NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN 91

THERMAL WATERS OF NEVADA

LARRY J. GARSIDE
JOHN H. SCHILLING

Descriptions of Nevada's thermal waters in springs, wells, and mine workings: locations, geology, temperatures, flow rates, water chemistry, well depths, drilling and other exploration activities, and past and present uses.

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA • RENO
1979

First edition, second printing, 1989: 1000 copies
Composed in IBM Press Roman type at the
Nevada Bureau of Mines and Geology
Printed by A. Carlisle, 1080 Bible Way, Reno, NV

Note:
Minor corrections to the first printing were made in text, appendixes, and plate.

For sale by the Nevada Bureau of Mines and Geology, University of Nevada-Reno, Reno, NV 89557-0088. Price $14.00

NEVADA BUREAU OF MINES AND GEOLOGY

BULLETIN

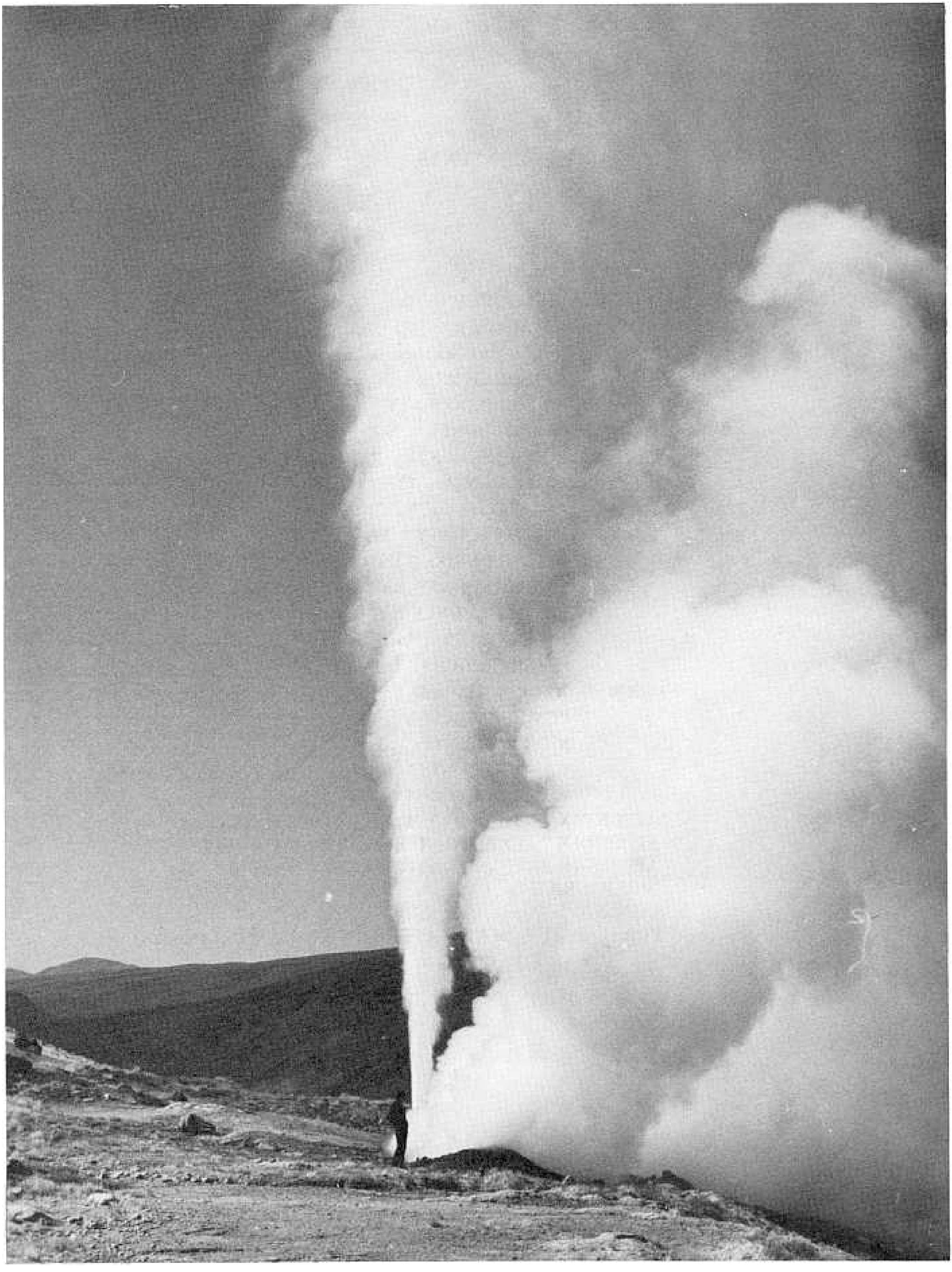
THERMAL WATERS OF NEVADA

LARRY J. GARSIDE
JOHN H. SCHILLING

Descriptions of Nevada's thermal waters in springs, wells, and mine workings: locations, geology, temperatures, flow rates, water chemistry, well depths, drilling and other exploration activities, and past and present uses.

MACKAY SCHOOL OF MINES
UNIVERSITY OF NEVADA • RENO
1979

CONTENTS



Steam well at Beowawe Geysers, Eureka County (photo by Dennis Trexler).

INTRODUCTION

Purpose and scope

The goal of this report is to provide basic information that can be used to determine the potential of Nevada's geothermal resources and aid in their exploration, development, and utilization—to bring together under one cover all the scattered data, published and unpublished, on Nevada's thermal waters, both hot water and steam. Information about springs, wells, mine workings, and other occurrences is included. Nevada does have huge geothermal-energy resources, as this report indicates, however, no attempt was made to evaluate the potential of any given area in the State.

Although we have tried to be as complete as practicable without making an exhaustive search, this report should be considered as preliminary and incomplete—a first pass at collecting existing data. The bibliography lists most of the references containing information on Nevada thermal waters. Many errors probably have been perpetuated because temperatures, flow rates, and chemical analyses were not field-checked.

The Nevada Bureau of Mines and Geology will continue to collect data on geothermal resources; this information will be available for inspection (by appointment), and staff members will continue to be available to answer questions.

Corrections, as well as additional information, are welcome (please send to Larry Garside, the senior author).

Organization of report

Much of the data collected is given in tabular form in *Appendix 1* (Nevada Thermal Water Data) and *Appendix 2* (Exploratory Geothermal Drilling in Nevada). It also is summarized in narrative form, alphabetically by county and by geothermal area, in the section preceding the two Appendices. In a general way the descriptions of geothermal areas within individual counties are arranged according to maximum reported temperature.

Definition of thermal water

This report lists all warm or hot (anomalously thermal) water—water that has a higher temperature than it would if affected only by "normal" wall-rock and/or surface temperatures. Unfortunately, it is difficult at best to determine an accurate cutoff for individual springs or wells.

Subsurface temperatures are affected by climatic conditions to depths of about 100 feet; below 100 feet temperatures in most of Nevada "normally" increase about 1°F every 55 feet, but increase more rapidly in areas of anomalously high heat flow. The water temperature in a spring or well depends on: (1) the surface-water temperature at the ground-water recharge point; (2) heating or cooling during near-surface movement; (3) heating during movement to greater depths; (4) cooling in returning to the surface or shallower depths; and (5) cooling or heating by mixing with other ground water.

Unfortunately all the information needed to determine accurately the absolute minimum temperature necessary for a well or spring to be thermal, is never available. *In this report we have used 70°F as an arbitrary cutoff for springs and water wells; in a few cases springs with temperatures above 70°F have been omitted for various specific reasons, and in Pahrump Valley and the Las Vegas basin water wells were omitted when they fell below the temperature expected from a normal geothermal gradient.*

Because an arbitrary cutoff had to be used, some truly thermal wells and springs undoubtedly have been left out of this report, and some nonthermal occurrences have undoubtedly been included. Users should also keep in mind that "cold" (nonthermal) and warm water can chemically indicate the presence of anomalously hot temperatures at depth; cold springs and wells should not be ignored when exploring for geothermal resources.

Definition of geothermal area

In this report a geothermal area must: (1) have at least one known occurrence of thermal water; and (2) form a geographic cluster and/or appear to have a common source and form a continuous anomaly at depth. Information is usually lacking to prove a connection between two or more occurrences, and in many cases springs and wells have been grouped together only to simplify their presentation. Thus the limits of each geothermal area have had to be defined in a rather arbitrary manner.

System of naming and numbering

Geothermal areas have been assigned geographical names—usually that of the largest, best known hot spring, or less commonly of a well-known feature in the area. Hot-spring names used in this report are those considered to be the most widely used; where needed, other alternate names are listed in parentheses after the primary name. It is hoped that the primary names will be used whenever possible.

Each hot-spring group, geothermal area, and isolated hot spring has been given a unique identification number which is used in the text and tables, as well as on plate 1.

Location

Section-township-range locations are given for each spring and well. Where more detailed locations are known the quarter-quarter-quarter system is used (for example: NE/4 SE/4 NW/4 S5,T20,R30E indicates that the occurrence is located within approximately a 10 acre parcel which is the northeast quarter of the southeast quarter of the northwest quarter of Section 5, Township 20 North, Range 30 East). In some cases, these described locations were estimated by projecting the land grid into unsurveyed areas.

Usually the location of springs and wells is from (or was cross-checked with) U. S. Geological Survey 7½′, 15′, and 1x2° topographic quadrangle maps, using the most detailed map available for a given area. Unless the well or spring is actually shown and named on the map, or the location was field-checked, the location information was taken from the reference listed and may be wrong. Incorrect locations were found in many published reports, and some undoubtedly are carried over to this report.

Acknowledgements

So many individuals and organizations have contributed to this report that we have not listed them individually in this section. Their help is gratefully acknowledged. We have tried to show their support by citing sources of information throughout the report, and by listing published sources in the Bibliography.

The Nevada Oil and Gas Conservation Commission contributed $1,500 toward the funding of this project. We greatly appreciate this support.

We also wish to thank other members of the Nevada Bureau of Mines and Geology staff who helped make this report possible: Janet Amesbury, Bill Daniels, Robert Kirkham, Helen Mossman, Susan Nichols, LaVerne Rollin, Georgianna Trexler, and Becky Weimer.

NEVADA RESOURCES

General Information

Geothermal energy is simply the natural heat of the earth. The earth can be thought of as a great furnace with the amount of contained heat so vast that it is impossible to comprehend. It has been estimated, for example, that heat equivalent to the combustion of 300 million barrels of oil is released if 1 cubic mile of hot, near-surface rock is cooled from 625°F to 350°F. The problem is in extracting and utilizing this energy.

The source of the earth's heat, which increases with increasing depth beneath the surface, is believed to be due to the decay of radioactive elements as well as to frictional (tidal) forces. Because heat continues to be produced, one should think of the earth as a heat generator, not simply as a reservoir.

At present it is probably not economically feasible to drill a deep well in any arbitrary area and obtain useful quantities of heat. Therefore, for the near term, geothermal energy utilization will be concentrated in those areas of the world where "hot spots" are known to occur, for example, the "Ring of Fire"—the belt of volcanoes and earthquake activity many thousands of miles in length that circles the Pacific Ocean. Nevada is located within this tectonically active belt. Hot springs or other areas where temperatures increase more rapidly than normal with depth may indicate near-surface sources of heat, such as magma chambers, or hot recently solidified rock. If water flows through such heated zones, it will, in turn, become heated. Therefore it is in these areas, where water can act as a transfer agent for the heat, that exploration for geothermal energy will be concentrated.

Although geothermal energy can be used directly for space heating, much of the exploration in Nevada will concentrate on finding naturally heated reservoirs that can produce steam or hot water for use in electric-power generation. The so-called dry-steam fields, like The Geysers in northern California, are probably rare in nature. When wells are drilled to tap a geothermal reservoir, the product may be dry steam unaccompanied by water, or it may be extremely hot water at elevated pressure. Hot-water fields are much more common, but more complicated equipment will be required to best utilize their energy. Minerals are much more soluble in hot water than in cold, therefore these fields often yield water with considerable amounts of dissolved minerals. Also, the amount of dissolved mineral matter varies from one geothermal area to another. Dissolved minerals can clog and corrode pipe and generating facilities, and equipment to handle these problems is still mainly in the experimental stages. (For example, down-hole heat exchange systems could prevent the mineral-laden water from coming in contact with generating equipment.)

Hydroelectric power is the only power source that has been found to be cheaper than geothermal power, and then only in certain cases. At The Geysers, California, the only commercial U. S. geothermal installation, geothermal electric power has proven to be cheaper than power from other fuel sources, regardless of plant size (Koenig, 1973). The cost of generation at The Geysers is in fact, about two-thirds of that which could be obtained from a coal-fired plant. The Geysers presently produce 500 megawatts of electricity, enough to supply all of San Francisco's needs.

Use

Hot springs and wells are scattered over the entire State (plate 1), and there are at least 300 thermal wells, springs, and spring clusters. The use of hot springs in Nevada dates back to prehistoric time, when Indians used them for bathing, scalding ducks and geese, and as an aid in removing the pitch from pinyon-pine cones and seeds. Early explorers and the wagon trains of the 49'ers used the hot springs for drinking, bathing, and watering stock. Because of the State's arid climate, water, even if mineralized and hot, has always been an important resource. The waters of almost all the springs in the State, whether hot or not, have been appropriated for some beneficial use. The mines of the Comstock Lode at Virginia City were famous for the great quantities of hot water encountered. At Tonopah, 3 million gallons of hot water were pumped every day from the workings; the flow from the Tonopah mines was used to operate greenhouses. In the 1800's and early 1900's resorts grew up around many of the hot springs. Many of these spas are now gone, but some, such as those at Steamboat and Lawton Hot Springs near Reno, are still popular. Today many hot-spring areas are used for swimming and other recreational activities. Swimming pools using the naturally heated water from hot springs are common in the less populated areas of the State. The hot water, either from springs or shallow wells, is often suitable for use in pools with no treatment, although mixing of water of various temperatures may be necessary. Natural pools and ponds at hot springs can be near boiling and are extremely dangerous. When investigating hot-spring areas, persons should exercise considerable caution. (Hot mud often occurs under a seemingly solid surface. This surface may break under a person's weight.)

Steamboat Hot Springs, 8 miles south of Reno, have been used for several commercial purposes, including bath resorts, processing asphalt emulsions, and in the melting and casting of plastic explosives. The hot water from Moana Hot Springs in Reno has been used in the past for a swimming pool and to melt winter ice and snow from streets. In the Stillwater area near Fallon in west-central Nevada, steam and hot water were encountered while drilling water wells in an area where there were no hot spings, and have been used to heat dwellings in this farming area. A number of homes in the southwestern part of Reno (along the Steamboat–Moana–Lawton's thermal anomaly) are heated by simple heat-exchange systems that utilize the heat from hot water encountered in wells. This source of home heating has considerable potential (Bateman and Scheibach, 1975).

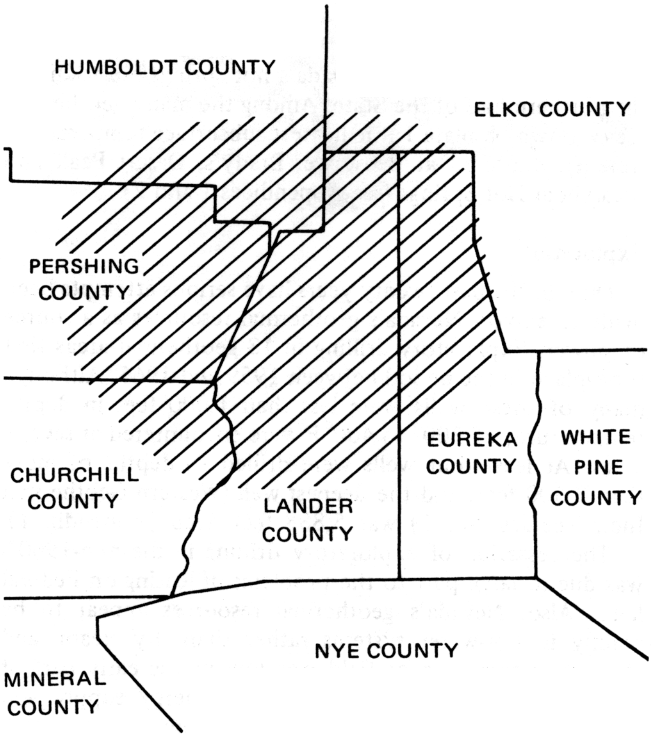


FIGURE 1. Location of Battle Mountain heat-flow high in north-central Nevada.

The heating of greenhouses with naturally heated water also has great potential. At Wabuska, near Yerington, water at temperatures of over 200°F has been used to heat greenhouses for growing vegetables, especially tomatoes. Geothermally heated greenhouses are also in use at Wendel Hot Springs near Honey Lake, Calif. (near the California–Nevada boundary) and, a food dehydration plant is being built at Brady's Hot Springs.

Although no electricity is generated in Nevada from geothermal steam, the utilization of geothermal energy for electric power is probably its highest potential dollar-value use. Although technological problems remain, the State is blessed with several areas that may soon be the sites of geothermal generating facilities, possibly utilizing heat-exchange systems.

Geothermal energy is of special importance to Nevada. Electric power needs in the State are expanding at a rapid rate because of the growing population and increased per capita consumption, as well as the extension of transmission lines to many remote areas. Power consumption in Nevada will probably be about 11 million megawatt-hours in 1978 and is expected to rise to approximately 18 million megawatt-hours per year by 1990. Generating capacity in Nevada will rise to an even higher level, as generating facilities are constructed in Nevada to supply the needs of population centers in California. Nevada's entire population of over half a million persons could be supplied by a single 1200-megawatt nuclear plant, or by a geothermal field the size of The Geysers in northern California (when this field is fully developed). Obviously the demand for electrical energy from outside the State will greatly influence both the development of electric generation facilities and the exploration for new energy sources, including geothermal power.

Geology

The Basin and Range physiographic province, in which Nevada is located, is an area of high heat flow, believed to result from near-melting conditions in the lower crust and upper mantle. The west-central and north-central areas of Nevada have higher hot-spring temperatures and are regions of greater than normal heat flow. An area of conspicuously higher heat flow, called the "Battle Mountain high," is located in north-central Nevada (fig. 1). The boundaries of this region, and possibly others as yet undetected, need to be delineated by more systematic heat-flow surveys. This would provide useful guidance in the search for economically exploitable geothermal fields (Sass and others, 1971). The Battle Mountain high has an indicated average flow of about three heat flow units (two heat flow units is an average value for Nevada), but the thermal gradients, which range from 30° to 60°C/km (about 2.6–4.3°F/100 ft), are not as high as might be expected because of relatively high thermal conductivities of the rocks in this area (White, 1973). The Battle Mountain high may be the result of fairly recent intrusion of magma into the earth's crust. The Quaternary volcanism within the region suggests that this view is reasonable (Sass and others, 1971).

Nevada has a considerable range in mean annual temperature due to both its variations in elevation and its extent over approximately 7 degrees of latitude. The mean monthly temperature usually varies 15° to 20°F from northern to southern Nevada. For this reason, comparisons of hot-spring temperatures with statewide mean annual air temperatures are usually not worthwhile.

In many areas of the world, hot springs and other high-temperature phenomena such as fumeroles are associated with geologically young igneous rocks, commonly less than 5 million years old. Young volcanic rocks or active volcanoes at the earth's surface often indicate that hotter bodies of rock, or fluid magma, are present below, in the upper part of the earth's crust.

Nevada lies in the center of a large province of Cenozoic volcanic rocks. Although many of these rocks are 10 to 30 million years old, younger volcanic rocks are found in many areas. In Nevada, young volcanic rocks are found in the Mono Lake–Aurora area of southwestern Mineral County and adjacent California, in southwestern Eureka County, north of Silver Peak (Esmeralda County), in the Carson and Virginia Ranges near Reno, at Lunar Crater in northeastern Nye County, at the north end of the Fish Creek Mountains in northern Lander County, in Reveille Valley and the Amargosa Desert in Nye County, on Railroad Point in northwestern Humboldt County, and in the Winnemucca–Battle Mountain area of north-central Nevada, as well as in a number of other areas (Stewart and Carlson, 1976a). K-Ar (potassium-argon) dating has defined the age relations of many volcanic centers in Nevada, and will continue to be useful in the future. Isotopic ages of Nevada rocks are listed in Schilling (1965b), and additional data have been and will continue to be reported in various articles of the journal Isochron/West.

Many of Nevada's numerous hot springs occur along major faults which bound the State's mountain ranges. The basin-and-range pattern of linear, north-south-trending mountain and valley blocks is a result of these faults. The ground water in the valleys often circulates to considerable depths along some of these fractures, and is heated by the

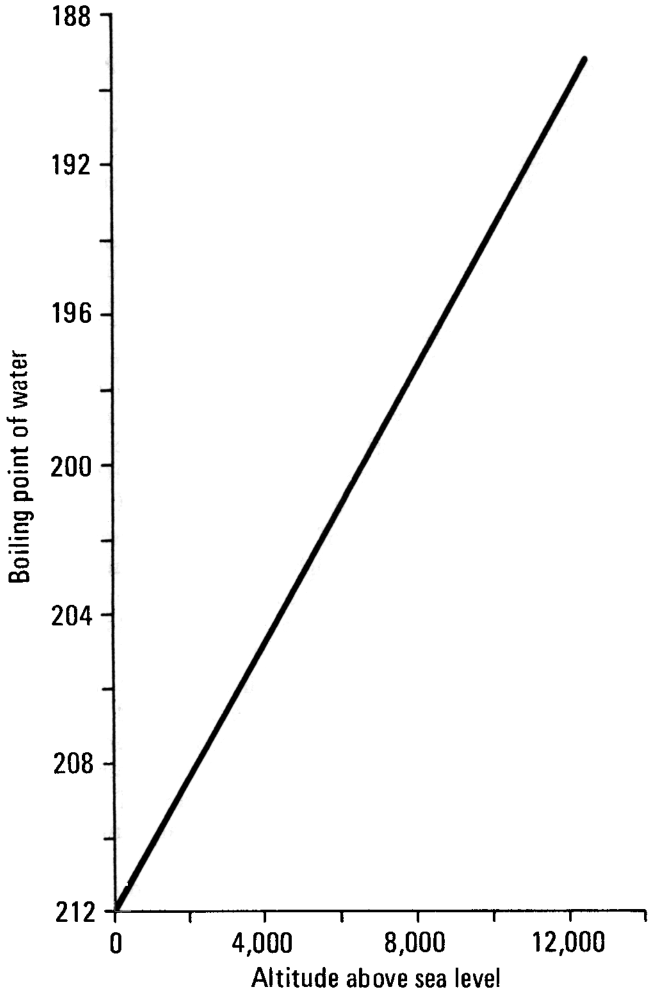


FIGURE 2. Variation of the boiling point of water with altitude above sea level (data from Waring, 1965).

hotter rocks found at these depths. If one knows the approximate geothermal gradient, the depth of circulation of ground water can often be estimated from water temperatures of springs (assuming little cooling has taken place as the water ascends to the surface). The ground water under many of Nevada's valleys is measured in the millions of acre feet per basin.

Hot-spring temperatures in the State range up to boiling, although surface-water measurements on boiling springs will commonly be somewhat below the boiling point for any given elevation because surface evaporation and other cooling phenomena may substantially reduce water temperatures. The best measurements are usually made directly in the orifice of the spring, below the water surface where the flow is greatest. Below altitudes of 5,000 meters (about 16,000 feet), the boiling point of water decreases 1°F for each 550-foot (1°C for each 303 meters) increase in elevation above sea level. Figure 2 is a graph showing altitude plotted against the boiling point; from this graph it can be seen that a spring at an elevation of 6,500 feet will be boiling at water temperatures nearly 12°F below the sea-level boiling point. Conversely, the boiling point rapidly increases with depth below the earth's surface (see fig. 3). Gases in solution lower the boiling point while mineral substances in solution raise the boiling point (however, the effect of elevation or depth is much greater than any change due to dissolved materials).

The major portion of Nevada's hot springs are found in the northern half of the State. Among the many geothermal areas shown on plate 1, the hottest subsurface temperatures were encountered at Beowawe, Brady's, Desert Peak and Steamboat Hot Springs (see Appendices 1 and 2).

Exploration

Only in the past twenty years have serious attempts been made to exploit Nevada's geothermal resources as a source of power. Exploratory drilling in 13 geothermal areas first took place in the period between 1959 and 1965. Although many of these wells were less than 1,000 feet in depth, temperatures of 300° to 400°F were encountered at several areas. At least four wells were drilled to depths of more than 3,500 feet, and the deepest well (Western Geothermal Inc., Needles No. 1) was 5,888 feet deep (Appendix 1).

The cessation of exploratory drilling in the mid-1960's was due in large part to the problems of leasing on Federal land. Also, Nevada's geothermal resources appear to be mainly in hot-water systems rather than dry steam, and interest in this type of field was low in the early part of the 1960's. Today, with changes in energy supply and investment attitudes, exploration is once again being carried on in Nevada for geothermal power. The geothermal wells in the 1970's are being drilled to greater depths and at locations outside of known hot-spring areas. In general, these major exploratory wells are considerably more expen-

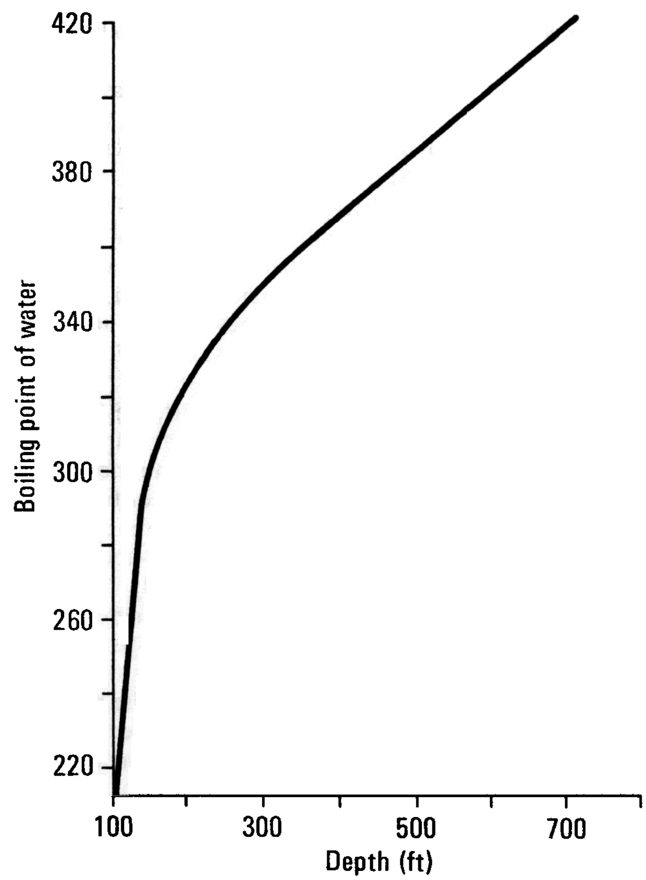


FIGURE 3. Variation of the boiling point of water with depth below a water surface at sea level (data from Waring, 1965).

sive than were those drilled in the 1960's and they are being located on the basis of sophisticated geological, geochemical, and geophysical exploration techniques. A large number of temperature-gradient drill holes were drilled in Nevada in the mid 1970's by private geothermal exploration companies and government agencies. In addition geophysical exploration (gravity, magnetics, seismic, electrical resistivity, etc.) has been used to site major exploration wells in a number of areas. Grose (1971) presents a review of the various exploration methods used in the search for geothermal energy.

A great deal of geothermal-related geologic research has been done in the State over the past several years. Much of this research has been directed toward the collection of basic geologic data on Nevada's known geothermal systems. This data has been released by a number of research groups as published and open-file reports, and these reports are cited where appropriate in the following sections of this report and are listed in the bibliography. The private sector has also collected a large amount of geothermal information; much of it has not been released to the public, although exchanges of this information between companies for their mutual benefit is quite common.

There are numerous sources of general background information on the geology of Nevada. Most of the geologic and geophysical reports and maps have been published by either the Nevada Bureau of Mines and Geology or the U. S. Geological Survey. Also, many of the open-file and limited-distribution reports on Nevada's geothermal resources are available at the Bureau's offices. For help in determining what is available, (including unpublished information) contact the Nevada Bureau of Mines and Geology (on the University of Nevada, Reno, campus: 702-784-6691).

Regulations

An August 1965 opinion by the Deputy Attorney General of Nevada considers geothermal resources as water resources, and has placed the regulatory jurisdiction with the Division of Water Resources, Department of Conservation and Natural Resources. Anyone planning to drill a geothermal well should therefore contact:

Roland G. Westergard, State Engineer
Division of Water Resources
201 South Fall Street
Carson City, NV 89701
(702) 885–4380

The State regulations for the drilling and plugging of temperature-gradient drill holes and geothermal wells are similar to those for drilling water wells. Although exploration and subsurface information obtained as a result of a geothermal project must be filed with the State engineer, this information is confidential for a 5-year period, unless written consent to disclose it is given by the operator (Nevada Revised Statutes, chapter 534A).

The Nevada Division of Environmental Protection establishes regulations for all forms of pollution. Although there are no laws specifically dealing with pollution caused by geothermal exploration and development, the general State laws and regulations definitely apply. For more information, contact:

Division of Environmental Protection
Department of Conservation and Natural Resources
201 South Fall Street
Carson City, NV 89701
(702) 885–4670

Nevada State land consists of less than 1 percent of the 110,540 square miles (70,745,600 acres) of total land area. Nearly half of all State-owned land consists of State parks. Because there is essentially no State land with geothermal potential on which leasing would be allowed, no State geothermal-leasing regulations have been issued.

Approximately 86 percent of Nevada's land area is under the jurisdiction of the Federal Government. Much of this land is public domain—public lands under Federal management which have not been reserved for special uses such as parks, National Forests, recreation areas, and military installations (Lutsey and Nichols, 1972). Public domain lands in Nevada total approximately 47 million acres (about 66 percent), and are administered by the Bureau of Land Management of the U. S. Department of the Interior. The Secretary of the Interior is authorized by Public Law 91–581 (The Geothermal Steam Act of 1970) to issue leases for the development and utilization of geothermal steam and associated geothermal resources. Lands administered by the Forest Service, U. S. Department of Agriculture, are included in those lands available for geothermal leases. Further information can be obtained from:

U.S. Bureau of Land Management
Nevada State Office
850 Harvard Way
Reno, NV 89502

The BLM office also has available for public inspection land plats and other maps which show land use, ownership, survey markers, and other data.

Only about 12 percent of the land area in Nevada, amounting to some 8 million acres, is held in private ownership. The Southern Pacific Co. is the single largest owner of private land, and holds about 1.5 million acres. Over 80 percent of Nevada's private land lies along the route of the Southern Pacific Railroad (and the Humboldt River), forming a 40-mile wide band across the northern third of the State. Much of the private land in Nevada is available for geothermal exploration and development through lease arrangements with private owners.

A recent ruling by the Ninth U. S. Circuit Court of Appeals has indicated that the geothermal rights were reserved to the Federal Government when it reserved the rights to "coal and other minerals" on grazing land conveyed to homesteaders through the Stock-Raising Homestead Act of 1916. The Supreme Court has upheld this ruling. The Ninth Court also ruled that all elements in geothermal systems—porous rock, magma, and steam—are minerals for the purpose of deciding ownership. Thus, the owner of the land surface and water rights may not necessarily hold title to the geothermal rights.

Indian lands, comprising 1.6 percent of the State, may also be available for geothermal exploration and exploitation through the U. S. Bureau of Indian Affairs or individual tribal councils.

Hot Springs and Geothermal Areas

This section of the report describes the State's major hot springs and geothermal areas. It consists of summaries of the geology and history of the better known geothermal localities, and is not intended to be a complete listing of data on all thermal springs and wells—Appendix 1 contains the detailed information on water quality, location, spring and well names, etc. The springs, spring clusters, and geothermal areas are organized by county, and in a general way, by the maximum reported temperature within an individual county.

CARSON CITY

Carson (Swift's, Shaw's) Hot Springs [1]

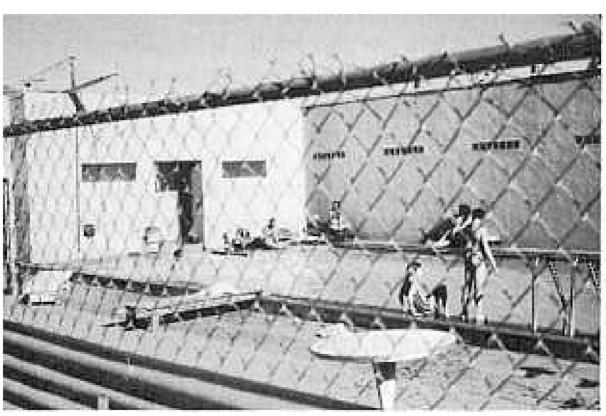
Hot springs on the north edge of the town of Carson City, have temperatures as high as 120°F. These springs, now referred to as Carson Hot Springs, were formerly called Swift's or Shaw's Hot Springs. The water is used in a swimming pool that is open to the public. Water supplied to the pool is pumped, probably from a shallow well near the pumphouse to the north of the pool area.

Nevada State Prison spring [2]

A hot spring is reported from the area of the Nevada State Prison (Waring, 1965). The old State Prison building was used for some of the early meetings of the Nevada Legislature in the early 1860's, and the legislators often used a large bathhouse there, probably Curry's Warm Springs Hotel (letter of Andrew Marsh to the *Sacramento Union*, Sept. 30, 1861, published in Nevada Highways and Parks, Spring, 1974). The Warm Springs Hotel was in operation adjacent to the prison in 1867 (Gillis, 1868).

Pinyon Hills [3]

There are a number of warm water wells in the Pinyon Hills subdivision about 2 miles southeast of the Nevada State Prison. The temperatures are generally 90° to 114°F, and the water is generally of poor quality (Glancy and Katzer, 1975; Center for Water Resources Research, University of Nevada, Reno, unpublished data).



Geothermal swimming pool at Carson Hot Springs, Carson City.

CHURCHILL COUNTY

Brady's (Springer's, Fernley) Hot Springs [10]

The hot springs along U. S. Highway I–80 about 20 miles northeast of Fernley have been referred to as Hot Springs, or Brady's, Springer's or Fernley Hot Springs, and are the Emigrant Springs of the Forty-Mile Desert. Some early travelers called it the Spring of False Hope. Coming across the desert, the oxen of the wagon trains could smell the moisture before reaching the springs. However, when they rushed forward to drink, they found the water scalding. The emigrants collected water in casks to cool, but pushed on to the Truckee River, as there was no forage at the springs (Work Projects Administration, 1940).

In the 1880's Russell (1885) reported that hot boiling water issued from a number of orifices, and when these became obstructed, the steam escaped with a hissing and roaring sound. During this same period there was an unsuccessful attempt to separate boric acid from the waters. In later years the hot water was used in a bathhouse and swimming pool which were located at a service station along U. S. Highway 40. The concrete pool, built in 1929, is all that remains today. The pool was apparently supplied by hot water directly from the springs. The hot springs do not flow at the surface today.

Brady's Hot Springs are located in NE/4 NE/4 SW/4 S12,T22N,R26E. Thermal ground water is found within an area of 6 to 8 square miles centered on this location (fig. 4). The elongate thermal area is parallel to the "Thermal Fault" mapped by Anctil and others (1960). Areas of hydrothermal alteration are aligned along this fault, and its trace has also been outlined by areas of observed snowmelt, indicating warm ground (Olmsted and others, 1975, fig. 37). This fault has had recent movement, as it cuts spring sinter and the alluvial fan deposits in the spring area and to the north. The fault is normal and dips steeply to the west, with the downthrown side to the west; the amount of displacement is unknown (Olmsted and others, 1975). All successful steam wells were collared in the hanging wall of the Brady Thermal Fault (Anctil and others, 1960).

The rocks exposed in the vicinity of Brady's consist of Tertiary basalt and andesite, Tertiary sedimentary rocks, Pleistocene lake sediments, and Quaternary alluvial deposits and siliceous sinter (figs. 5, 6). None of the wells drilled at Brady's (up to 7,275 ft. deep) penetrated the pre-Tertiary rocks, although they are exposed in the northern Hot Springs Mountains and were found in steam wells near Desert Peak (see the following section).

Bailey and Phoenix (1944, p. 51) report the presence of cinnabar and sulfur in S6(?),T22N,R27E about one-quarter mile southeast of U. S. Highway 40 and one-half mile east of the hot springs. The best showings of cinnabar are reported from around an active hot-spring vent. The occurrence is in hydrothermally altered tuff. Soil gas in the vicinity of the main Thermal Fault and around active steam vents at Brady's is anomalous in mercury (John Robbins, Scintrex Limited, written communication, 1973).

The spring sinter at Brady's is predominantly opal, and is quite extensive. It is concentrated along the main Thermal Fault and a small subsidiary fault to the east (Oesterling and Anctil, 1962).

The ground water in Fireball Valley (Hot Springs Flat) to the north probably moves as underflow to Brady's Hot