"	a78;b3	35&43	75	----	1911-12	
a								c15C5	45	90	1,800	1965	
5	Eldorado Springs	1S	71W	25	6	39°55'56"	105°16'46'	a52;b4	21	10-15	----	1911-12	
a								c24D5	26	160T	475	1965	
b									28	---	370	1970	Well B, N. side of Boulder Creek
c									26	---	150	1970	Well H, S. side of Boulder Creek
6	Idaho Springs	3S	73W	36	6	39°44'23"	105°30'43'	a85;b5	39	35-50	----	1911-12	Hot Soda Spring
a								c16C6	48	50E	3,000	1965	at Radium Hot Springs Hotel
b									40	---	2,740	1968	Spring in men's tunnel
c									40	---	2,100	1968	spring, tunnel E.of Hotel.
d									50	---	2,720	1968	Well, 50' N. of Hotel.
e									25	---	1,900	1968	Spring, 100' S. of Hotel
f									34	---	2,660	1968	Spring, 50' N. of Hotel.
7	Dotsero Hot Springs	5S	87W	12cc	6	39°37'39"	107°06'22"	a45;b7	28	400-500E	----	1911-12	At mouth of Glenwood Canyon, at
a								c12C2	32	520	+10,000	1965	contact of Leadville Ls. and shale.
8	Glenwood Springs	6S	89W	9ad	6	39°33'00"	107°19'18"	a55;b6	51	400E	----	1911-12	
a								c1A1	52	3,000E	+10,000	1965	Feeds swimming pool.
9	Penny Hot Springs	10S	88W	4ba	6	39°13'33"	107°13'28"	a7;b8	50	100	----	1911-12	
a								c10B5	51	200	2,700	1965	E. side of Crystal River
10	Rhodes' Spring	10S	78W	24cb	6	39°09'49"	106°03'53"	a53;b16	26	250-300E	----	1911-12	Four miles S. of Fairplay at foot
a								c23D4	26	250	----	1965	of Sheeps Ridge.
b									26	---	328	1968	

*
** Footnotes at end of table
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Table 1. Physical Properties of Thermal Springs and Wells in Colorado (Continued)

No.	Name	T	R	Sec.	P.M.	Latitude	Longitude	Reference *	Temp. °C	Discharge (gpm) **	Specific Conductance (Micromhos)	Year Sampled ***	Remarks
11	Hartsel Hot Springs	12S	75W	8da	6	39°01'06"	105°47'40"	a71;b17	57	-3	----	1911-12	
a								c20D1	57	8	3,800	1965	
b									57	---	3,680	1968	On S. side of main street.
c									31	---	1,490	1968	Spring, behind general store.
12	Conundrum Hot Springs	12S	85W	16	6	39°00'44"	106°53'26"	a2;b9	38	20-25E	----	1911-12	
a								c17C7	38	130T	2,400	1965	
13	Cement Creek Springs	14S	85W	22dd	6	38°48'58"	106°52'28"	a30;b12	24	40E	----	1911-12	About 10 miles SE of Crested Butte
a								c22D3	26	340T	----	1965	
14	Cottonwood Hot Springs	14S	79W	21dc	6	38°48'42"	106°13'25"	a18;b19	49-62	100-150E	----	1911-12	
a								c13C3	52	100	510	1965	
b									57	---	538	1968	Spring, 5.6miles SW Buena Vista
c									50	---	496	1968	Buena Vista Medicinal Hot Spring.
15	Mt. Princeton Hot Springs	15S	78W	19bc	6	38°43'56"	106°09'53"	a144;b20	54	250-300E	----	1911-12	Big Spring
a								c6B1	57	400	325	1965	#16 maybe included also.
b									54	---	328	1968	Spring, 50' east of lower pool.
c								a143	49	---	----	1911-12	Heywood Spring
d									48	---	307	1968	Spring, 750'N. of Lodge.
16	Hortense Hot Spring	15S	79W	24bd	6	38°43'57"	106°10'06"	a142	84	22-33	----	1911-12	
a								c6B1	84	---	----	1965	Maybe included in #15 above.
b									84	---	461	1968	500' north of Hortense
c									74	---	369	1968	At Wright greenhouse, Hortense
17	Waunita Hot Springs	49N	4E	11cc	N.M.	38°30'53"	106°30'26"	a245;b14	71	10	----	1911-12	
a								c3A3	68	1,000T	800	1965	
18	Poncha Springs	49N	8E	15cb	N.M.	38°29'48"	106°04'36"	a176;b21	68	+100E	----	1911-12	East Mound Spring
a								c7B2	69	135	1,300	1965	
b									68	---	963	1968	Main spring, 500' E. of pool
c									68	---	965	1968	Spring #13, 500' S.E. of b
d									55	---	977	1968	500' north of main spring.

*
** Footnotes at end of table
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Table 1. Physical Properties of Thermal Springs and Wells in Colorado (Continued)

No.	Name	T	R	Sec.	P.M.	Latitude	Longitude	Reference *	Temp. °C	Discharge (gpm) **	Specific Conductance (Micromhos)	Year Sampled ***	Remarks
19	Wellsville Warm Spring	49N	10E	19bb	N.M.	38°29'16"	105°54'42"	a252;b22	34	150-200	----	1911-12	
a								c18C8	34	150	780	1965	
b									33	---	752	1969	N. side of Ark. River, 5 miles SE of Salida
20	Fremont Natatorium	18S	70W	26bb	6	38°27'37"	105°12'02"	a20;b22A	38	125-150	----	1911-12	
a									36	---	1,840	1969	Central and Doffer Ave., Canon City
21	Canon City Hot Spring	18S	70W	31d	6	38°25'57"	105°15'46"	a21;b22A	38	---	----	1911-12	
a								a21?	20	---	1,910	1969	S. side of river at SW end of Riverside Drive.
22	Artesian Well	19S	68W	7ba	6	38°24'24"	105°02'41"	-------	27	---	2,180	1969	0.5 miles SW of U.S. 50 and Colo. 115, east side of road.
23	Artesian Well	22S	68W	5aa	6	38°10'18"	105°00'48"	a204	22	200	----	1911-12	
a								a204?	28	---	2,150	1969	Upper end of s. Red Creek Rd.
24	Artesian Well	21S	65W	1aa	6	38°15'30"	104°36'28"	a190	26	---	----	1911-12	
a								a190?	25	---	1,650	1969	Clark and B St., Pueblo
25	Artesian Well	20S	63W	30a	6	38°16'58"	104°29'00"	------	28	---	950	1969	At airport.
26	Valley View Hot Springs	46N	10E	36db	N.M.	38°11'30"	105°48'52"	a152;b24	36	200	----	1911-12	
a								c14C4	36	275	380	1965	
b									35	---	382	1968	Bath House Spring.
27	Mineral Hot Springs	45N	9E	12ac	N.M.	38°10'02"	105°55'31"	a136;b23	32-56	10E	----	1911-12	
a								c8B3	57	350T	1,300	1965	Chamberlain Hot Springs
b									58	---	980	1968	S. side of mound,1,500'E. of Mineral Spring
c									62	---	979	1968	N. side of mound,500'E. of b
28	Cebolla Hot Springs	46N	2W	4ab	N.M.	38°16'26"	107°05'54"	a182;b15	-46	2	----	1911-12	
a								c28D9	38	20	2,000	1911-12	

*
** Footnotes at end of table
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Table 1. Physical Properties of Thermal Springs and Wells in Colorado (Continued)

No.	Name	Location T	R	Sec.	P.M.	Latitude	Longitude	Reference *	Temp.	Discharge (gpm) **	Specific Conductance (Micromhos)	Year Sampled ***	Remarks
29	Orvis Hot Springs	44N	8W	22cd	N.M.	38°08'00"	107°44'02"	a196;b27	52	10-20E	---	1911-12	
a								c21D2	54	20	---	1965	
30	Ouray Hot Springs	44N	7W	31--	N.M.	38°01'04"	107°40'02"	a157;b28	71	10-20E	---	1911-12	Spring, Mouth Box Canyon
a								c4A4	66	800T	1,750	1965	
31	Lemon Hot Spring	44N	11W	34dd	N.M.	38°00'55"	108°03'11"	a165;b26	34	---	---	1911-12	Geyser Warm Spring
a								c29D10	34	8	3,250	1965	
32	Dunton HotSpring	41N	11W	32--	N.M.	37°46'18"	108°05'38"	b29	43	20	---	----	
a								c27D8	42	20	1,800	1965	
33	Geyser Spring	40N	11W	6	N.M.	37°45'06"	108°07'12"	c32D13	30	20	2,300	1965	
34	Iron Spring	40N	11W	25--	N.M.			a191;b30	28	25-30	---	1911-12	
a								c35D16	27	15	3,000	1965	
35	Antelope Warm Spring	40N	2W	1dd	N.M.	37°44'36"	107°02'14"	c30D11	32	10	210	1965	
a									32	---	194	1968	13 miles SW of Creede.
36	Wagon Wheel Gap Hot Springs	41N	1E	35dd	N.M.	37°41'06"	106°49'47"	a234;b31	56	50	---	1911-12	Boiling Spring
a								c11C1	58	50E	2,250	1965	
b									57	---	2,180	1968	100' S. of Hotel, 1 mile S.of Town
c		40N	1E	2ab?	N.M.	37°45'04"	106°49'47"	a235	49	6-8	---	1911-12	Hot Saline Spring
d									50	---	2,290	1968	750' South of Hotel.
37	Shaw's Spring	41N	6E	33dd	N.M.	37°45'01"	106°19'01"	a38;b33	31	10-12	---	1911-12	
a								c33D14	30	10	509	1965	
b									30	---	557	1968	25' NE of swimming pool.
38	Pinkerton Hot Springs	37N	9W	25ab	N.M.	37°26'58"	107°48"54"	a50;b34	30	4-8	---	1911-12	
a								c25D6	30	75T	4,000	1965	
39	Tripp Hot Springs	36N	9W	10cc	N.M.	37°23'44"	107°50'49"	a229;b35	32	50-60	---	1911-12	
a								c31D12	30	15	1,800	1965	

*
** Footnotes at end of table
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Table 1. Physical Properties of Thermal Springs and Wells in Colorado
(Continued)

No.	Name	Location T	Location R	Location Sec.	Location P.M.	Location Latitude	Location Longitude	Reference *	Temp. °C	Discharge (gpm) **	Specific Conductance (Micromhos)	Year Sampled ***	Remarks
40	Trimble Hot Springs	36N	9W	15bb	N.M.	37°23'25"	107°50'49"	a230;b36	51	150-200	---	1911-12	
a								c26D7	42	24	---	1965	
41	Pagosa Springs	35N	2W	13cd	N.M.	37°15'52"	107°00'37"	a162;b39	71	600-800	---	1911-12	
a								c5A5	60	700	4,000	1965	

* a: George and others, 1920, Colo. Geol. Survey Bull. 11.
b: Waring, G.A., 1965, U.S. Geol. Survey Prof. Paper 492.
c: Lewis, R. E., 1966.

** E: Estimated
T: Total

*** 1911-12; George, R. D., and others, 1920
1965: Lewis. E. L., 1966
1968-1970; Mallory, E.C., Jr.; and Barnett, P.R., 1972

Table 2. Chemical Analyses of Thermal Waters in Colorado
(Chemical constituent in milligrams per liter)

Number	Name	Date Sampled	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Flouride (F)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	pH Field
1	Juniper Hot Springs	1911-12	37	5	5.4	328	50	833	0	28	76.1	--	1,224	----	---	--	---
2	Routt Hot Springs	1911-12	88	8	0	162	11.1	141	5	44	136.9	--	552	----	---	--	---
3	Steamboat Springs	1911-12	48	21	T	300	16.4	100	11	141	323.9	--	884	----	---	--	---
4	Hot Sulphur Springs	1911-12	32	16	1.6	378	80	770	0	137	145.3	--	1,189	----	---	--	---
5	Eldorado Springs	1911-12	17	10	4.4	17	1	46	0	38	6.8	--	110	----	---	--	---
b		1970	19	33	8.3	21	5	89	0	89	1.5	0.4	211	220	120	45	7.5
c		1970	15	13	4.3	7	3.1	58	0	18	0.3	0.2	102	93	50	3	7.5
6	Idaho Springs	1911-12	68	145	39.4	573	T	1,514	0	396	71.5	--	2,045	----	---	--	---
b		1968	57	142	28	500	90	1,460	0	396	69	4.0	---	2,000	470	0	6.5
c		1968	48	102	20	370	56	1,060	0	290	48	3.0	---	1,460	337	0	6.7
d		1968	58	138	29	500	77	1,430	0	400	65	3.8	---	1,970	464	0	6.6
e		1968	46	91	18	310	10	816	0	214	87	2.9	---	1,180	302	0	6.4
f		1968	60	140	28	490	83	1,410	0	396	64	4.4	---	1,960	465	0	6.5
7	Dotsero Hot Springs	1911-12	21	279	67	3,304	460	449	0	495	5,575	--	10,446	----	---	--	---
8	Glenwood Springs	1911-12	37	431	91	6,950	460	437	0	1,194	11,025	--	20,056	----	---	--	---
9	Penny Hot Springs	1911-12	85	369	51.6	329	191	612	0	1,226	239.4	--	2,850	----	---	--	---

Table 2. Chemical Analyses of Thermal Waters in Colorado (continued)

Number	Name	Date Sampled	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Flouride (F)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: non-carbonate	pH Field
10	Rhode's Spring	1911-12	12	36	23	11	5	163	0	18	44.3	--	236	----	---	--	---
b		1968	13	33	20	8	1.2	197	0	9	1.8	0.1	178	184	165	4	7.7
11	Hartsel Hot Springs	1911-12	46	99	29.1	613	24.2	310	0	333	801.2	--	2,091	----	---	--	---
b		1968	39	113	19	654	32	424	0	300	818	1.9	2,240	2,190	362	15	7.0
c		1968	25	61	15	226	16	317	0	124	230	1.1	874	856	215	0	6.8
12	Conundrum Hot Springs	1911-12	44	627	8.6	40	9	37	0	1,522	6.8	--	2,262	----	---	--	---
13	Cement Creek Springs	1911-12	35	79	22.7	30	8	251	0	80	13.7	--	438	----	---	--	---
14	Cottonwood Hot Springs	1911-12	61	5	2.7	81	34.2	79	8	108	28.4	--	382	----	---	--	---
b		1968	55	6	T	108	2.6	72	2	108	28	11	392	356	14	0	8.5
c		1968	53	6	0.4	95	2.4	65	6	98	27	13					
15	Mt. Princeton Hot Springs	1911-12	60	11	T	38	32	86	T	62	1.8	--	270	----	---	--	---
b		1968	61	10	0.3	57	1.7	69	3	64	0.4	9.6	253	242	26	0	7.7
c		1911-12	52	9	T	51	5.5	86	0	51	11.8	--	225	----	---	--	---
d		1968	56	11	0.4	52	2	74	0	58	3.5	9	242	229	29	0	7.7
16	Hortense Hot Spring	1911-12	76	4	T	94	1.5	104	T	103	7.7	--	357	----	---	--	---
b		1968	76	4	T	90	2.9	47	17	91	9	16	353	329	10	0	8.4
c		1968	71	5	0.2	74	2.2	52	10	77	5.7	12	290	284	14	0	8.3
17	Waunita Hot Springs	1911-12	86	5	3.7	155	2	175	0	182	27.4	--	559	----	---	--	---

Table 2. Chemical Analyses of Thermal Waters in Colorado (continued)

Number	Name	Date Sampled	Silica (SiO_2)	Calcium	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Flouride (F)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	pH Field
18	Poncha Springs	1911-12	80	18	2.3	174	21	221	0	199	54.7	--	691	----	---	--	---
b		1968	78	16	0.4	196	7.6	212	0	193	49	12	663	657	42	0	7.4
c		1968	75	18	0.6	198	8	198	7	188	47	10	684	649	48	0	7.5
d		1968	78	17	0.3	205	8.1	194	11	201	48	10	666	674	44	0	7.7
19	Wellsville Warm Spring	1911-12	35	82	26.8	45	18.5	312	0	67	61.6	--	481	----	---	--	---
b		1969	30	75	23	51	5.8	304	0	55	64	0.5	456	455	282	33	7.1
20	Fremont Natatorium	1911-12	43	151	65.2	172	79.7	564	0	584	35.4	--	1,376	----	---	--	---
a		1969	15	140	59	215	14	638	0	534	19	1	1,320	1,310	595	72	6.9
21	Canon City Hot Spring	1911-12	26	169	53.6	161	33	804	0	112	184.1	--	1,184	----	---	--	---
a		1969	23	131	54	184	15	906	0	119	76	2.2	1,180	1,050	551	0	6.4
22	Artesian Well	1969	22	162	66	275	32	1,230	0	202	95	1.8	1,440	1,460	678	0	7.0
23	Artesian Well	1911-12	20	144	40.6	527	37	1,169	0	341	288.7	--	2,035	----	---	--	---
a		1969	49	121	48	340	55	1,340	0	45	86	3.1	1,510	1,410	502	0	6.5
24	Artesian Well	1911-12	12	202	34.2	160	1.2	351	0	629	39.8	--	1,237	----	---	--	---
a		1969	10	65	37	260	19	323	0	569	18	1.4	1,150	1,140	316	52	6.6
25	Artesian Well	1969	17	5	4	225	5.8	402	0	159	7.8	1.9	612	624	30	0	7.5
26	Valley View Hot Springs	1911-12	29	59	16	5	8	137	0	94	8.6	--	265	----	---	--	---
b		1968	21	50	14	3.2	2.2	120	0	91	1.9	0.4	263	243	183	85	7.8

Table 2. Chemical Analyses of Thermal Waters in Colorado (continued)

Number	Name	Date Sampled	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Flouride (F)	Dissolved solids: Residue at 180°C	Dissolved solids: Calculated	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	pH Field
27	Mineral Hot Springs	1911-12	57	45	14.1	144	5	310	0	175	41	--	636	----	---	--	---
b		1968	46	58	13	146	13	347	0	159	38	4.3	672	649	199	0	7.2
c		1968	47	57	13	146	14	345	0	165	38	4.3	683	655	197	0	7.2
28	Cebolla Hot Springs	1911-12	80	133	48.7	267	74.7	1,107	0	132	119.7	--	1,453	----	---	--	---
29	Orvis Hot Springs	1911-12	58	274	20.6	374	102	278	0	1,287	102.6	--	2,283	----	---	--	---
30	Ouray Hot Springs	1911-12	52	383	11.1	81	45	37	0	1,016	51.3	--	1,667	----	---	--	---
31	Lemon Hot Springs	1911-12	99	156.9	13	677	130	1,005	0	879	259.9	--	2,764	----	---	--	---
34	Iron Spring	1911-12	90	701	72.3	57	31.5	1,410	0	861	6.8	--	2,706	----	---	--	---
35	Antelope Warm Springs	1968	42	2	T	43	T	85	13	0	4.5	1.7	160	149	6	0	8.9
36	Wagon Wheel Gap Hot Springs	1911-12	94	68	17.6	420	276	1,048	0	210	205	--	1,796	----	---	--	---
b		1968	86	65	14	462	46	477	182	165	231	8	1,440	1,500	222	0	7.0
c		1911-12	75	73	18.9	427	35	994	0	147	205.2	--	1,497	----	---	--	---
d		1968	71	66	15	448	44	1,020	0	132	199	8.7	1,540	1,490	228	0	6.7
37	Shaw's Spring	1911-12	96	4	2.5	112	5	230	T	54	17.1	--	415	----	---	--	---
b		1968	75	1	T	132	1.4	131	70	47	6	3.3	424	400	3	0	9.3
38	Pinkerton Hot Springs	1911-12	35	538	37.2	636	120	1,310	0	634	935.8	--	3,829	----	---	--	---

Table 2. Chemical Analyses of Thermal Waters in Colorado (continued)

													Dissolved solids		Hardness as $CaCO_3$		
Number	Name	Date Sampled	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (CO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Flouride (F)	Residue at 180°C	Calculated	Calcium, Magnesium	Non-carbonate	pH Field
39	Tripp Hot Springs	1911-12	35	558	41.9	396	165	1,121	0	1,312	254	--	3,450	----	---	--	---
40	Trimble Hot Springs	1911-12	28	332	28.1	37	12.5	498	0	612	0	--	1,407	----	---	--	---
41	Pagosa Springs	1911-12	68	247	16.8	525	370	636	0	1,504	179.6	--	3,327	----	---	--	---

T: Trace

Table 3. Spectrographic analyses of thermal waters
(micrograms per liter)

(Data from: Mallory and Barnett, 1972)

No.	Name	Alu-mi-num (Al)	An-ti-mony (Sb)	Ar-sen-ic (As)	Bar-ium (Ba)	Be-ryl-lium (Be)	Bis-muth (Bi)	Boron (B)	Cad-mium (Cd)	Ce-sium (Cs)	Chro-mium (Cr)	Co-balt (Co)	Cop-per (Cu)	Gal-lium (Ga)	Ger-ma-nium (Ge)	Iron (Fe)	Lan-tha-num (La)	Lead (Pb)	Lith-ium (Li)	Man-ganese (Mn)	Mo-lyb-denum (Mo)	Nick-el (Ni)	Ru-bid-ium (Rb)	Sil-ver (Ag)	Stron-tium (Sr)	Tin (Sn)	Tita-nium (Ti)	Vana-dium (V)	Yt-ter-bium (Yb)	Yt-tri-um (Y)	Zinc (Zn)	Zir-co-nium (Zr)
5b	Eldorado Springs	22	<10	<46	70	<0.3	<1	36	<5	<12	0.8	<1	2	<9	<2	14	<5	<1	20	2	3.0	<1.0	10	<0.1	840	< 4	<3.0	7	<0.1	<1.0	<11	<0.5
5c	Eldorado Springs	15	<10	<46	160	<0.3	<1	19	<5	<12	0.5	<1	2	<4	<1	18	<5	1	5	2	0.7	<1.0	4	0.3	180	< 2	<3.0	4	<0.1	<1.0	19	<0.5
6b	Idaho Springs	14	<10	<100	36	3.0	<2	450	<2	83	<0.2	<2	<10	<18	<20	590	<4	2	55	110	3.0	0.9	30	2.0	3,100	<29	1.0	<14	<2.0	<2.0	<22	<2.0
6c	Idaho Springs	11	<10	<100	28	4.0	<2	320	<2	65	<0.2	<2	8	<13	<15	40	<4	4	45	78	2.0	2.0	25	0.7	2,100	<21	0.9	<11	<2.0	<2.0	<22	<2.0
6d	Idaho Springs	69	<10	<100	31	4.0	<2	460	<2	70	<0.2	<2	<10	<17	<20	470	<4	2	50	78	2.0	1.0	25	3.0	3,400	<28	1.0	<14	0.5	<2.0	<22	<2.0
6e	Idaho Springs	10	<10	<100	33	3.0	<2	280	<2	47	<0.2	<2	<10	<12	<13	36	<4	2	35	54	1.0	1.0	20	0.3	1,900	<19	0.8	<10	<2.0	<2.0	<22	<2.0
6f	Idaho Springs	10	<10	<100	28	4.0	<2	380	<2	69	<0.2	<2	<10	<18	<20	760	<4	2	50	150	3.0	2.0	25	0.2	4,700	<28	1.0	<14	<2.0	<2.0	<22	<2.0
10b	Rhodes' Spring	28	<10	<10	260	<0.2	<2	30	<4	<11	<2.0	<4	1	<3	<3	94	<4	0.4	18	1	0.6	<1.0	5	<0.2	110	< 4	4.0	< 2	<4.0	<0.4	<11	<2.0
11b	Hartsel Hot Springs	22	<10	<10	64	<2.0	<2	450	<4	39	<4.0	<2	<2	<17	<20	80	<4	0.5	540	130	1.0	<1.0	250	0.9	1,100	<30	<2.0	<14	<4.0	<0.4	<46	<2.0
11c	Hartsel Hot Springs	15	<10	<10	50	<0.7	<2	210	<4	24	<4.0	<2	<.7	<8	<9	1,000	<4	0.1	300	120	<0.4	<1.0	95	0.2	1,200	<13	<2.0	< 7	<4.0	<0.4	<46	<2.0
14b	Cottonwood Hot Springs	23	<10	<10	45	<0.2	<1	42	<2	<14	<2.0	<1	<10	<3	<14	8	<2	1	70	2	53	<2.0	16	0.2	240	<10	<0.5	< 6	<1.0	<1.0	<10	<2.0
14c	Cottonwood Hot Springs	31	<10	<10	66	<0.2	<1	41	<2	<14	11.0	<1	0.1	<3	<13	28	<2	2	65	3	49	35.0	13	0.4	190	< 5	<0.5	< 6	<1.0	<1.0	<10	<2.0
15b	Mt. Princeton Hot Springs	28	<10	<10	96	<0.2	<1	12	<2	<10	<2.0	<1	0.1	<2	<10	8	<2	1	26	2	62	<2.0	10	<0.1	180	< 7	0.6	< 5	<1.0	<1.0	<10	<2.0
15d	Mt. Princeton Hot Springs	26	<10	<10	93	<0.2	<1	15	<2	<10	<2.0	<1	0.3	<2	<9	19	<2	1	27	6	56	<2.0	9	1.0	190	< 7	<0.5	< 4	<1.0	<1.0	<10	<2.0
16b	Hortense Hot Spring	66	<10	<10	89	<0.2	1	25	<2	<14	<2.0	<1	0.1	<3	<13	18	<2	3	55	2	77	<2.0	20	<0.1	180	< 9	<0.5	< 6	<1.0	<1.0	<10	<2.0
16c	Hortense Hot Spring	34	<10	<10	52	<0.2	<1	19	<2	<11	<2.0	<1	0.3	<3	<11	80	<2	0.7	32	25	100	2.0	14	<0.1	160	< 8	<0.5	< 5	<1.0	<1.0	<10	<2.0
18b	Poncha Springs	14	<10	<10	91	0.3	<1	44	<2	<27	<2.0	<1	<10	<6	<26	14	<2	1	90	80	33	<2.0	24	<0.1	530	<18	<0.5	<12	<1.0	<1.0	<10	<2.0
18c	Poncha Springs	18	<10	<10	88	0.4	<1	44	<2	<27	<2.0	<1	<10	<6	<26	20	<2	1	80	70	34	<2.0	24	<0.1	540	<18	2.0	<12	<1.0	<1.0	<10	<2.0
18d	Poncha Springs	18	<10	<10	67	<0.2	<1	57	<2	<27	<2.0	<1	<10	<6	<27	16	<2	<0.8	80	14	35	5.0	30	<0.1	530	<19	<0.5	<12	<1.0	<1.0	<10	<2.0
19b	Wellsville Warm Spring	14	<5	<20	95	<1.0	<.4	52	<5	<21	<1.0	<2	<20	<5	<6	8	<5	<1	100	<1	2	<1.0	14	<0.2	440	<21	<0.5	<11	<0.2	<2.0	<46	<1.0
20a	Fremont Natatorium	18	<10	<22	31	<0.2	<10	74	<10	<53	<0.5	<2	<20	<11	<14	920	<5	<1	120	43	<0.2	<1.0	18	<0.2	2,000	<18	<2.0	<26	<0.2	<2.0	<10	<1.0
21a	Canon City Hot Spring	27	<10	<22	100	.06	<10	170	<10	<56	<0.5	<2	170	<11	<15	46	<5	1	220	14	2.0	<1.0	33	<0.2	1,100	<19	2.0	<28	<0.2	<2.0	3,400	<1.0
22	Artesian Well	20	<10	<22	30	0.4	<10	88	<10	<33	<0.5	<2	<20	< 7	< 9	510	<5	<1	140	50	3.0	<1.0	56	0.6	1,300	<11	<2.0	<16	<0.2	<2.0	<10	<1.0
23a	Artesian Well	57	<10	39	300	4.0	<10	430	<10	<66	<0.5	2	<20	<13	<18	1,600	<5	<1	370	640	22.0	<1.0	75	<0.2	840	<22	5.0	<32	<0.2	<2.0	<10	<1.0
24a	Artesian Well	39	<10	<22	40	<0.2	<10	110	<10	<45	<0.5	<2	1	< 9	<12	4,100	<5	<1	130	29	0.4	<1.0	13	<0.2	2,800	<15	<2.0	<22	<0.2	<2.0	<10	<1.0
25	Artesian Well	70	<10	<22	33	<0.2	<10	36	<10	<27	<0.5	<2	.7	< 6	< 8	6,200	<5	1	75	68	<0.2	<1.0	5	<0.2	350	< 9	<2.0	<13	<0.2	<2.0	<10	<2.0
26b	Valley View Hot Springs	11	<10	<10	93	<0.2	< 1	20	< 2	<11	<2.0	<1	1	< 3	<10	28	<2	1	5	.4	4.0	4.0	4	<0.1	600	< 7	<0.5	<11	<1.0	<1.0	<10	<2.0
27b	Mineral Hot Springs	14	<10	25	100	<0.2	< 1	200	< 2	<27	<2.0	<1	<10	< 6	<27	22	<2	1	280	20	14.0	<2.0	50	<0.1	950	<19	<0.5	<12	<1.0	<1.0	<10	<2.0
27c	Mineral Hot Springs	15	<10	20	130	<0.2	< 1	317	< 2	<27	<2.0	<1	<10	< 6	<27	36	<2	1	290	15	18.0	<2.0	45	<0.1	860	<20	<0.5	<12	<1.0	<1.0	<10	<2.0
35a	Antelope Warm Spring	50	<10	<10	4	<0.2	< 1	78	< 2	< 7	<2.0	<1	.3	< 2	< 2	62	<2	<0.8	4	10	8.0	5.0	.8	<0.1	24	< 2	<0.5	< 1	<1.0	<1.0	<10	<2.0
36b	Wagon Wheel Gap Hot Springs	13	<10	<10	130	2.0	< 1	2,100	< 2	180	<2.0	<1	<10	<14	<22	240	<2	<0.8	1,900	310	<0.5	8.0	250	<0.1	2,000	<16	<0.5	<11	<1.0	<1.0	<10	<2.0
36d	Wagon Wheel Gap Hot Springs	36	<10	<10	120	4.0	< 1	2,200	< 2	230	<2.0	<1	<10	<13	<22	170	<2	<0.8	1,600	500	<0.5	<2.0	290	<0.1	1,800	<15	<0.5	<11	<1.0	<1.0	<10	<2.0
37b	Shaw's Spring	26	<10	<10	57	<0.2	< 1	68	< 2	<18	<2.0	<1	<10	< 4	<17	20	<2	<0.8	3	2	8.0	7.0	2	<0.1	170	<12	<0.5	< 8	<1.0	<1.0	<10	<2.0

Table 4. Alphabetical list of thermal springs and wells.

Name	Number
Antelope Warm Spring, Mineral County	35
Canon City Hot Springs, Fremont County	21
Cebolla Hot Springs, Gunnison County	28
Cement Creek Springs, Gunnison County	13
Cottonwood Hot Springs, Chaffee, County	14
Conundrum Hot Springs, Pitkin ;County	12
Dotsero Hot Springs, Garfield County	7
Dunton Hot Spring, Dolores County	32
Eldorado Springs, Boulder County	5
Fremont Natatorium, Fremont County	20
Geyser Spring, Dolores County	33
Glenwood Springs, Garfield County	8
Hartsel Hot Springs, Park County	11
Hortense Hot Spring, Chaffee County	16
Hot Sulphur Spring, Grand County	4
Idaho Springs, Clear Creek County	6
Iron Spring, Dolores County	34
Juniper Hot Springs, Moffat County	1
Lemon Hot Springs, San Miguel County	31
Mineral Hot Springs, Saguache County	27
Mount Princeton Hot Springs, Chaffee County	15
Orvis Hot Springs, Ouray County	29
Ouray Hot Springs, Ouray County	30
Pagosa Springs, Archuleta County	41
Penny Hot Springs, Pitkin County	9

Table 4. Alphabetical list of thermal springs and wells (continued)

Name	Number
Pinkerton Hot Springs, La Plata County	38
Poncha Springs, Chaffee County	18
Rhodes' Spring, Park County	10
Routt Hot Springs, Routt County	2
Shaw's Spring, Rio Grande County	37
Steamboat Springs, Routt County	3
Trimble Hot Springs, La Plata County	40
Tripp Hot Springs, La Plata County	39
Valley View Hot Springs, Saguache County	26
Waunita Hot Springs, Gunnison County	17
Wagon Wheel Gap Hot Springs, Mineral County	36
Well, artesian, Fremont County	22
Wells, artesian, Pueblo County	23,24,25
Wellsville Warm Spring, Fremont County	19

Table 5. List of thermal springs and wells by counties.

County	Number
Archuleta	41
Boulder	5
Chaffee	14,15,16,18
Clear Creek	6
Dolores	32,33,34
Fremont	19,20,21,22
Garfield	7,8
Grand	4
Gunnison	13,17,28
La Plata	38,39,40
Mineral	35,36
Mofatt	1
Ouray	29,30
Park	10,11
Pitkin	9,12
Pueblo	23,24,25
Rio Grande	37
Routt	2,3
Saguache	26,27
San Miguel	31

Table 6. Heat flow measurements in Colorado

No.	Locality	Latitude North	Longitude West	Drill Hole (Feet)	Tunnel (Feet)	H.F.U.	Rock Types	Source of data	Comments
1.	Yellow Creek	$40^{o}03'$	$108^{o}20'$	151- 2,890	----	1.5	Oil Shale	d	CH-1
2.	Yellow Creek	$39^{o}58$	$108^{o}28'$	249- 2,349	----	1.4	Oil Shale	d	CH-2
3.	Yellow Creek	$40^{o}03'$	$108^{o}21'$	2,024- 3,225	----	1.5	Oil Shale	d	CH-3
4.	Barcus Creek	$40^{o}03'$	$108^{o}31'$	1,348- 1,785	----	2.0	Oil Shale	d	Little more than a rough est.
5.	Rio Blanco	$39^{o}46'$	$108^{o}09'$	151- 1,056	----	1.5	Oil Shale	d	Little more than a rough est.
6	Rifle	$39^{o}30'$	$107^{o}46'$	- 6,280	----	1.4	Oil Shale	c	
7.	Adams Tunnel	$40^{o}14'$	$105^{o}47'$	----	69,244	1.6	Granite	a	
8	Rocky Mountain Arsenal	$39^{o}51'$	$104^{o}51'$	1,207-11,802	----	2.0	Metamorphics	b	
9	Golden	$39^{o}47'$	$105^{o}16'$	328- 1,739	----	1.5	Metamorphic	b	
10	Urad	$39^{o}46'$	$105^{o}47'$	- 2,198	----	2.0	Metamorphic?	c	
11.	Roberts Tunnel	$40^{o}37'$	$106^{o}00'$	----	8,760	2.5	Crystalline	b	
12	Gilman	$39^{o}31'$	$106^{o}18'$	- 1,070	----	2.2	Crystalline	c	
13.	Paradise Pass	$39^{o}00'$	$107^{o}04'$	- 689	----	1.6	Granodiorite	b	
14.	Canon City	$38^{o}30'$	$105^{o}19'$	- 410	----	1.8	Granite	c	
15.	Ouray	$38^{o}03'$	$107^{o}40'$	???	----	3.7	?????	b	(1972 personal comm.)
16.	Hesperus	$37^{o}23'$	$108^{o}04'$	1,345- 1,788	----	2.1	Crystalline	b	

a: Birch, Francis, 1950
b: Decker, E. R., 1969
c: Roy, and others, 1968
d: Sass, and others, 1971

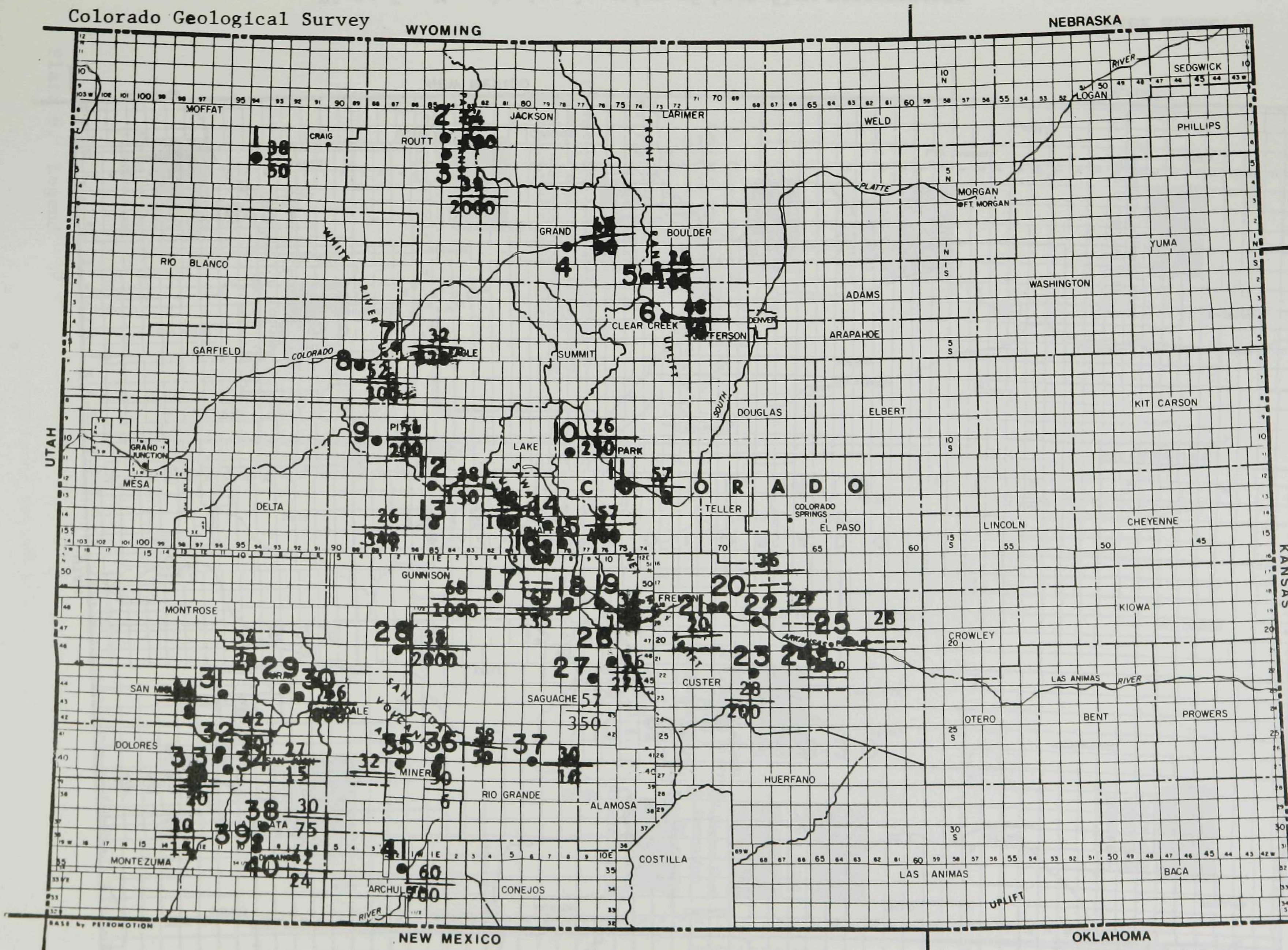

Plate 4. Map showing location of thermal springs and wells

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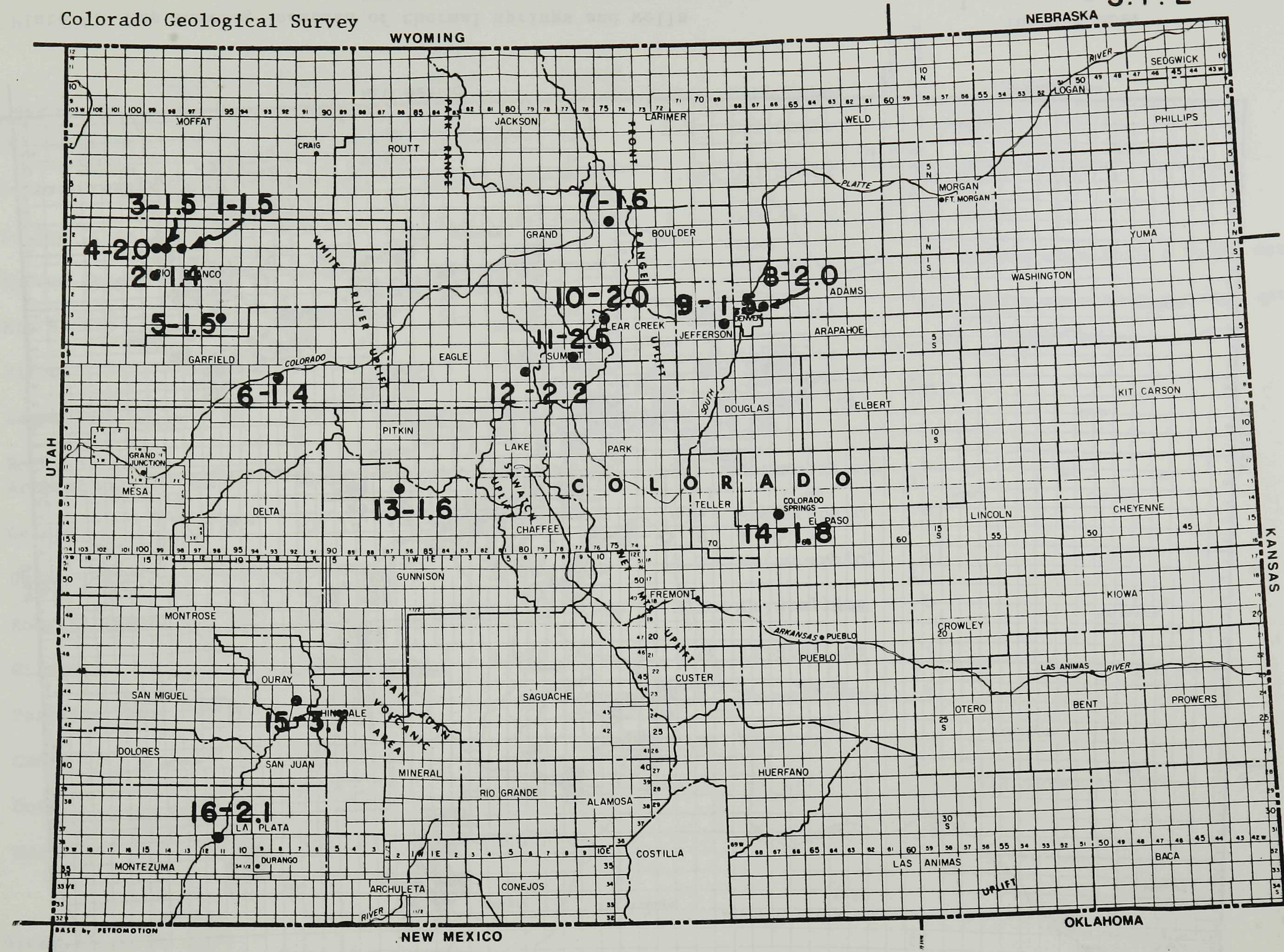
Index number

1. $\frac{38}{50}$ °C



Index number

7-1.6 Heat flow units

Plate 5. Map showing location of heat flow measurements

Richard Howard Pearl

EXPLANATION

QUATERNARY

Qtf
Compound alluvial fans and torrential wash

TERTIARY

Tbp
Browns Park formation
Early Pliocene or late Miocene.

Tcd
Creede formation
Local sand, gravel, and tuff, and some flows of rhyolite; repeated above under sedimentary rocks.

EROSION SURFACE

Tpv
Piedra rhyolite (youngest), Huerto andesite, Alboroto quartz latite, Sheep Mountain andesite, and Treasure Mountain quartz latite (oldest)

Tlv
Late Tertiary intrusive rocks

Ti
Tertiary intrusive rocks undivided

Tei
Early Tertiary intrusive rocks

CRETACEOUS

K
Cretaceous undivided
In part pre-Mesaverde only.

Kmv
Mesaverde group of Colorado River Valley
Largely continental.

Klw
Lewis shale

Kwf
Williams Fork formation

Ki
Iles formation

Kd
Dakota sandstone

Plate 6. Legend

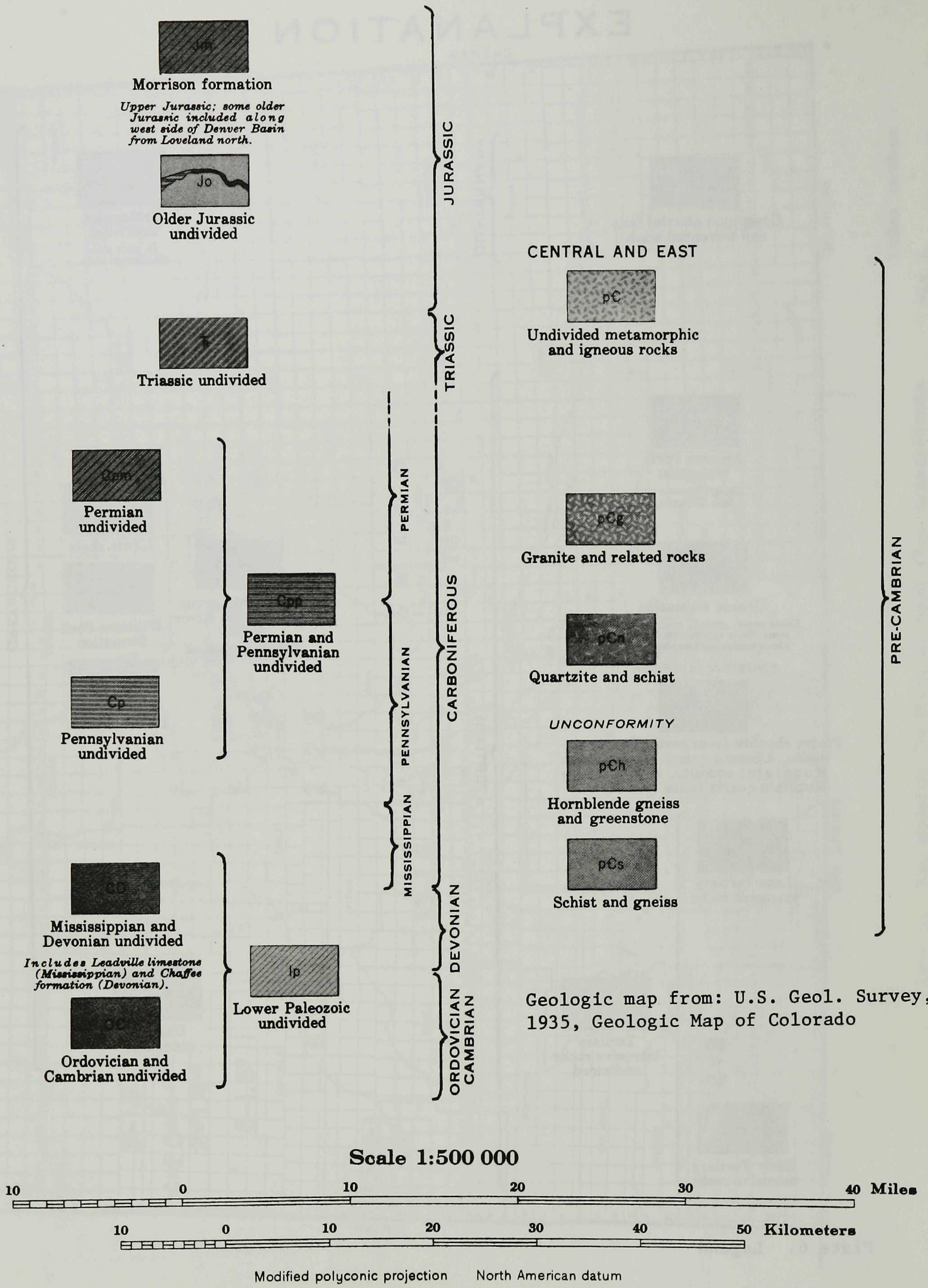


Plate 6. Legend (continued)

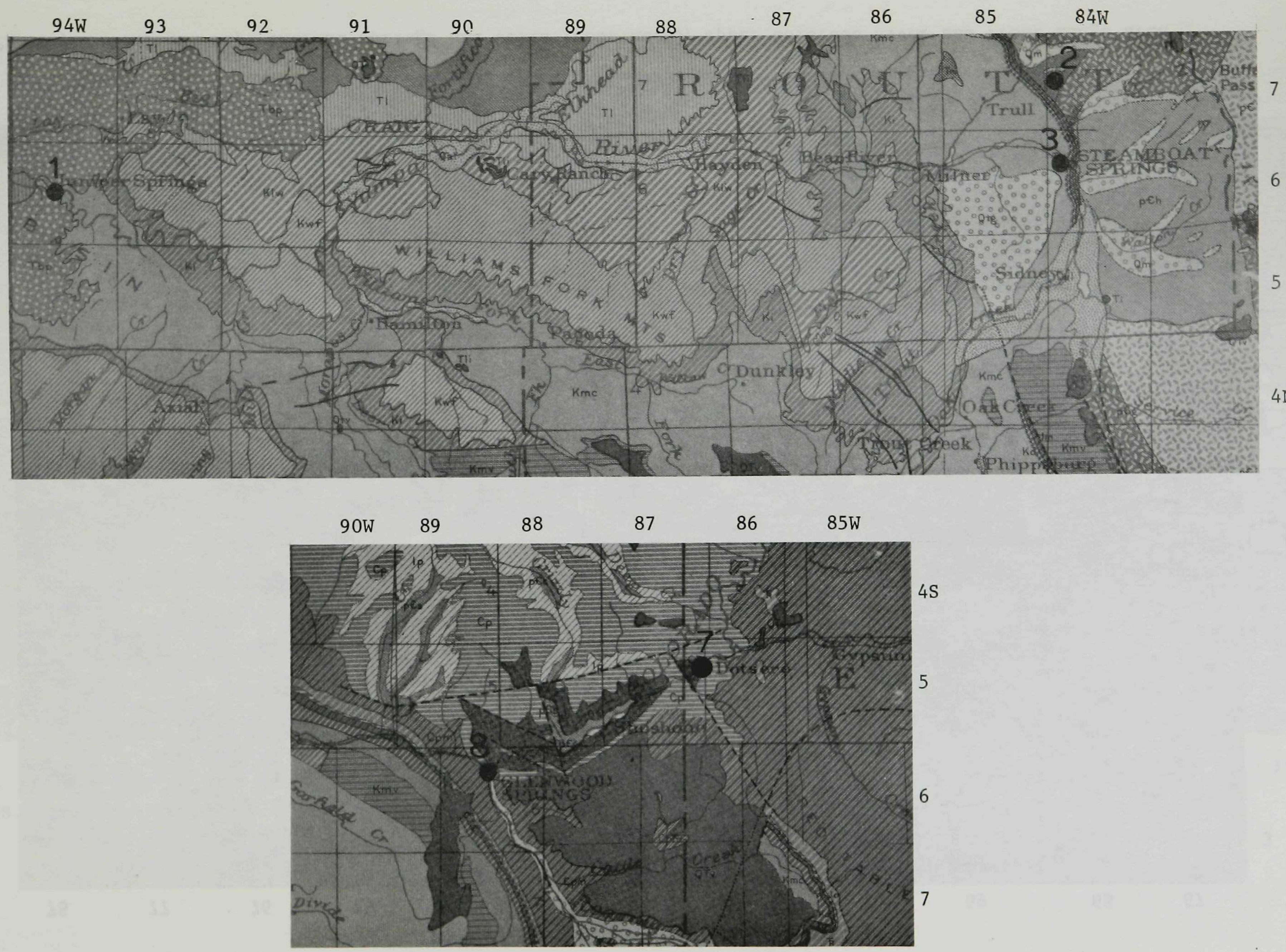


Plate 6. Geologic map--thermal springs and wells; northwest Colorado and Glenwood Springs area

Plate 7. Geologic map--thermal springs and wells (continued); Upper Colorado River and Front Range area

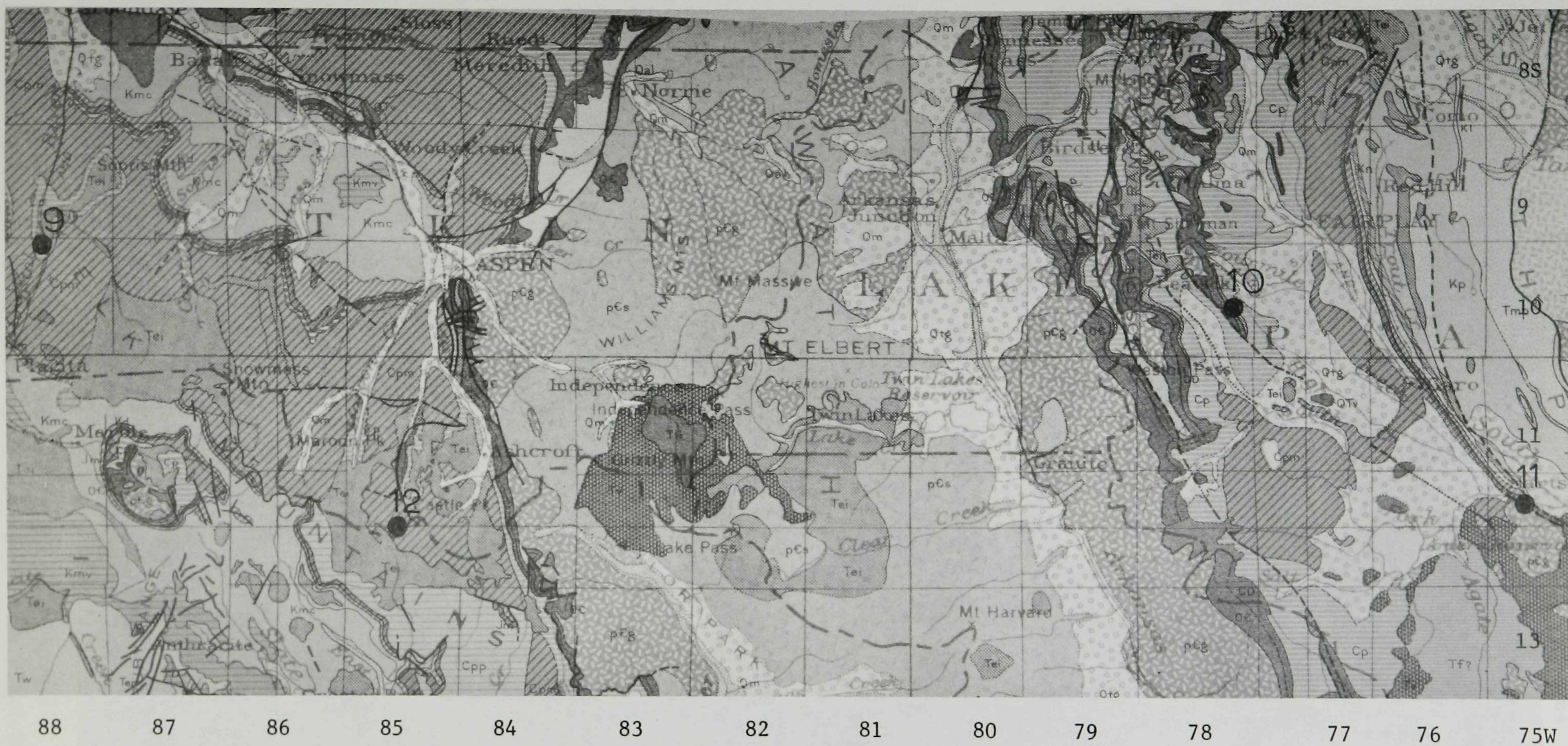


Plate 8. Geologic map--thermal springs and wells (continued); Aspen and South Park areas.

Plate 9. Geologic map--thermal springs and wells; Upper Arkansas River and Gunnison areas.

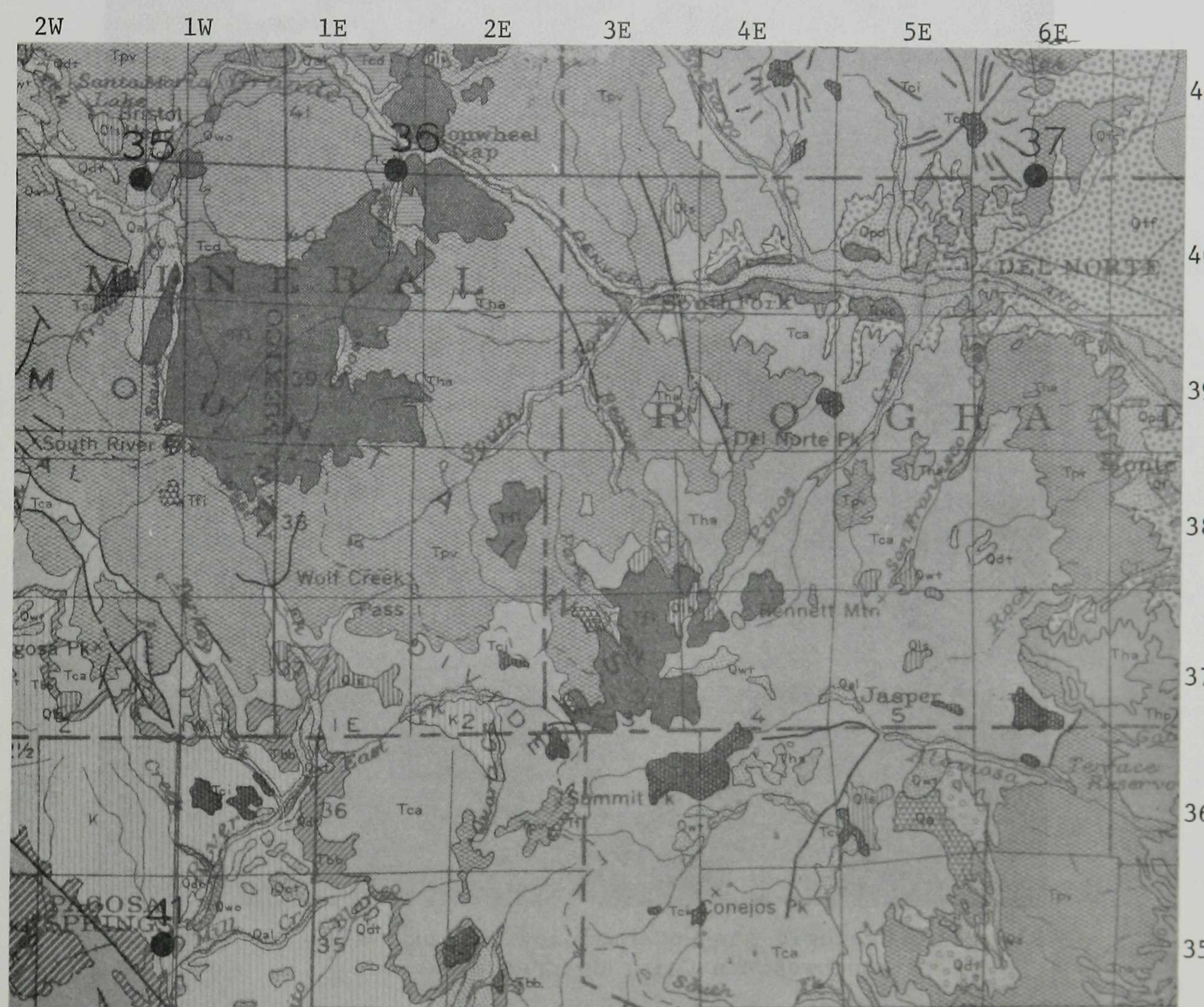


Plate 10 Geologic map--thermal springs and wells (continued).
Lower Arkansas River and Pagosa Springs--Wagon Wheel Gap

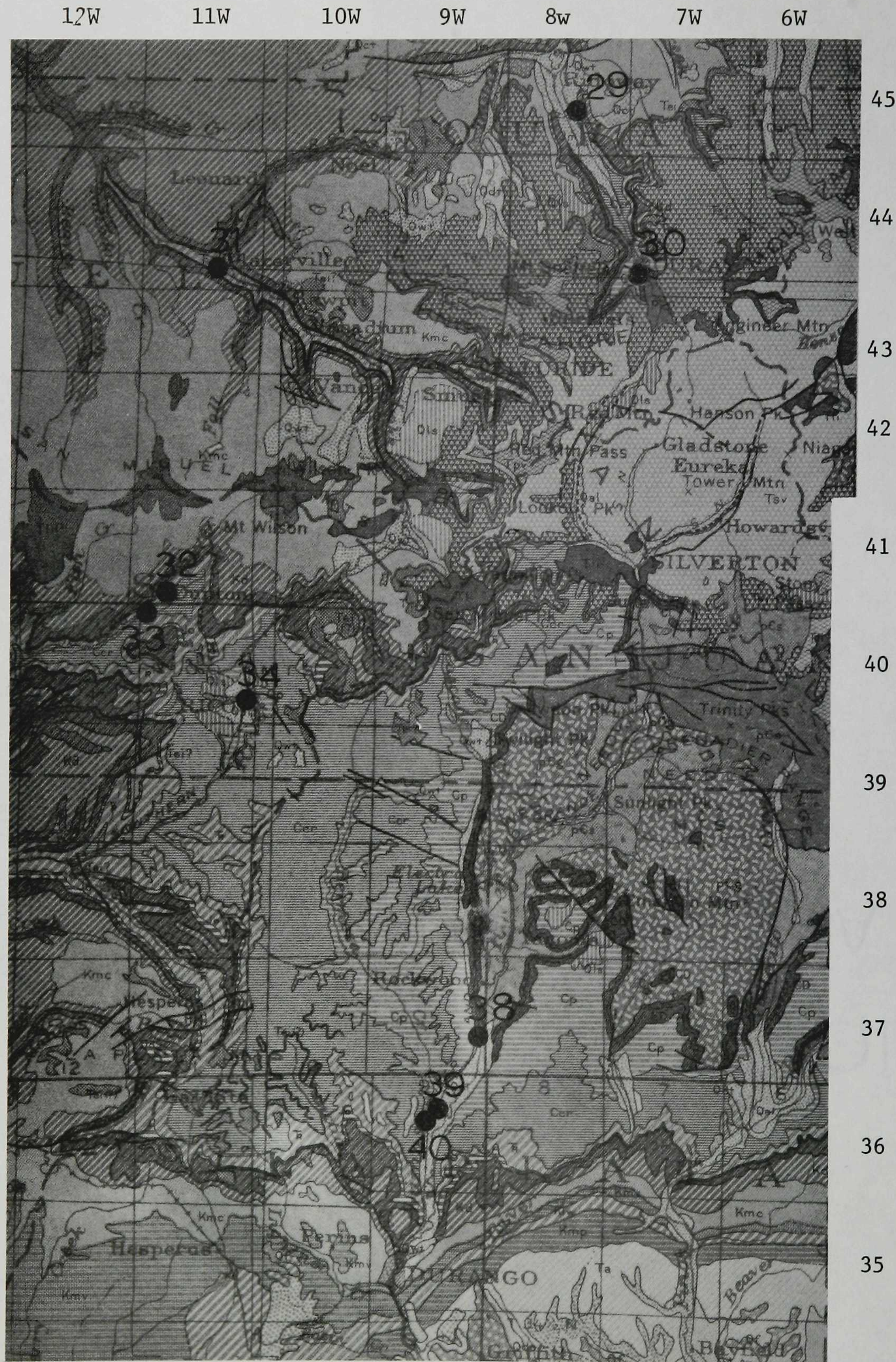


Plate 11. Geologic map--thermal springs and wells (continued); southwestern Colorado area

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MAP SERIES 11 -- Uranium-Vanadium Mining Activity Map of Colorado with Directory, J. Collier, A. L. Hornbaker, and W. Chenoweth, 1978 (in press).

GENERAL

GEOLOGIC MAP OF COLORADO -- U.S. Geological Survey, 1935, 1 sheet, multi-colored, scale 1:500,000; reprinted by Colorado Geological Survey, 1975, $5.00 ($6.50 rolled and mailed).

MAP MF-788 -- Preliminary Geologic Map of Colorado, compiled by Ogden Tweto, published by U.S. Geological Survey, 1976, 2 sheets, black and white, scale 1:500,000, $1.50.

MAP I-1039 -- Energy Resources Map of Colorado, compiled by U.S. Geological Survey and Colorado Geological Survey, 1 sheet, multi-color, scale 1:500,000, $2.00.

MAP SERIES 1 -- Geologic, Energy and Mineral Resources Maps of Routt County, Colorado, by A. E. Miller, 1975, 2 maps, scale 1:126,720, $5.00.

MAP SERIES 3 -- Geology of Moffat County, by A. E. Miller, 1977, scale 1:126,720, $8.00.

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BULLETIN 37 -- Bibliography and Index of Colorado Geology 1875-1975, compiled by American Geological Institute, 1976, $7.50 (soft cover) $10.00 (hard cover) (mail orders add $1.00 for each copy, postage and mailer).

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