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GEOLOGICAL ASPECTS OF AN ASSESSMENT OF THE NATIONAL POTENTIAL FOR NON-ELECTRICAL UTILIZATION OF GEOTHERMAL RESOURCES

C.R. Nichols
K.W. Hollenbaugh
(Boise State University)

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Boise State University

K. M. Hollenbaugh

C. R. Nichols

Project Direction By

Aerojet Nuclear Company

J. F. Kunze
A. S. Richardson

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AEROJET NUCLEAR COMPANY
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PREFACE

The work included in this report was performed by the Geology Department of Boise State University and was coordinated by the Geothermal Projects Branch of Aerojet Nuclear Company, prime contractor to the Energy Research and Development Administration at the Idaho National Engineering Laboratory.

Financial support for this work was supplied through funds assigned by the Energy Research and Development Administration. These funds were made available to collect and assemble existing geological, geophysical and geochemical data relative to geothermal resources in the Western third of the United States.

The information presented in this report has been made an integral part of the "National Program Definition Study for the Non-Electrical Utilization of Geothermal Energy," ANCR-1214, prepared by the Geothermal Projects Branch of Aerojet Nuclear Company.

This report is being issued separately since it contains a wealth of vital information never before collected in one place. It is anticipated that the data presented herein will be of value to many government and non-government enterprises engaged in geothermal activities.

The staff of the Aerojet Nuclear Company Geothermal Projects Branch wishes to thank the to thank the contributors to this report, particularly, Dr. K. M. Hollenbaugh, Dr. C. R. Nichols, Dr. J. K. Applegate and their cohorts for their fine work and for this valuable contribution.

J. F. Kunze, Manager
Geothermal Projects

A. S. Richardson, Manager
Non-Electric Applications

ABSTRACT

This report presents exhaustive data on the potential sources and uses of geothermal water particularly in the Western third of the United States. This data includes the currently known or expected location, quality, quantity, and temperatures of geothermal sources. Included are discussions of the more important sources. Recommendations are made relative to potential utilization of these sources. In addition, suggestions are presented for the scientific evaluation of these and other potential geothermal sources.

ACKNOWLEDGEMENTS

The preparation of this report was a group effort. Dr. K. M. Hollenbaugh was the principal investigator and coordinated the effort at Boise State University. Dr. C. R. Nichols was instrumental in writing of the narrative and the presentation of background data and interpreatations. Two students, Charles Bryan and Ann Cochrane, spent much time drafting maps and collecting references. The manuscript was typed by Kay Johnson. The principal investigator prepared the state-by-state summaries, coordinated the total effort, and assumes full responsibility for any inaccuracies or omissions that may have escaped detection. Finally, grateful appreciation is extended to the many authors and agencies who have cooperated so freely in providing data included in the report.

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INTRODUCTION

The geologic assessment of the potential of the non-electrical utilization of the resource must consider the whole question of natural hot water origins, occurrences and characteristics as opposed to the rather narrow portion of the total resource which may be economically utilized at present for electrical power generation. As compared with the relatively rare coincidence of geologic factors necessary for economic geothermal power production utilizing presently available technology, the portion of the geothermal resource available for non-electrical utilization actually constitutes the major portion of the total geothermal picture. In a very real way, the non-electrical resource may be considered the bulk of the "iceburg" obscured beneath the surface, and the relatively rare high temperature brine or dry steam systems remain the very visible but volumetrically insignificant part of the resource.

There are two major types of geothermal systems as defined in terms of the nature of the fluid phase existing in the thermal reservoir (White,Muffler & Truesdell, 1971. In "vapor dominated" systems, a steam phase is present within the reservoir and may be produced directly for turbine generation of electrical power. "Hot water" systems may produce a steam-water mixture, due to boiling during fluid production, but water is the dominant reservoir fluid. For the purpose of this report, systems are defined in terms of their reservoir temperatures: low temperature, < 100°C; intermediate temperature, 100-180°C; and high temperature, > 180°C.

White (1970) has estimated that only one out of twenty geothermal systems are of the dry steam or vapor-dominated type. Both actual drilling of geothermal zones and chemical techniques for differentiating between wet and dry systems are tending to confirm White's prediction. Likewise, the very high temperature brines, such as those produced in the geothermal fields of Cerro Prieto, Mexico, and Imperial Valley, California, are relatively rare in the wet type of geothermal systems as compared to the much more common systems which have base temperatures below 200°C. The majority of the geothermal systems under investigation in the western U.S. seem to have base temperatures clustered between 100 and 180°C. These low to intermediate temperature geothermal systems constitute the majority of the nation's known geothermal resource areas (KGRA's). When the number of these known geothermal resource areas with observed or predicted temperatures of 100°C or greater are compared with the number of lower temperature hot spring areas, the true preponderance of the lower temperature portions of the geothermal resource is clearly understood. The geologic assessment of the nation's non-electrical geothermal resource must then avoid the human tendency to concentrate on the higher temperature or even the intermediate temperature resources to the exclusion of the volumetrically more impressive and geographically more significant low temperature portions of the resource. Economic considerations already make it evident that the thermal water effluent produced as a by-product of either higher temperature geothermal or non-geothermal power production will ultimately be utilized. The utilization of the low temperature portion of the geothermal resource will, however, require some special attention to its unique geologic and hydrologic characteristics which will affect its potential for development.

The true assessment of the potential for non-electrical geothermal resource utilization must also take into consideration the thermal fluid resource which will be encountered routinely on a truly national scale as oil and gas exploration and production drilling reaches to greater and greater depths within sedimentary basins. Just as development of the Geysers area heralded the beginning of a geothermal rush in the western states, the geopressurized zones encountered at relatively shallow depths in the Gulf Coast states may be merely the forerunner to discoveries and development of thermal fluids at greater depths in other sedimentary basins.

Previous Investigations

Previous assessments of the geothermal resource relevant to its non-electrical utilization include the cataloging of thermal waters by Waring (revised, 1965). This study presents specific data as to individual hot spring locations, observed temperatures and flow rates, but lacks any comprehensive cataloging of geochemical data for the thermal water occurrences. The lists of thermal water occurrences by Waring are, however, relatively complete and very few major natural hot water occurrences were omitted.

Designations of known geothermal resource areas (Godwin, et al., 1971) and a growing number of statewide surveys sponsored by individual state governments and the U.S. Geological Survey have focused geologic interest on the higher temperature geothermal zones. The designation of known geothermal resource areas under the Geothermal Steam Act of 1970 provides a comprehensive guide to geographic areas in the western U.S. reasonably expected to have an economic potential for geothermal power exploitation as judged by 1972 standards. The listing of the areas, however, includes no quantitative data for the individual areas and much additional detailed geologic and geochemical data has been acquired since that time.

More recently, a number of comprehensive state surveys have begun to provide the quantitative geochemical and hydrologic data necessary for the initial pre-drilling evaluation of the total geothermal resource. Notable among these investigations are those for Utah (Mundorff, 1970), Idaho (Young and Mitchell, 1973), and New Mexico (Summers, 1965). A series of geothermal water quality investigations under way by geochemists at the Menlo Park office of the U.S. Geological Survey are presently available as open file reports. These include studies of thermal waters of northern and central Nevada (Mariner, et al., May 1974) and hot springs in Oregon (Mariner, et al., March, 1974). Other studies in progress by this group include investigations in Montana, California, and New Mexico (J.B. Rapp, personal communications, September, 1974). California's Division of Oil and Gas investigators, particularly Marshall Reed, have collected samples according to established U.S. Geological Survey procedures. These samples from selected geothermal zones in California were analyzed in U.S. Geological Survey laboratories (Reed, 1974).

Geologic, geophysical and hydrological investigations of areas with a known geothermal potential are continuing under programs of the geologic and geophysical branches of the U.S. Geological Survey. Detailed geologic investigations have followed the initial phase of the resource investigations which have been primarily concerned with water chemistry and geothermometry.

Objectives of the Study

An important objective of the present investigation is the assessment of geologic techniques and evaluations especially applicable to the non-electrical utilization of the geothermal resource. The indicia and kinds of data generally considered to be crucial in the evaluation of the economic potential of the geothermal resource in a particular geographic area have been outlined by Godwin, et al. (1971). These criteria were intended specifically for the determination of areas with a power-producing potential. Obviously, the areas possessing these sorts of indications of the presence of a higher temperature geothermal resource will also have a potential for non-electrical utilization, at least as a by-product of power generation. The purpose of the present study is, however, to assess the techniques and evaluations applicable to the much broader geothermal resource with particular emphasis on the lower temperature portion of the spectrum.

A second objective of the present study is to assess the geographic distribution of the non-electrical resource on a national scale from presently available published and unpublished data. This involved a tabulation of data relevant to the distribution of the resource in terms of such variables as temperature, water quality and volume. A third objective is an assessment of additional data and types of investigations necessary for the completion of this resource evaluation phase.

ASSESSMENT OF GEOTHERMAL EVALUATION TECHNIQUES

Evaluation Criteria Applied by the Federal Government

The indicia and techniques applied by agencies of the federal government to the evaluation of the economic potential of a geothermal zone have been outlined by Godwin, et al. (1971). Three indicia listed as necessary for the retention classification of lands in geothermal resource provinces are:

1. Volcanism of late Tertiary or Quaternary age--especially caldera structures, cones, and volcanic vents.
2. Geysers, fumaroles, mud volcanoes, or thermal springs at least 40°F higher than average ambient temperature.
3. Subsurface geothermal gradients generally in excess of two times normal, as reflected in deep water wells, oil well tests, and other test holes.

The authors further stated that the following kinds of data were to be considered in the geological, geophysical and geochemical evaluation of the economic potential of an area.

1. Siliceous sinter and natural geysers both imply high subsurface temperatures, generally 350°F or greater (D.E. White, "Geochemistry Applied to the Discovery, Evaluation and Exploitation of Geothermal Energy Resources": Rapporteur rept., Sec. V, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September, 1970) in hot-water systems, because of relationships generally existing between temperature and SiO_2 content of liquid water.
2. The temperatures of fumaroles, thermal springs, and mud volcanoes provide minimum subsurface temperatures.

3. The SiO_2 content of spring water is a very useful chemical geothermometer for indicating the reservoir temperatures of many hot-water systems (R.O. Fournier and A.H. Truesdell, "Chemical Indicators of Subsurface Temperature Applied to Hot Spring Waters of Yellowstone National Park, Wyoming, U.S.A": Paper V/2, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September, 1970; D.E. White, see above).
4. The Na/K ratio in spring waters of many hot-water systems is also a useful chemical geothermometer when there is adequate knowledge of competing influences (D.E. WHite, see above).
5. Most known potential geothermal systems occur in or near volcanoes and calderas of late Tertiary or Quaternary age.
6. Abnormally high conductive heat flow and the geothermal gradient are the best indicators of deep, concealed geothermal reservoirs. Although specific limits have not yet been established, two to 10 times the world-wide average (heat flow of 1.5 microcalories per cm^2 per second; temperature gradient of 1°F per 100 ft.) extended consistently over hundreds of feet of depth appears favorable.
7. The porosity and the permeability of a potential reservoir are important parameters, but can be established only by drilling and testing. Where stratigraphic control of the reservoir fluid or steam by a caprock is expected, near-surface characteristics of the rocks may provide preliminary evaluations.
8. Electrical resistivity surveys are probably the best geophysical means to geothermal evaluation available at this time, especially for the hot-water systems.
9. Magnetic, gravity, and airborne infrared geophysical surveys may provide useful supplemental data.
10. Other geophysical methods, such as microseismic, seismic ground noise, electromagnetic, and telluric surveys may have significant future use in evaluation.

These considerations constitute an excellent summary of the geological, geophysical and geochemical criteria applicable to the high temperature geothermal systems. However, as the non-electrical utilization of the geothermal resource also encompasses the lower end of the temperature spectrum, additional considerations are pertinent to the evaluation of the total resource. Specifically, the resource which may be economically utilized for non-electrical purposes may occur in a wider range of geologic environments. Surface indications of the development at depth of a geothermal reservoir may be lacking in the lower temperature system which yet has a significant potential for non-electrical utilization.

Subtle differences exist in the techniques applicable to the evaluation of low and high temperature geothermal resources. These differences arise as a result of the differing origins of the majority of the lower temperature thermal water areas as opposed to the more unique geologic environment conducive to high temperature geothermal zone development.

Geologic Environment

The statement in the federal criteria that "Most known potential geothermal systems occur in or near volcanoes and calderas of late Tertiary of Quaternary age" is especially relevant to high temperature systems and may be expanded in terms of the petrologic type of volcanism. Rhyolitic volcanism is especially indicative of high, near-surface temperatures and the possiblity of major, high-temperature geothermal zone devlopment.

The geologic environments conducive to the high heat flow necessary for volcanism in general have been discussed by Muffler and White (1972). Regions with a high heat flow, roughly 1.5 to 5 times the world average of 1.5 x 10^{-6} calories per square centimeter per second occur along the margins of crustal plates. It is in these areas that molten rock is generated with resultant volcanism. In the absence of continental crustal material in the ocean basins, basaltic volcanism dominates. Rhyolite forms predominantly through crustal melting and is in itself prima facie evidence for an abnormally high heat flow situation in the crustal rocks. A late Tertiary-Quaternary age of the rhyolitic volcanism is necessary, as older volcanic rock may have lost its heat content and older thermal events in the crust may have terminated. The length of time required for the cooling of a shallow magma body within the crust will be dependent on a number of factors such as the size, initial temperature and depth of emplacement of the molten body. Thermal history of an area intruded by a magma body, such as the study by Mundry (1971) indicates that a relatively rapid decrease in thermal gradients occurs after an initial heating up of the ground rock during magmatic intrusion. The rate of decrease of geothermal gradients in the natural situation will depend on the stability of regional temperature gradients subsequent to magmatic intrusion. The results of the modeling indicate, however, that a small magmatic intrusion will cease to be a viable geothermal heat source in a relatively short geologic time after intrusion (1-4 million years?). The maintenance of a localized high geothermal gradient associated with a shallow cooling magma body is a relatively short-term geologic phenomena. Regionally high heat flow may be a much longer term geologic event.

Types of volcanism other than "rhyolitic" may not provide the higher temperatures required for power generation but may be associated with higher than normal regional thermal gradients conducive to low temperature zone development. Basaltic volcanism, for example, originates through partial melting in the mantle at depths averaging 40-60 km. The relatively fluid, molten, rock flows through fissures to the surface where its heat content is rapidly lost. Andesite tends to form at even greater depths in the mantle but may have a greater tendency towards entrapment in relatively shallow magma chambers, thus forming a shallow, but still relatively short-lived heat source.

The net result of these considerations is the prediction of a relatively few intense high temperature geothermal zones directly associated with abnormal heat flow in the crust. These will be associated with crustal melting and will be evidenced by young rhyolitic volcanism if this flow occurs in continental areas with a silicic crust. Lower temperature geothermal occurrences related to broad areas of regionally high heat flow should be much more common. These "normal" low temperature occurrences constitute the portion of the geothermal resource uniquely suited to non-electrical utilization. The rare high temperature zones and the thermal waste water produced by high temperature utilization will also be put to non-electrical uses, but the main portion of the geothermal resources, both volumetrically and geographically, appears to be of the low temperature type.

Most lower temperature geothermal occurrences are related genetically to faulting and deep water circulation in areas with a regionally high geothermal gradient. This seems to be the explanation for the numerous hot spring occurrences in granitic areas such as the "Idaho Batholith" of Idaho and Montana. The abnormally low regional heat flow throughout the Sierra Nevada is responsible for the relative absence of hot springs there. Porosity and permeability factors are equally important in either high or low temperature systems, although a premium may actually be places on these factors in low temperature systems where high flow rates may be required in order to provide the total energy required from low enthalpy fluids.

Geochemical Techniques

Geochemical techniques referred to by Godwin, et al., are equally pertinent to the electrical and non-electrical resource assessment. At present, geochemical thermometry (particularly predictions based on SiO_2 content assuming quartz equilibrium) provides the most useful single technique of the pre-drilling assessment of temperature characteristics of the geothermal resource. Basic assumptions pertinent to the application of geochemical thermometry as outlined by Fournier, White and Truesdell (1974) include:

1. A temperature-dependent reaction at depth.
2. An adequate supply of the solid phase involved in the reaction to permit saturation of the constituent used for geothermometry.
3. Water-rock equilibrium at depth.

4. Negligible re-equilibration as the water flows to the surface.
5. No dilution or mixing of hot and cold waters.

In cases where high flow rate springs discharge water rather directly from its high temperature reservoir without significant surface water dilution, the SiO_2-predicted temperatures are generally valid. Normally, however, at least some dilution or mixing of thermal water with shallow, relatively cool ground water may occur, resulting in geochemically-predicted temperatures below the actual "base" of maximum temperature attained by the geothermal water during its convective circulation.

Fournier and Truesdell (1974) have suggested geochemical calculations for determining if mixing has occurred and present a technique for calculating the original, undiluted reservoir temperature. Preliminary applications of the technique to selected, relatively low temperature springs in Yellowstone National Park predict high reservoir temperatures. These temperatures appear reasonable in terms of reservoir temperatures encountered by test drilling in several of the areas. Studies by Mariner, et al. (1974) applying the mixing techniques of Fournier and Truesdell have indicated the probability of significant mixing in 11 of 32 hot springs in Oregon. The geochemical thermometers applied by Fournier and Truesdell (1974) and Willey, et al. (1974) are summarized in Table 1.

TABLE I

1. For quartz solubility with SiO_2 in mg/kg

$$T\ (°C) = \frac{1309}{5.19 - \log (SiO_2)} - 273.15$$

1a. For quarts solubility with cooling by steam loss

$$T\ (°C) = \frac{1522}{5.75 - \log (SiO_2)} - 273.15$$

2. For albite-orthoclase solubility, cations in mole/kg

$$T\ (°C) = \frac{777}{.47 + \log (Na/K)} - 273.15$$

3. For sodium, potassium, calcium in mole/kg

$$T\ (°C) = \frac{1647}{2.24 + \log (Na/K) + \beta \log (\sqrt{Ca}/Na)} - 273.15$$

Where $\beta = 4/3$ is to be used, except if the calculated temperature is above 100°C; then $\beta = 1/3$ is to be used.

from Reed, 1974

Geophysical Techniques

Geophysical techniques provide two differing types of information for geothermal exploration. Most geophysical techniques provide varying degrees of structural information, depending on the geologic conditions. Some of the techniques used to provide structural information include: active seismic, gravity, magnetic, electrical, and passive seismic. Some geophysical techniques are also considered a direct detection tool. Among these techniques are: resistivity, thermal gradient measurements, and microseismic studies. However, the relatively limited experience in the actual drilling of geophysical anomalies thought to be associated with geothermal reserves is insufficient to label any tool or technique as a panacea.

In exploration for a low temperature geothermal resource, techniques such as active seismic, gravity and magnetics are utilized to define the structural relationships in the province. The direct detection techniques might not be as useful in directly delineating low temperature reserves. For example, normal ground water conditions may mask any thermal gradient associated with convective hot water systems driven by a regional anomaly. Also, a regional anomaly might not have the localized seismic activity which would be detected by a microearthquake program. Present knowledge in the area of seismic noise sources is probably not sufficient to be conclusive on the micorearthquake activity and seismic noise level associated with low temperature geothermal activity.

The technique that seems to offer the most promise for low temperature geothermal resource exploration is electrical resistivity. Because the resistivity of rock is primarily a function of fluid content, fluid salinity and temperature, resistivity measurements may be extremely helpful in delineating the spatial distribution of the highly conductive geothermal reservoir.

The major factors controlling the applicability and the amount of information obtained from any of these geophysical techniques are the local geology and the grade of the geothermal deposit. In other words, there must be a variation in properties between the "country rock" and the resource. The larger the variation in properties, the greater the chance of detection. Thus, in any area the utilization of a number of geophysical techniques will probably be required. A premium will be placed on the application of all the geological and geophysical techniques designed to clarify the geology and hydrology of the low temperature geothermal occurrence.

GEOGRAPHIC DISTRIBUTION OF THE GEOTHERMAL RESOURCE

The cataloging of reported hot spring locations by Waring (1965) and the designation of KGRA's and AVP's (Areas Valuable Prospectively) by Godwin, et al. (1971) provide a starting point for consideration of the national geothermal potential. The assessment of the non-electrical utilization of the geothermal resource requires, however, an evaluation of the geographic distribution of the resource in terms of temperatures to be reasonably expected, water quality, and flow volumes. The present investigation involved a tabulation and graphic presentation of the resource distribution in terms of these variables which determine its potential for utilization.

Conclusion

Exploratory drilling and the application of geochemical thermometers indicate that the bulk of the major thermal occurrences in the western states have reservoir temperatures in the 100-180°C range. Waring listed 852 thermal springs and wells for the 10 western states, exclusive of Yellowstone National Park (which has more than 10,000 mapped thermal features). Analyses reported to date for the 852-plus known thermal occurrences indicate approximately 250 with silica predicted temperatures in the 100-140°C range, 67 in the 140-180°C range, 15 in the 180-220°C range and two above 220°C. The remainder of the thermal occurrences (approximately 90%) have apparent temperatures below 100°C. Approximately 2% have known or predicted temperatures above 180°C, the minimum temperature presently required for economic geothermal power generation. The additional application of refined geochemical thermometers and the newly developed "mixing" techniques will undoubtedly increase the number of suspected high temperature systems. The present data, however, is weighted in favor of known high temperature occurrences, i.e., 10 reported analyses from Long Valley. Therefore, the inference of the overwhelming predominance of the low temperature portion of the resource is valid.

Data Presentation

Temperature data is shown graphically on a state by state basis for the 10 westernmost states. Predicted temperature ranges were subdivided into three catagories: 15° above ambient – 100°C, 100-180°C, and > 180°C. Temperatures plotted in the intermediate and high temperature range were ordinarily those temperatures predicted by the SiO_2 geothermometer assuming quartz equilibrium. Temperature prediction for Idaho, Nevada, Oregon, New Mexico, Utah and California are based on relatively complete coverage by state or U.S. Geological Survey geothermal water quality reports. Data for Washington, Montana and Arizona is less complete, but work in progress will soon provide almost total geochemical coverage of the western states.

Data for the "geopressurized zone" of the Gulf Coast is extracted entirely from the work of Jones (1970). Temperatures shown are for an average depth of 8000 feet as calculated from observed gradients.

The water quality data is presented in both tabular form and graphically in terms of total dissolved solids and boron expressed in ppm. The total dissolved solids content was chosen for presentation as a general indication of overall water quality important to both industrial process and agricultural application. The boron level is shown as it constitutes the limiting factor in many agricultural applications.

Flow data is included in tabular form and discussed on a local or regional basis where geothermal production is significant.

State Summaries

California contains two unique geothermal occurrences, Salton Sea-Imperial Valley high temperature brine reservoirs and the Geysers Area, Sonoma County, one of the world's prime examples of a developed dry steam geothermal system. The exploitation of the Geysers area for electrical development and attempts to develop the Imperial Valley area for desalination purposes have been well documented elsewhere (Armstrong, 1971). The 14 KGRA's and additional areas studied by Reed (1974) and Hannah (1974) possess an obvious potential for non-electrical geothermal development. Of the areas investigated by Reed, only the Long Valley area appeared to possess definite indications of reservoir temperatures above 180°C. In California, 86 analyses of geothermal waters with temperatures in the 100-180°C range have been reported in the literature, with the majority of these (74) between 100-140°C. Areas with a particular potential of non-electrical geothermal potential include: Alturas area, Big Valley, Wendel-Amedee area, Sierra Valley area, Long Valley area, and northern Napa Valley in Calistoga.

Idaho possesses at least 380 known hot springs and wells, 82 of which have silica predicted reservoir temperatures above 100°C. Of these, 73 are in the 100-140°C range, and nine are in the 140-180°C range. The state possesses eight major geothermal resource areas, including two areas, the Raft River in Cassia County and the Island Park caldera in Fremont County, which received the federal KGRA designation. In view of the abundant 100-140°C resource, the state possesses an exceptionally high potential for non-electrical geothermal development.

Numerous hot wells in northern Owyhee County in an area of ranch and farm land bordering the Snake River Plain and the Mt. Bennett Hills anomaly, an agricultural area in southern Elmore County, possess a major potential for agricultural uses of the geothermal resource. Water quality is excellent, and the hot water is used extensively for irrigation. The coincidence of high volume wells producing 178°F water within Boise, the state capital, make this a prime site for space heating applications. The Raft River KGRA has undergone extensive geological, geophysical and nydrological investigations in conjunction with its possible utilization as a low temperature power generation site; and there is a limited potential for non-electrical utilization of the effluent waste water.

Montana: The western third of the state is block faulted and composed in part of Tertiary granitic and volcanic rocks where the thermal springs occur. Approximately 40 thermal springs occur in the state, and their temperatures range up to 80°C. There is one KGRA near Yellowstone National Park in the southern part of the state. Flow rates range up to 50,000 gpm. The water quality is good in the areas underlain by granitic rocks of the Idaho Batholith, but water quality is variable in the region of Yellowstone Park.

The steepest geothermal gradient measured is in the area around Marysville, where conducted heat flow range is from 3.2 to 19.5 u cal/cm^2 sec. At one locality, a temperature of 58°C was measured at a depth of only 220 meters. Drilling has indicated that the immediate source of the high heat flow is an unexposed reservoir of thermal fluids present within the fractured granite. The drilling confirms the convective circulation of water within the fractured granite to depths of 6000 feet, and thus casts doubts on the relative abundance of hot "dry" geothermal systems.

Nevada contains 152 thermal occurrences as reported by Waring (1965). Nineteen areas in Nevada have geochemically predicted temperatures in the 100-140°C range; sixteen areas have reported temperatures in excess of 140°C. Applications of refined geothermometry techniques by Mariner, et al. (1974) indicate that a relatively high number of the Nevada geothermal areas (five) have reservoir temperatures above 180°C. These higher temperature systems, including Beowawe, Sulfer Hot Springs and Steamboat Springs, have a potential for non-electrical utilization secondary to any attempted utilization of the wet steam resource for power generation. The principal deterrent to non-electrical utilization of the state's abundant intermediate temperature geothermal areas is the low population density.

New Mexico: The thermal occurrences of New Mexico are associated with high heat flow and recent volcanism along the Rio Grande trough. The presence of young silicic volcanism in the Jemez Volcanic Field and the Valles caldera west of Los Alamos indicate a marked potential for high temperature geothermal development and possible "non-electrical" utilzation of the effluent. The presence of steam has been confirmed by exploratory drilling, and the area is also being explored for its hot, dry rock geothermal potential. The remainder of New Mexico's geothermal occurrences appear to be associated with the high regional heat flow and faulting rather than a localized shallow heat source.

Oregon: Waring reported 86 thermal occurrences in Oregon. Thirty-two analyses of the hotter springs were reported by Mariner, et al. (1974). Aquifer temperatures between 140-181°C were predicted for nine springs, based on both silica and Na-K or Na-K-Ca geothermometers. These results indicate that the principal use of Oregon's geothermal potential will continue to be non-electrical. Individual areas with a definite non-electrical utilization potential include: 1. Lake County, where predicted temperatures range from 120-155°C, but boron contents will generally eliminate direct agricultural uses; 2. Vale area, Malheur County, with the highest predicted temperature in the state, 181°C. Non-electrical utilization in Vale may be possible as an aftermath of exploration for higher temperature steam; 3. Klamath Falls - the established utilization of the low temperature fluids for space heating at Klamath Falls illustrates the economic value of the low temperature resource. The geographic distribution of the shallow hot water resource has been established by drilling, but studies of the hydrology of the system and its actual productive capacity are needed; 4. Breitenbush Hot Springs, Marion County and 5. Hot Lake, Union County, both possess high flow rates of hot or near-boiling water; 6. Alvord Hot Spring in southern Harney County and 7. Belknap Hot Spring in the Cascade Range are very saline, with total dissolved solids of 2,980 and 3,020 ppm respectively, and are better suited for industrial process use than for agricultural use.

Utah: The thermal springs of Utah are closely associated with the Wasatch-Hurricane fault zone and appear genetically related to deep circulation in this high-heat flow, tectonically active area. The known and predicted thermal occurrences are all low or intermediate temperature areas, and the major (if not exclusive) utilization of the geographically dispersed resource will be non-electrical.

RECOMMENDATIONS FOR FURTHER STUDY

1. Detailed water quality analyses coverage should be extended to include all significant thermal water occurrences not presently reported in the literature or available on an open-file basis from state or federal agencies. Specifically, these analyses should be of a completeness and accuracy comparable with the standards met by the U.S.G.S. water quality program. These analyses are necessary both for the pre-drilling estimation of reservoir temperatures and an assessment of the best use of the thermal water as influenced by its total chemistry. The absence of boron analyses, for example, is a hindrance to the assessment of the potential of thermal waters in many areas.

2. Studies of the frequency distribution of geothermal systems as a function of observed and geochemically predicted base temperatures should be conducted as the geochemical data is obtained. Application of geothermometers to the almost complete data available at present indicates an overwhelming predominance of the low and intermediate temperature systems. The data is also susceptible to treatment in terms of the geologic environment (i.e., recent rhyolitic volcanism, basalt provinces, regional faulting, Basin and Range faulting, geopressurized zones, etc.).

3. In view of the apparent dominance of the low temperature resource, a major research effort should be directed towards the utilization of relatively low temperature, low enthalpy fluids.

4. The drilling of geothermal, oil and gas, and deep water wells should be closely monitored for situations where the "mixing function" may be applied and confirmed. The major unknown concerning the temperature distribution is the degree to which mixing has masked the presence of higher temperature wet systems.

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Appendix I.

STATE GEOTHERMAL DISCUSSIONS

ARIZONA

INTRODUCTION

Intensive geological, geophysical, exploration surveys, and studies are actively underway; and one group has uncovered sufficient information to warrant the beginning of an exploration drilling program.

Hot springs are localized in the southeastern part of the state in the Basin and Range Province, plus a few in the southwest.
Heat flow in southern Arizona is 2 HFU.
Most recent volcanism occurred 900 years ago at Sunset Crater.
Most springs are related to fault structures and/or Cenozoic igneous rocks.
Hottest surface water - Gillard Hot Springs in Greenlee County 183°F (84°C)
Average temperature 100°F (38°C)
25 thermal areas (11 of which are wells)
Discharge average 200 gpm, up to 600 gpm
Dissolved solids range up to 100,000 ppm, and most have a high salt content.

Gillard Hot Springs
Maximum temperature 184°F (84°C)
Discharge 100-400 gpm

Clifton Hot Springs
Maximum temperature 160°F (71°C)

Radium Hot Springs
Maximum temperature 140°F (60°C)

There are sparse data indicating a possiblity that latent geothermal energy may be present at depth at several areas in southern Arizona. Data on springs and wells have been compiled on Table 1, which is a listing of localities where thermal waters of 100°F or greater are known. The locations of these occurrences, shown on Figure 1, are relatively close to population centers which could possibly utilize thermal energy. There are no known geothermal resources areas which produce geothermal steam in Arizona, and no known boreholes have been drilled to explore the potential of geothermal energy.

GEOLOGIC AND HYDROLOLOGIC RESUME OF CONDITIONS RELATED TO POTENTIAL GEOTHERMAL RESOURCES

Arizona contains parts of two distinct physiographic provinces, the Colorado Plateau and the Basin and Range, which are shown on Figures 1 and 2. In both provinces, rocks of nearly all the geological ages and types are known to be present.

The rocks of Arizona have been faulted and folded many times throughout geologic time. The faulting and folding occurred during short episodes, and concurrent periods of igneous activity were common. The entire area had the most intense deformation during the late Cretaceous and early Tertiary periods. In the Basin and Range Province these structural features were disrupted by later structural features which, in turn, have been followed by late Cenozoic volcanism.

In the middle Tertiary, about 30 million years ago, the first phase of block faulting began which developed the Basin and Range structural features; and many of these uplifted blocks cut across previous structures. Large amounts of volcanic material were emplaced in the basins which, in places, dammed the drainage systems. These structural troughs have been filled with heterogeneous mixtures of clastic materials ranging from fine-grained lake-bed deposits to boulder-cobble conglomerate interbedded with lava flows. During this phase, several intrusive bodies were emplaced in the southeastern part of the state. Some volcanic activity continued to about 1,000 years ago, such as in the Flagstaff area.

Arizona has been divided into three water provinces: Basin and Range Lowlands, the Central Highlands, and the Plateau Uplands. Large amounts of groundwater occur in the alluvial basins in the Lowlands which have been filled to depths of several thousands of feet of low permeable silt and clay bodies. Large amounts of groundwater are in storage in the sandstone and limestone aquifers in the Uplands area, but the lesser permeability of the sandstones constrain well yields. Both areas receive recharge from the Highlands area which occurs across the central part of the state.

The quality of water resources ranges widely throughout the state. The groundwater quality ranges from less than 200 to more than 100,000 ppm (parts per million). The streams and rivers carry variable amounts of dissolved salts. A large percentage of the salt in some drainages is from springs which contribute saline water to the streamflow.

An examination of the available thermal data in Table 1 in relation to the tectonic fabric and occurrence of Tertiary igneous rocks reveals several interesting suggestions. Nearly all the occurrences are in the Basin and Range Lowlands; most of the springs and some of the wells appear to be related to fault structures and/or Cenozoic igneous rocks; the highest temperatures occur in Greenlee County; and the geothermal gradient is about 30 feet per 1°F in southeastern Arizona. These data and geological features appear to indicate that most of southern Arizona comprises a target area to conduct studies and exploration for potential geothermal resources, particularly in the southeastern quadrant and western section. The Plateau Uplands area is not necessarily ruled out, as reservoir rocks may be deeply buried and the overlying extensive groundwater system could have a cooling effect on any leakage through the thick blanket of fine-grained sediments. The youngest volcanism activity occurs in this area, and a geothermal reservoir could be enclosed by fine-grained rock sequences.

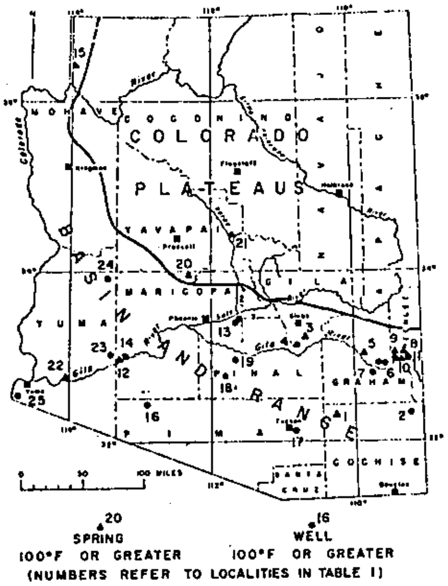
CONCLUSIONS

1. There are no Known Geothermal Resources Areas in Arizona.
2. There are several investigations on geothermal resources being conducted by private enterprise which indicate a potential occurrence. Exploration borehole drilling is reported to start within the next 60 days.
3. In southern Arizona there are many geologic structural and rock characteristics similar to known geothermal reservoirs.
4. There are no surface indications of steam leakage, but the occurrence of thermal water nearby favorable geologic features suggests the potential occurrence of geothermal energy.
5. There are several favorable target areas in southern Arizona; the application of skillful study, creative imagination, and data from borehole drilling programs could lead to successful geothermal development.

TABLE 1 – SELECTED THERMAL SPRINGS AND WELLS IN ARIZONA

Locality No. on Fig. 1	County and Location	Maximum Temperature (°F) Reported	Discharge in Gallons Per Minute	Depth (feet)	Gradient (feet/ 1°F
	Cochise				
1	Hookers Hot Spring Sec 6, T 13 S, R 21 E	130	40	–	–
2	San Simon Valley-wells	103	–	920	26
	Gila				
3	Spring Sec 1, T 3 S, R 16 E	95	90	–	–
4	Well, Sec 29, T 3 S, R 15 E	110	–	150	–
	Graham				
5	Indian Hot Springs Sec 17, T 5 S, R 24 E	118	200-300	–	–
6	Wells in Safford Area	99+	–	1095	30
7	Safford Golf Course Well	100	–	2180-2420	30
	Greenlee				
8	Clifton Hot Springs Sec 30, T 4 S, R 30 E	160	–	–	–
9	Spring, Eagle Creek Sec.26, T 4 S, R 28 E	120	–	–	–
10	Gillard Hot Springs Sec 27, T 5 S, R 29 E	184	100-400	–	–
11	Well, Clifton	130		220-490	31
	Well, Clifton	143	–	140-500	33
	Maricopa				
12	Agua Caliente Spring Sec 19, T 5 S, R 10 W	104	–	–	–
13	Buckhorn Area Wells	107	–	325	8
14	Well Sec 16, T 5 S, R 10 W	114	–	884-1268	–
	Mohave				
15	Pakoon Spring Sec 24, T 35 N, R 16 W	100	200-400	–	–
	Pima				
16	Wells near Ajo	99	–	1021	39
17	Wells, SE Tucson	126+	–	2500	42
	Pinal				
18	Well, near Redrock	108	–	1950	49
19	Hana Well Sec 6, T 6 S, R 8 E	161	500-600	2700	–
	Yavapai				
20	Castle Hot Springs Sec 3, T 7 N, R 1 W	122	280	–	–
21	Verde Hot Springs Sec 3, T 11 N, R 6 E	106	10	–	–
	Yuma				
22	Radium Hot Springs Sec 12, T 8 S, R 18 W	40	–	–	–
23	Wells in Sections 2, 5, 11, T 4 S, R 11W	105	–	280-585	–
24	Wells in Palomas Plain	108	–	443	13
25	Oil Test Well	125	–	6015	120

Data tabulated from: Haigler (1969) and Wright (1971) in Selected References

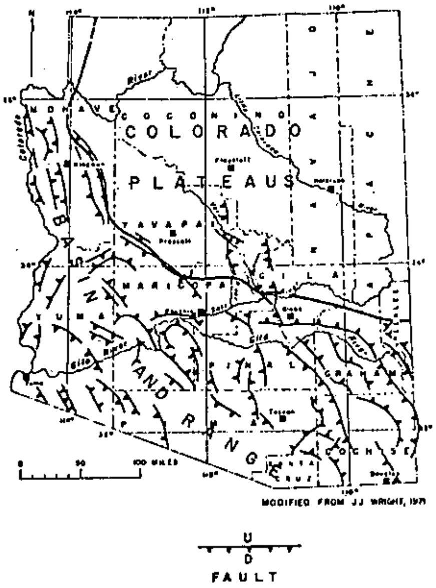


20 SPRING 100°F OR GREATER

16 WELL 100°F OR GREATER

(NUMBERS REFER TO LOCALITIES IN TABLE 1)

FIGURE 1.--THERMAL SPRINGS AND WELLS IN ARIZONA.



MODIFIED FROM J.J. WRIGHT, 1971

FIGURE 2.--FAULT TRENDS IN SOUTHERN ARIZONA.

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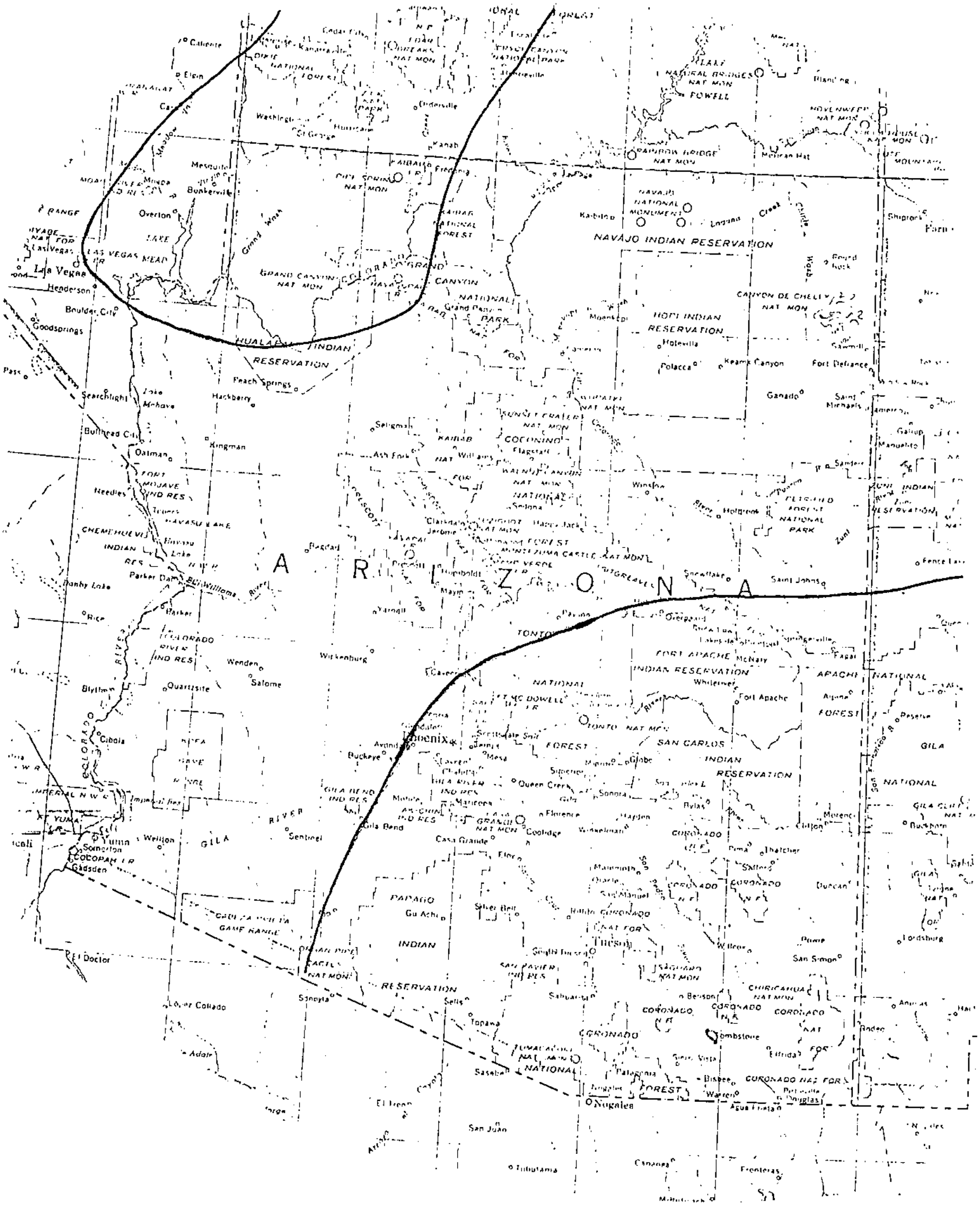

A R I Z O N A
Las Vegas
Phoenix
Tucson
Nogales
Yuma
Flagstaff
Kingman
Prescott
Grand Canyon National Park
Navajo Indian Reservation
Hopi Indian Reservation
Fort Apache Indian Reservation
San Carlos Indian Reservation
Papago Indian Reservation
Lake Mead
Colorado River
Gila River

COLORADO

Most of Colorado's 200 hot springs occur in central and southwestern mountainous parts of the state in the Tertiary volcanics. The Late Cenozoic Rio Grande Rift Valley extends northward from New Mexico through the Rockies of central Colorado; and together with the San Juan volcanic field of southwestern Colorado, represents a region of above-normal heat flow (from 1.52 to 2.4 HFU). There are no KGRA's in Colorado. The hottest areas:

Poncha Springs
Temperature 75°C (167°F)

Waunita Hot Springs
Temperature 72°C (162°F)

Pagosa Hot Springs
Temperature 72°C (162°F)

Greatest flow occurs at Glenwood Springs
3,000 gpm at 41°C to 65°C (106-149°F)

Steamboat Springs
2,000 gpm at 39°C to 65°C (102-149°F)

Alamosa
An area of hot oil and gas exploration wells under investifation by the USGS.

Ta 1-- Chemical analyses of water from selected s ngs in Colorado.
(Analytical results in parts per million)

No.	Name	Discharge (gpm)c	Temp. (°F)d	Silica (Si)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Chloride (Cl)	Sulphate (SO_4)	Bicarbonate (HCO_3)
1	Routt	130a	150a	88	162	11	8	-	137	44	146
2	Steamboat Springs	2,000b	150b	85	2048	155	113	32	1346	486	3253
3	Eldorado	10a	70a	17	17	1	10	4	7	38	46
4	Glenwood Springs	400a	150b	37	6950	460	431	91	11025	1194	437
5	Buena Vista (Cottonwood)	150a	144a	61	81	34	5	3	28	108	87
6	Mount Princeton	300a	150a	60	38	32	11	T	12	62	86
7	Poncha Spgs	500b	168b	80	174	21	18	2	55	199	221
8	Waunita (Tomichi)	1,000b	160a	86	146	15	12	3	20	179	175
9	Powderhorn	100b	114a	80	267	75	133	49	120	132	1107
10	Ridgway	300b	132b	58	374	102	274	21	103	1287	278
11	Wagon Wheel Gap	100b	131a	94	420	276	68	18	205	210	1048
12	Ouray	200b	158a	52	81	45	383	11	51	1016	37
13	Pagosa Spgs.	600a	158a	68	525	370	247	17	180	1504	636

Remarks:

a. Colorado Geological Survey Bull. 11. Discharge value given is maximum for a group of springs.
b. U. S. Geological Survey Prof. Paper 492. Discharge value given is total for a group of springs. Analytical analyses from Colo. Geological Survey Bull. 11.
c. **Table extracted from: Pearl, R. H., Geothermal resources of Colorado - A Summary, Geothermal Overview of the Western U.S., p. D1-D-8 (1972)**

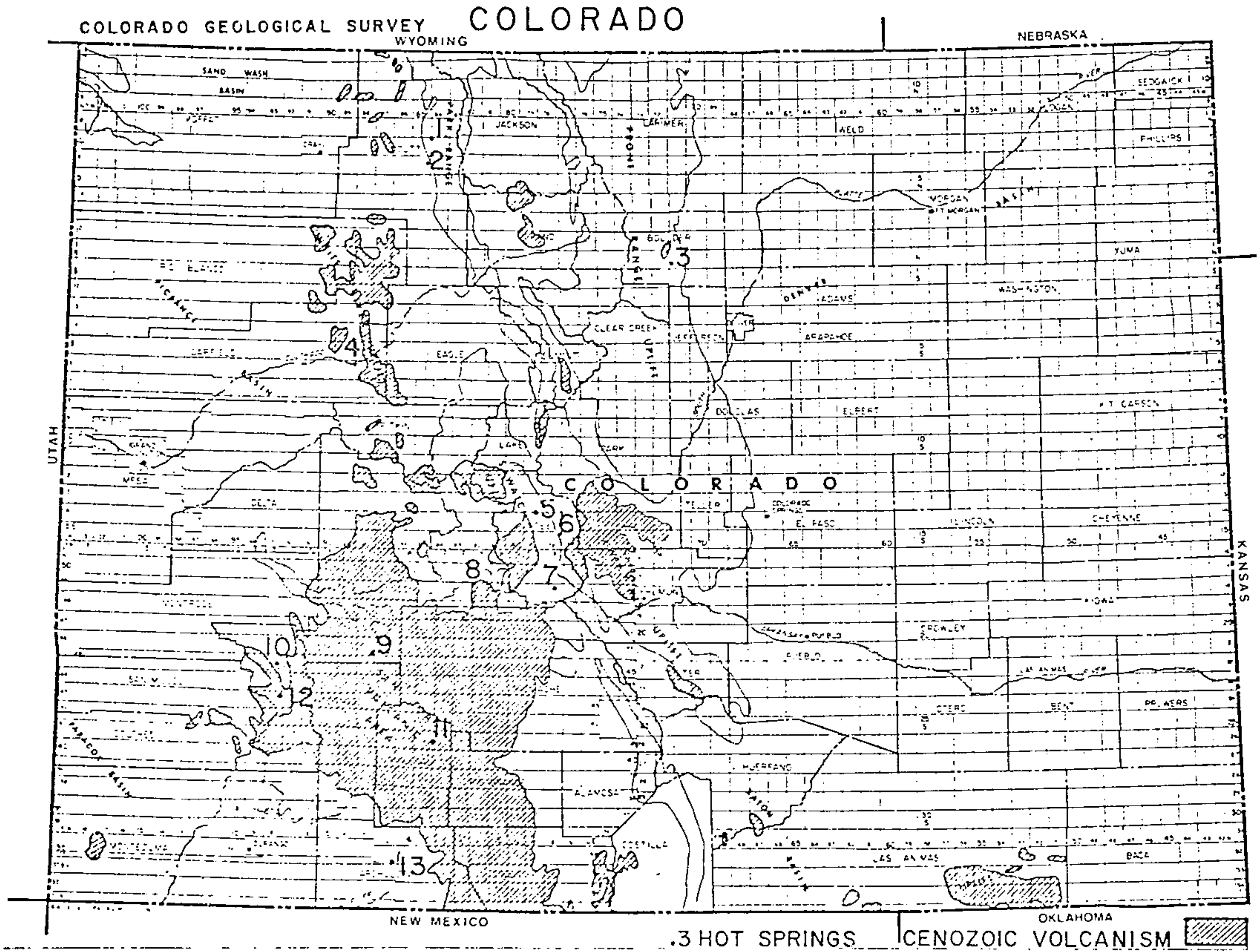

Figure I--Map showing selected hot springs and areas of Cenozoic volcanism

CALIFORNIA

Summary

The chemical composition and geologic setting of six potential geothermal areas are described by Reed in a forthcoming report of the California Division of Mines, Oil and Gas Commission. The areas described are: Imperial Valley, Long Valley, Sierra Valley, Honey Lake Valley, Surprise Valley, and Modoc Plateau. In most areas, calculated temperatures are below 150°C, but in Long Valley temperatures between 200°C and 250°C are indicated and a potential for generation of electricity seems to exist. Boron content in excess of 2.0 ppm is common in all areas, although a few scattered samples show lower values. Dissolved solids range from about 1,000 to 3,500 ppm except at Honey Lake and Modoc Plateau, where the values average less than 1,000 ppm.

Tabular Data

Data concerning thermal spring or well location, temperature, pH, chemical analysis, flow volume, dissolved solids, etc., are presented in table form for each thermal area discussed.

Imperial Valley Area

Geologic Setting

The Imperial Valley geothermal region is the landward extension of the Gulf of California rift. It is roughly aligned along the East Pacific rise and the San Andreas fault system. The depression narrows and topographically rises in the Coachella Valley north of the Salton Sea and is terminated by the junction of the San Jacinto Range with the Transverse Ranges. To the southeast, it gradually widens into the Gulf of California. The Salton - Imperial rift is generally bounded by faults and diagonally transected by normal and strike-slip faults that are genetically associated with active, modern seismicity. The trough is filled with up to six km of water-saturated, weakly consolidated sand and silt of the Colorado River Delta and coarse detritus of local marginal origin which have been accumulating on granitic basement since earliest Pliocene time. The Salton Sea geothermal brines contain 220,000 to 260,000 ppm total weight of dissolved solids which are rich in chlorides of sodium, calcium and potassium and have significant amounts of lithium, cesium, manganese, silver, iron, strontium, barium, lead, zinc and copper. This is one of the highest natural concentrations of salts known in the world. Major problems of brine deposition, corrosion and disposal have retarded development at the Salton Sea field.

The Colorado River Delta sediments consist of dominant quartz and calcite, with lesser amounts of dolomite, plagioclase, potassium feldspars, mica and clay; and gypsum occurs sporadically throughout the sediments (Muffler and Doe, 1968). Metamorphic reactions occur in the sediments, and greenschist facies minerals are forming at temperatures up to 300°C at depths of 900 m or more (Muffler and White, 1969).

There is little rainfall in the Imperial Valley (average 1.5 cm/yr), and water from the Colorado River maintains the ground water table at or near the surface in undeveloped areas of the valley. For agricultural use, the land is drained to lower the water table three to four miles below the surface. Many artesian wells have been drilled along the eastern side of the valley for domestic or stock use.

Crustal thinning has occurred in the Salton Trough (Biehler and others, 1964), and the geothermal activity in the Imperial Valley appears to be related to heat from the mantle moving through the thinner crust.

Water Chemistry

The chemistry and isotopic composition of water samples from the Imperial Valley shows a dominating influence by Colorado River water. Subsurface flow of the Colorado River water appears to have entered the valley from the southeast and moved to all parts of the area sampled, but the age of the ground water is unknown. Runoff water from the local mountains seems to have its greatest contribution in the northeastern-most samples where isotopic and chemical differences are greatest.

Water from 30 of the wells was of the sodium-chloride type, and the remainder was of the sodium-bicarbonate type. The occurrence of the sodium-bicarbonate water appears to be random within the area sampled, but is restricted to depths of 150 to 300 m. Sulfate is a significant anion in some of the samples and may reflect the occurrence of gypsum and anhydrite in the sediments. Generally, higher concentrations of major constituents correlate with higher temperature and greater depth. The chemistry of the subsurface water is primarily controlled by the solubility of minerals within the upper part of the sedimentary section, and the chemical indicators of temperature suggest that the water had never been in equilibrium with the rock of a high temperature system.

There seems to be little contribution from the deep geothermal system thought to exist in the area near Brawley. High bicarbonate content of certain samples, especially samples 2 and 3, could be indicative of the metamorphism of calcite described by Muffler and White (1968). The high concentration of boron found in many analyses may also be a contribution from deeper, high temperature water.

The discharge volume of thermal springs is generally low, ranging up to 240 liters per minute but averaging less than 100 l/min. Calculated dissolved solids range from 1020 ppm to 3810 ppm, and calculated temperatures do not exceed 116°C. The hot brine system of the Salton Sea area was not included in Reed's report, but dissolved solids in excess of 300,000 ppm have been reported.

Long Valley

Geologic Setting

The Long Valley Caldera formed by crustal collapse 680,000 years ago following the explosive eruption of the rhyolitic Bishop Tuff, and intermittent volcanic activity continued in the caldera up to 650 years ago (Bailey and others, 1973). It is estimated from geophysical evidence that between 2700 m and 4000 m of accumulated sediments, flows, and pyroclastic material overlie granitic basement in the eastern half of the caldera. The deepest well drilled in the caldera penetrated 324 m of sediment and pyroclastic rock in the Casa Diablo area. The hydrothermal activity in the area may be related to a cooling magma chamber beneath the caldera, and the recent history of activity makes a magmatic heat source most likely for the geothermal system.

Water Chemistry

The chemical constituents in the water appear to be controlled by mineral solution reactions at temperatures between 200°C and 250°C. The agreement of several of the chemical indicators of temperature implies that the water reached equilibrium in some reservoir and moved rapidly to the surface without re-equilibration. The great depth of the basin fill makes it possible that a deeper, hotter reservoir exists with no communication directly to the surface. Boron content ranges from 0.18 ppm to 15.0 ppm. Calculated dissolved solids range from 1290 ppm to 1810 ppm, but two samples show anomolous values of 202 ppm and 235 ppm. Flow rates are in the range of 100 to 400 liters per minute, with the exception of sample locality 4. The flow rate there is 3200 l/min. Calculated water temperatures exceed 100°C at all but one of the sampled locations. Temperatures in excess of 200°C are indicated at two locations.

Sierra Valley

Geologic Setting

Sierra Valley is an intermountain basin of the Basin and Range Structural Province and is situated just east of the crest of the Sierra Nevada Mountains. Late Pliocene (post-Warner basalt) block faulting created the valley, and its form has changed little since that time (Durrell, 1966). The Sierra Valley was the site of a large lake from late Pliocene until late Pleistocene, when it and the Mohawk Lake (Durrell, 1966) downstream were drained by the Feather River. Headward erosion by the river has not yet reached Sierra Valley and the lake sediments have not been dissected. A geothermal test well, drilled in the center of the valley, penetrated 400 m of lake sediments and 250 m of rhyolite tuff and breccia (possibly Miocene Delleker formation) before entering the biotite granite basement.

The elevation of Sierra Valley is approximately 1500 m, and the shoreline of the former lake lies at about 1550 m. The valley is bordered by structural blocks of Cretaceous granitic rocks and Tertiary andesite and basalt. Several northwest trending faults cut the valley sediments and the igneous rocks on both sides. It is not known if the faulting is still active; but faults through the valley are visible from the air, because they disrupt the ground water flow and the vegetation on the surface. The valley has an average precipitation of about 50 cm/yr and collects a great deal of runoff from the surrounding mountains. The ground water table is near the surface in most of the valley, and extensive marshes exist in the central and northern portions of the valley.

Water Chemistry

Sample 9, from Campbell Hot Springs, is a sodium-bicarbonate chloride type water issuing from Tertiary andesite. Sample 8, from a cold aresian well, is a sodium-bicarbonate water thought to represent local meteoric water. The remaining samples, from hot artesian wells, are sodium-chloride type water.

All of the samples from the hot artesian wells show a very similar chemistry, indicating that they are only various dilutions of the same thermal source. It appears that deep circulating ground water is rising along a northwest striking fault in the area of sample 5. Hot water (above 130°C) then moves into the permeable sand which is tapped by the well at 5. Leakage from the fault into other aquifers may feed the other wells.

There is little likelihood of a significant quantity of high temperature water in this area. Thermal energy seems localized along a bedrock fracture zone, and the deep circulation of ground water appears to be the major means of heat transfer to the surface.

Boron content ranges from 0.07 to 8.8 ppm. Only two localities show values of less than 7.3 ppm. Dissolved solids exceed 980 ppm for all but two samples, which are less than 370 ppm. Discharge rates are very low. Calculated temperatures are generally grouped in the range of 110 to 140°C as determined by quartz solubility.

Honey Lake Valley

Geologic Setting

Honey Lake Valley is a part of the Basin and Range Structural Province. The valley is bounded on the southwest by the Honey Lake Fault and the uplifted granitic and volcanic Diamond Mountains block. There appears to be more than 2400 m of vertical offset on the Honey Lake Fault since the late Pliocene (post-Warner basalt). The valley is bordered on the northeast by the Pliocene basalts of the Skedaddle Mountains and on the north by the Pliocene and Pliestocene basalts of the Modoc Plateau.

An unpublished gravity survey for the Califronia Department of Water Resources indicates that granite basement lies at a depth of 1600 m ± 100 m below the center of the valley. A dry gas test well drilled northwest of Herlong penetrated 250 m of Quaternary lake depoists, 820 m of interbedded sandstone and shale, and 140 m of andesite breccia and flows. Long lines of calcareous tufa deposits lead back toward the Skedaddle Mountains from both Wendel and Amedee Hot Springs on the northeast shore of Honey Lake. The tufa deposits trace the existence of two faults by marking the former positions of hot springs.

The valley is a closed drainage basin, and the entire basin has an average precipitation of about 6 cm/yr. The local basalts have a high permeability and supply significant recharge to the ground water in storage. Honey Lake, an alkali lake, occupies the lowest part of the basin throughout most of the year.

Water Chemistry

The dilute water in samples 1 and 4 are of the sodium-bicarbonate type, and the remaining three samples are sodium-sulfate type water. The sodium-bicarbonate type water is thought to represent local meteoric water. The chemical geothermometers seem to be unreliable in this area. Because of extensive volcanism in the area, it is possible that a significant amount of volcanic ash is contained in the valley sediments. If the silica in solution were in equilibrium with cristobalite, this would explain higher concentrations of silica than expected from quartz solubility. The ash could also supply a higher than normal amount of potassium to the solution and affect the calculated temperatures from the cation ratios.

Samples from both Wendel and Amedee Springs appear to be from the same thermal reservoir containing water above 140°C. Deep circulation of ground water seems to be the source of this thermal system.

Flow volume is greatest at Wendel Hot Springs where a discharge of 1200 l/min was measured. Boron content ranges from less than 0.02 ppm to 5.5 ppm. Dissolved solids range from 233 ppm to 1040 ppm.

Surprise Valley

Geologic Setting

Surprise Valley is a graben lying between the horsts of the Warner Mountains on the west and the Hays Canyon Range on the east. At least 2000 m of sediments and volcanic debris have accumulated in the valley, and the crest of the Warner Mountains is up to 1500 m above the valley floor. Vertical displacement on the Sruprise Valley Fault, which marks the west edge of the valley, is thus greater than 3500 m. Scarps in alluvium indicate recent motion, and radiometric ages suggest faulting began less than 15 million years ago (Duffield and Fournier, 1974).

Quaternary rhyolite flows and obsidian bodies crop out in the Fandango Valley of the northern Warner Mountains and also near the south end of the range (Duffield and Fournier, 1974). The possibility exists that the volcanic rocks are related to a shallow crustal magmatic heat source in the area.

Surface and ground water is supplied by runoff mainly from the Warner Mountains; and streams, springs and artesian wells are numerous on the western side of the valley. The east side is an alkali desert. Surprise Valley forms a closed basin, and lakes have occupied the basin since the late Tertiary. At present, three shallow, alkali lakes exist on the valley floor during most of the year.

Water Chemistry

All but one of the samples from Surprise Valley are sodium-sulfate type water. The sample from Fort Bidwell is a sodium-bicarbonate type water. The thermal water appears to rise along several faults which are subparallel to the sides of the valley.

The chemical compositions and temperature indicators of the samples seem to reflect shallow aquifers with water up to 170°C. The greater depth of the valley fill makes it possible that a deeper geothermal reservoir exists but is not reflected in water chemistry. Duffield and Fournier (1974) have applied various mixing models to chemical analyses from Surprise Valley wells and springs, and they calculate temperatures of 220°C for the Leonards Hot Springs and Fort Bidwell areas.

Boron content ranges from 0.61 ppm to 7.6 ppm. Calculated temperatures generally exceed 90°C, but are less than 180°C. Dissolved solids range from 370 ppm to 1210 ppm. Discharge volumes do not exceed 500 l/min.

Modoc Plateau, Modoc, Lassen, & Shasta Counties

Geologic Setting

The Modoc Plateau is an area of extensive flood basalts and pervasive normal faulting. Large quantities of Tertiary volcanic rocks covered the area, and volcanism and faulting have continued into the Holocene with a diminishing rate of activity (MacDonald, 1966). The area has been generally uplifted to elevations between 1500 m and 1800 m, and a very large number of north to northwest trending faults cut the plateau.

High permeability, flood basalts control the hydrology in the Modoc Plateau. Through most of the region the water table is at an altitude of 1220 m to 1250 m, and most of the surface flow is drained to the water table in areas over 1250 m elevation (MacDonald, 1966). The plateau receives an average precipitation of about 25 cm/yr, but in some areas there is no surface flow at all.

The Likely Fault Zone is a large, northwest striking, structural feature cutting across the Modoc Plateau southwest of Alturas. The fault appears to have normal vertical offset, but it is unclear if any horizontal offset is present (Duffield and Fournier, 1974). Kelley Hot Spring (sample 1) may be associated with the Likely Fault. A geothermal test well drilled near the spring penetrated 977 m of volcanic and sedimentary rock, and the bottom of the well is possibly in the Cedarville Series of Miocene age.

Hunt Hot Springs (sample 7) issue from the contact between Eocene conglomerate of the Montgomery Creek Formation and the Jurassic, Bagley andesite. Samples 2 through 6 came from valleys covered with Quaternary continental sediments or pyroclastic rocks.

Water Chemistry

Sample 2, from the Williams Ranch well, is a dilute, sodium-bicarbonate type water; and the remaining samples are more concentrated sodium-sulfate type water. The chemical indicators of temperature give values below 155°C for all the samples. It is possible that all the samples in this group are mixtures of cold near-surface water with deeper thermal water.

Several of these samples could come from hot water rising along faults. Faulting is pervasive in the plateau; but, except for Kelley Hot Spring, none of the sampling localities is close to mapped faults. Because of the highly permeable basalts underlying most of the region, it is probable that all the hot springs are rising along structural barriers to the ground water flow.

Boron content ranges from 0.22 ppm to 12.8 ppm. Calculated dissolved solids range from 231 ppm to 1220 ppm. Discharge volumes are less than 300 l/min, except for Kelley Hot Spring, where a flow of 1250 l/min was measured.

Conclusions

In evaluating the results of the six areas studied, Reed concludes that the thermal waters generally show the effects of dilution by cold, near-surface water, which adversely affects the use of chemical geothermometers. Many of the samples showed the effects of reacting with the surrounding rocks at above-normal temperatures; but the indicated temperatures were, in most cases, below 150°C.

Table 1a. Imperial Valley Artesian Wells

Sample Number	Location	Owner or Operator	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (°C)	pH	Conductivity (mmho/cm)	Discharge (1/min)	δO^{18} (‰)	δH^2 (‰
1	NW/SW Sec. 23 T. 12S., R. 15E., S.B.	D. Brownell	12/15/70	86.9- 99.1	-23.8	31.5	7.85	3.17			
2	SE/SE Sec. 27 T. 12S., R. 15E., S.B.	C. Brownell	12/15/70	125.0-131.1	-25.9	34.1	8.12	2.75		-7.3	-63
3	NE/NE Sec. 35 T. 12S., R. 15E., S.B.	Cowell	12/15/70	92.7-104.9	-19.8	33.0	8.13	2.61			
4	SW/SW Sec. 31 T. 12S., R. 16E., S.B.	P. Rebik	12/16/70	281.9	-7.6	39.1	7.79	6.08	20		
5	SE/NE Sec. 1 T. 13S., R. 15E., S.B.	Taylor	12/15/70	325.2-331.9	-19.8	55.2	7.66	6.90	64	-9.3	
6	SW/SW Sec. 3 T. 13S., R. 15E., S.B.	Mulberry School	12/14/70	271.3	-34.4	40.3	8.12	2.70			
7	NW/NW Sec. 5 T. 13S., R. 15E., S.B.	J. Williams	12/14/70	259.4-264.0	-43.3	35.7	7.80	2.89	40		
8	NW/NW Sec. 5 T. 13S., R. 15E., S.B.	Wiest Store	12/14/70	235.3-247.5	-42.1	37.7	7.83	2.55			
9	SW/SE Sec. 16 T. 13S., R. 15E., S.B.	M. Lunceford	12/14/70	231.6	-36.0	39.4	8.29	2.58	40		
10	SW/SE Sec. 23 T. 13S., R. 15E., S.B.	J. Ratliff	12/13/70	396.2	-25.0	55.7	7.74	6.15	160	-8.8	
11	SW/SW Sec. 24 T. 13S., R. 15E., S.B.	V. Butters	12/13/70	213.4	-22.6	42.8	8.36	2.84	60	-7.6	
12	NW/NW Sec. 32 T. 13S., R. 15E., S.B.	T. Shank	12/12/70	304.8	-38.7	43.5	7.82	4.76			

Table extracted from: Reed, M. J., Chemistry of Thermal Water in Selected Geothermal Areas of California, 38 pgs.,(1974)

Table 1a. Imperial Valley Artesian Wells

Sample Number	Location	Owner or Operator	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (°C)	pH	Conductivity (mmho/cm)	Discharge (1/min)	δO^{18} (‰)	δH^{2} (‰)
13	NE/NE Sec. 33 T. 13S., R. 15E., S.B.	Magnolia School	12/12/70	386.8-423.4	-33.5	50.9	7.70	6.61	140		
14	NW/SW Sec. 34 T. 13S., R. 15E., S.B.	M. Phegley	12/13/70	285.3-290.8	-31.4	44.3	8.17	3.14	40	-8.9	
15	SE/SE Sec. 6 T. 13S., R. 16E., S.B.	F. Schoneman	12/16/70	187.7	-11.6	33.3	8.16	2.83			
16	SE/SW Sec. 6 T. 13S., R. 16E., S.B.	T. Olesh	12/16/70	91.4	-15.2	32.0	8.12	3.14	20		
17	NW/NE Sec. 6 T. 14S., R. 15E., S.B.	N. Fifield	12/12/70	364.2-393.2	-40.2	51.4	7.77	6.72			
18	SW/SW Sec. 9 T. 14S., R. 15E., S.B.	J. Birger	12/11/70	117.3	-34.4	31.1	7.79	4.79	20		
19	NW/NW Sec. 11 T. 14S., R. 15E., S.B.	Moiola Feed Lot	12/13/70	198.1	-26.8	42.0	8.20	2.80	28		
20	SW/SW Sec. 12 T. 14S., R. 15E., S.B.	Mendiburu Feed Lot	12/13/70	356.9-375.8	-21.9	51.7	7.63	5.71			
21	NW/NE Sec. 15 T. 14S., R. 15E., S.B.	A. Gisler	12/11/70	355.1	-29.0	47.5	8.08	3.56	240	-9.9	-90
22	NW/SW Sec. 23 T. 14S., R. 15E., S.B.	J. Birger	12/11/70	228.6	-25.9	39.3	8.16	2.59	20		
23	NE/NE Sec. 27 T. 14S., R. 15E., S.B.	J. Birger	12/11/70	121.9	-26.8	31.8	7.87	2.51	16		
24	NW/NE Sec. 34 T. 14S., R. 15E., S.B.	Jenson	12/11/70	108.8	-26.8	29.5	8.01	2.83	120		

Table 1a. Imperial Valley Artesian Wells

Sample Number	Location	Owner or Operator	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (^{o}C)	pH	Conductivity (mmho/cm)	Discharge (l/min)	δO^{18}(‰)	δH^{2}‰
25	SW/SE Sec. 34 T. 14S., R. 15E., S.B.	Gaddis	12/11/70	165.9	-24.4	35.5	7.95	3.07	60	-9.9	
26	SW/SE Sec. 4 T. 14S., R. 16E., S.B.	F. Borchard	12/10/70	118.9-139.0	-4.6	37.3	8.35	1.99			
27	SW/SE Sec. 4 T. 14S., R. 16E., S.B.	F. Borchard	12/10/70	139.3	-4.6	38.4	8.38	1.96	48		
28	SE/NE Sec. 11 T. 14S., R. 16E., S.B.	U.S.-B.L.M.	12/16/70	86.9	7.6	34.5	8.23	2.26		-7.2	-62
29	NW/SE Sec. 16 T. 14S., R. 16E., S.B.	M. Axler	12/12/70	121.9	-5.2	25.4	8.17	1.41	4	-7.2	
30	NW/NE Sec. 21 T. 14S., R. 16E., S.B.	S. Stacey	12/10/70	133.2	-4.9	32.5	8.32	1.85	20		
31	NW/NW Sec. 22 T. 14S., R. 16E., S.B.	C. Singh	12/10/70	212.8-216.1	-2.1	41.7	7.91	4.95	20	-9.9	
32	SW/NE Sec. 10 T. 15S., R. 15E., S.B.	Shawner	12/3/70	140.2	-22.6	31.6	7.77	3.08	108	-7.8	
33	SE/NE Sec. 14 T. 15S., R. 15E., S.B.	C. Allen	12/3/70	263.3	-13.7	40.0	8.14	2.60	40	-9.1	
34	SW/NE Sec. 26 T. 15S., R. 15E., S.B.	J. DePaoli	11/29/70	240.8-289.6	-7.6	40.1	7.97	2.58		-9.4	-90
35	NE/NE Sec. 35 T. 15S., R. 15E., S.B.	Holtville Ice Co.	11/29/70	335.3	-5.5	44.6	7.96	4.33	116	-10.5	-94
36	NW/NW Sec. 36 T. 15S., R. 15E., S.B.	City of Holtville	11/28/70	255.4-259.7	-4.6	29.0	7.77	1.71	12	-7.8	

Table 1a. Imperial Valley Artesian Wells

Sample Number	Location	Owner or Operator	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (^{o}C)	pH	Conductivity (mmho/cm)	Discharge (1/min)	δO^{18}(‰)	δH^{2}(‰)
37	SE/SE Sec. 7 T. 15S., R. 16E., S.B.	Hooke	12/3/70	202.4-211.8	-11.3	35.6	8.25	2.20	12		
38	SW/NW Sec. 8 T. 15S., R. 16E., S.B.	G. Hoyt	12/3/70	144.8-148.7	-10.4	30.8	8.12	2.27	4		
39	SE/SW Sec. 15 T. 15S., R. 16E., S.B.	R. Garewal	12/2/70	243.8	0	32.0	8.39	1.92		-7.2	
40	SW/NW Sec. 19 T. 15S., R. 16E., S.B.	F. Strahm	12/2/70	254.2	-8.2	35.6	8.36	1.53	40	-7.4	
41	NE/SW Sec. 22 T. 15S., R. 16E., S.B.	D. Starr	12/2/70	228.6	0.3	34.7	8.15	2.88	12	-9.8	
42	SE/NW Sec. 23 T. 15S., R. 16E., S.B.	L. Foster	12/2/70	137.8-165.2	4.6	34.1	8.38	1.75	100	-8.2	
43	SW/SE Sec. 29 T. 15S., R. 16E., S.B.	A. Fusi	11/30/70	163.7-187.8	-3.0	30.6	8.26	1.19	8	-6.9	
44	SW/SE Sec. 30 T. 15S., R. 16E., S.B.	A. Fusi, Jr.	11/30/70	270.7-285.9	-3.0	39.7	8.17	2.26			
45	SE/NW Sec. 4 T. 16S., R. 16E., S.B.	C. Ansiel	11/30/70	268.2-285.9	0	34.5	8.22	2.96			
46	NE/NE Sec. 14 T. 16S., R. 16E., S.B.	Watton Labor Camp	12/1/70	343.8	5.2	43.0	8.09	3.29		-10.0	
47	NW/NE Sec. 15 T. 16S., R. 16E., S.B.	Alamo School (abd.)	12/1/70	263.3-267.3	3.7	37.2	8.33	2.21	16	-9.0	
48	NE/NW Sec. 9 T. 17S., R. 16E., S.B.	L. Bornt	12/9/70	184.1-216.4	9.4	37.2	8.13	2.35		-10.3	

Table 1b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations							Anions					Other		Calculated Dissolved Solids
		Li	Na	K	Mg	Ca	Sr	Fe	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
1	NW/SW Sec. 23	0.50	670	5.5	23	32	1.0	0.24	1.9	620	360	2.3	450	32	2.6	2200
2	SE/SE Sec. 27	0.24	530	3.7	9.7	19	0.4	0.09	1.5	510	290	3.4	300	36	2.7	1710
3	NE/NE Sec. 35	0.28	510	3.8	11	19	0.57	0.05	1.6	520	290	3.5	230	33	2.7	1680
4	SW/SW Sec. 31	0.68	1200	7.7	11	37	1.7	0.25	1.3	1700	290	2.0	60	27	8.9	3350
5	SE/NE Sec. 1	0.63	1100	9.4	14	43	1.6	0.03	1.3	1200	400	2.5	620	33	9.7	3440
6	SW/SW Sec. 3	0.17	500	3.0	4.2	9.7	0.25	0.19	2.0	450	480	6.0	120	38	2.4	1620
7	NW/NW Sec. 5	0.32	620	5.4	11	11	0.25	0.20	1.4	230	1300	7.7	100	36	2.6	2330
8	NW/NW Sec. 5	0.20	530	4.5	8	8.7	0.18	0.28	1.4	200	1200	8.7	53	43	5.8	[illegible]
9	SW/SE Sec. 16	0.18	490	3.1	3.3	9.9	0.14	0.10	1.9	400	540	9.8	120	30	2.4	1610
10	SW/SE Sec. 23	0.56	980	8.7	10	29	0.95	0.12	1.3	960	450	3.2	540	33	3.7	3020
11	SW/SW Sec. 24	0.17	500	2.9	3.3	8.7	0.16	0.09	1.4	450	470	10	130	29	1.8	1610
12	NW/NW Sec. 32	0.13	900	4.5	12	19	1.2	0.17	1.2	820	680	4.9	160	30	5.7	2640
13	NE/NE Sec. 33	0.51	1100	8.9	14	29	1.4	0.19	1.0	1400	550	3.5	270	32	2.2	3410
14	NW/SW Sec. 34	0.14	570	3.4	4.0	8.8	0.21	0.12	1.9	380	830	13	100	44	4.9	1960
15	SE/SE Sec. 6	0.32	560	3.8	10	21	0.87	0.03	1.2	610	250	3.2	250	22	2.5	1730
16	SE/SW Sec. 6	0.41	580	4.1	9.3	23	0.83	0.04	1.0	660	270	3.1	240	31	4.7	1830
·17	NW/NE Sec. 6	0.23	1200	6.9	15	40	1.2	0.32	1.0	1300	890	6.9	310	35	2.0	3810
18	SW/SW Sec. 9	0.17	1000	5.9	45	52	1.3	0.19	1.2	1200	560	3.3	490	36	3.7	3400

Table 1b. Chemical Constituents (in mg/1)

Sample Number	Location	Cations							Anions					Other		Calculated Dissolved Solids
		Li	Na	K	Mg	Ca	Sr	Fe	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
19	NW/NW Sec. 11	0.12	520	3.1	4.2	10	0.13	0.20	2.0	340	810	12	81	31	5.5	1820
20	SW/SW Sec. 12	0.42	940	8.0	10	33	0.75	0.11	1.2	1000	380	2.3	550	33	6.8	2970
21	NW/NE Sec. 15	0.15	610	3.7	4.2	22	0.47	0.19	1.6	490	800	11	130	36	13	2120
22	NW/SW Sec. 23	0.11	500	3.0	3.9	8.7	0.07	0.12	2.3	350	740	10	87	37	2.6	1740
23	NE/NE Sec. 27	0.09	530	4.2	15	26	0.49	0.24	1.7	330	700	4.4	280	24	3.7	1920
24	NW/NE Sec. 34	0.11	590	4.2	13	29	0.59	0.60	1.3	530	740	6.3	190	33	2.8	2140
25	SW/SE Sec. 34	0.11	620	4.6	17	30	1.3	0.34	1.3	420	650	5.4	370	24	2.7	2150
26	SW/SE Sec. 4	0.12	390	2.0	2.1	6.2	0.20	0.05	2.9	200	610	12	120	23	1.1	1270
27	SW/SE Sec. 4	0.11	390	2.1	2.0	4.8	0.12	0.07	3.3	170	640	14	130	23	7.6	1390
28	SE/NE Sec. 11	0.25	420	3.0	5.2	12	0.36	0.03	1.3	500	200	2.9	130	30	9.0	1310
29	NW/SE Sec. 16	0.08	310	2.2	5.3	13	0.33	0.10	1.6	300	310	3.1	57	18	0.8	1020
30	NW/NE Sec. 21	0.08	380	2.0	3.0	7.6	0.31	0.06	2.6	300	440	7.4	100	28	2.8	1270
31	NW/NW Sec. 22	0.36	900	5.7	8.2	31	0.61	0.22	1.7	1200	270	2.4	130	28	2.7	2580
32	SW/NE Sec. 10	0.12	670	4.9	17	22	0.95	0.12	1.8	600	670	3.4	190	37	1.9	2220
33	SE/NE Sec. 14	0.11	490	2.9	4.0	11	0.50	0.16	2.0	320	790	10	84	33	2.5	1750
34	SW/NE Sec. 26	0.12	500	3.2	4.7	11	0.47	0.19	2.0	300	790	6.9	110	26	3.6	1760
35	NE/NE Sec. 35	0.21	790	4.6	6.1	20	0.72	0.08	1.4	950	370	3.6	150	29	3.6	2330
36	NW/NW Sec. 36	0.04	350	2.5	7.9	15	0.44	0.32	1.7	290	490	2.1	79	23	3.2	1270

Table 1b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations							Anions					Other		Calculated Dissolved Solids
		Li	Na	K	Mg	Ca	Sr	Fe	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
37	SE/SE Sec. 7	0.11	460	2.5	3.5	9.1	0.15	0.12	2.8	260	710	11	110	38	4.4	1610
38	SW/NW Sec. 8	0.08	510	3.3	8.6	16	0.39	0.42	1.4	280	880	9.4	130	24	6.7	1870
39	SE/SW Sec. 15	0.12	420	2.2	2.7	7.6	0.10	0.10	3.9	220	600	12	160	25	2.7	1460
40	SW/NW Sec. 19	0.05	320	1.8	2.7	6.5	0.11	0.16	3.2	72	650	12	100	35	1.2	1200
41	NE/SW Sec. 22	0.16	570	3.7	5.5	17	0.44	0.14	2.2	600	430	5.4	170	22	2.9	1830
42	SE/NW Sec. 23	0.13	370	2.1	2.0	6.7	0.09	0.04	3.4	160	580	12	140	23	3.5	1300
43	SW/SE Sec. 29	0.04	260	2.0	2.5	7.1	0.25	0.40	2.9	40	580	7.6	110	21	1.9	1040
44	SW/SE Sec. 30	0.09	450	2.5	3.3	9.0	0.18	0.20	2.3	260	690	9.4	130	41	6.7	1600
45	SE/NW Sec. 4	0.12	610	3.5	5.2	11	0.31	0.24	1.6	490	850	13	74	22	3.2	2080
46	NE/NE Sec. 14	0.25	560	3.6	3.5	17	0.57	0.05	2.1	630	310	3.8	120	26	3.4	1680
47	NW/NE Sec. 15	0.10	420	2.4	2.7	10	0.41	0.05	2.3	310	510	9.3	130	25	2.2	1420
48	NE/NW Sec. 9	0.11	450	2.9	4.2	17	0.70	0.12	1.7	400	370	4.4	180	29	1.5	1460

Table 1c. Calculated Temperatures, Imperial Valley (in ^{o}C)

Sample Number	Location	Quartz Solubility (regular)	Quartz Solubility (with steam loss)	Na/K	Na, K, Ca (B = 1/3)	Na, K, Ca (B = 4/3)	Measured Temperature
1	NW/SW Sec. 23	82		6	89	90	31.5
2	SE/SE Sec. 27	87		-1	84	85	34.1
3	NE/NE Sec. 35	83		2	85	86	33.0
4	SW/SW Sec. 31	75		-5	86	106	39.1
5	SE/NE Sec. 1	83		8	94	108	55.2
6	SW/SW Sec. 3	89		-7	82	93	40.3
7	NW/NW Sec. 5	87		8	96	115	35.7
8	NW/NW Sec. 5	95		7	95	111	37.7
9	SW/SE Sec. 16	79		-5	83	93	39.4
10	SW/SE Sec. 23	83		9	97	114	55.7
11	SW/SW Sec. 24	78		-9	81	94	42.8
12	NW/NW Sec. 32	79		-14	78	99	43.5
13	NE/NE Sec. 33	82		5	95	116	50.9
14	NW/SW Sec. 34	96		-8	83	101	44.3
15	SE/SE Sec. 6	67		-2	83	85	33.3
16	SE/SW Sec. 6	81		-1	84	86	32.0
17	NW/NE Sec. 6	86		-9	82	100	51.4
18	SW/SW Sec. 9	87		-8	79	86	31.1
19	NW/NW Sec. 11	81		-8	82	94	42.0

Table 1c. Calculated Temperatures, Imperial Valley (in ^{o}C)

Sample Number	Location	Quartz Solubility (regular)	Quartz Solubility (with steam loss)	Na/K	Na, K, Ca (B = 1/3)	Na, K, Ca (B = 4/3)	Measured Temperature
20	SW/SW Sec. 12	83		7	94	107	51.7
21	NW/NE Sec. 15	87		-7	80	84	47.5
22	NW/SW Sec. 23	88		-7	82	96	39.3
23	NE/NE Sec. 27	70		4	86	83	31.8
24	NW/NE Sec. 34	83		0	83	81	29.5
25	SW/SE Sec. 34	70		1	85	84	35.5
26	SW/SE Sec. 4	69		-13	76	86	37.3
27	SW/SE Sec. 4	69		-12	79	94	38.4
28	SE/NE Sec. 11	79		0	84	85	34.5
29	NW/SE Sec. 16	60		-1	80	71	25.4
30	NW/NE Sec. 21	77		-12	76	82	32.5
31	NW/NW Sec. 22	77		-5	83	95	41.7
32	NW/NE Sec. 10	88		1	87	95	31.6
33	SE/NE Sec. 14	83		-8	80	89	40.0
34	SW/NE Sec. 26	74		-5	83	92	40.1
35	NE/NE Sec. 35	78		-9	82	97	44.6
36	NW/NW Sec. 35	69		0	81	73	29.0
37	SE/SE Sec. 7	89		-11	78	87	35.6
38	SW/NW Sec. 8	70		-4	82	85	30.8

Table 1c. Calculated Temperatures, Imperial Valley (in °C)

Sample Number	Location	Quartz Solubility (regular)	Quartz Solubility (with steam loss)	Na/K	Na, K, Ca (B = 1/3)	Na, K, Ca (B = 4/3)	Measured Temperature
39	SE/SW Sec. 15	72		-13	77	86	32.0
40	SW/NW Sec. 19	86		-10	77	80	35.6
41	NE/SW Sec. 22	67		-4	83	89	34.7
42	SE/NW Sec. 23	69		-10	78	86	34.1
43	SW/SE Sec. 29	65		3	84	79	30.6
44	SW/SE Sec. 30	93		-10	78	87	39.7
45	SE/NW Sec. 4	67		-9	82	96	34.5
46	NE/NE Sec. 14	74		-5	82	88	43.0
47	NW/NE Sec. 15	72		-9	78	83	37.2
48	NE/NW Sec. 9	78		-4	80	78	37.2

Table 2a. Long Valley Springs and Wells

Sample Number	Location	Name	Date Sampled (mo/dy/yr)	Altitude (m)	Water Temperature (°C)	pH	Conductivity @ 25°C (mmho/cm)	Discharge (l/min)	δO^{18} (‰)	δH^2 (‰
1	NE/NE Sec. 25 T. 2S., R. 27E., M.D.	Big Springs	5/21/72	2220	11	6.83	0.182	380	-15.89	-115.4
2	SW/NW Sec. 13 T. 3S., R. 28E., M.D.	Little Hot Creek hot spring	5/13/72	2135	79	6.51	1.95	280	-15.34	-121.6
3	NE/NE Sec. 25 T. 3S., R. 28E., M.D.	Hot Creek hot spring	8/29/73	2145	90	7.89	1.77	400		
4	SW/NW Sec. 32 T. 3S., R. 26E., M.D.	"Endogenous" 5 Magma Power Co. (123.4 m deep)	5/19/72	2231	94	9.25	1.92	3200 (kg/min) mixed steam & water	-14.16	-115.3
5	SW/NW Sec. 35 T. 3S., R. 28E., M.D.	hot pool	5/24/72	2165	60	7.15	1.80	0	-12.44	-111.9
6	NE/NW Sec. 13 T. 3S., R. 29E., M.D.	artesian well (24.4 m deep)	5/23/72	2075	10	8.82	0.191	25	-17.07	-129.5
7	SW/SW Sec. 21 T. 3S., R. 29E., M.D.	hot spring	5/22/72	2105	56	6.53	1.79	100	-16.17	-123.9
8	SE/NE Sec. 28 T. 3S., R. 29E., M.D.	hot spring	5/22/72	2095	49	6.60	1.90	200	-15.85	-123.4
9	NE/NE Sec. 31 T. 3S., R. 29E., M.D.	hot spring	5/20/72	2130	58	7.53	1.50	190	-15.23	-121.2
10	NW/SE Sec. 34 T. 3S., R. 29E., M.D.	hot spring	5/23/72	2090	41	6.64	1.63	150	-16.08	-124.9

Table 2b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations								Anions							Other		
		Li	Na	K	Rb	Cs	Mg	Ca	Sr	F	Cl	Br	I	HCO_3	CO_3	SO_4	SiO_2	B	H_2
1	NE/NE Sec. 25	0.04	23	4.0	0.01	<0.05	5.9	5.1	0.07	0.5	5.7	0.20		90	0	8.1	58	0.37	<0.
2	SW/NW Sec. 13	2.8	410	30	0.26	0.30	0.6	50	0.60	8.4	200	0.80	0.8	735	0.3	96	110	10.5	2.
3	NE/NE Sec. 25	2.3	400	24	0.22	0.2	0.1	1.6		9.6	225			580	25.9	100	150	10.5	2.
4	SW/NW Sec. 32	2.8	390	45	0.48	0.60	0.1	0.9	0.14	12	280	1.10	0.4	450	29.6	130	340	15	10
5	SW/NW Sec. 35	2.5	380	25	0.28	0.45	0.1	3.3	0.10	11	250	0.80	0.5	466	0.7	120	300	13	1.
6	NE/NW Sec. 13	0.14	38	1.3	<0.01	<0.05	0.2	5.3	0.04	0.6	3.0	0.03		111	2.8	3.7	64	0.18	3.
7	SW/SW Sec. 21	1.5	310	37	0.11	0.10	0.6	25	0.20	4.6	150	0.50	0.4	828	0.3	68	250	7.7	0.
8	SE/NE Sec. 28	1.7	400	43	0.14	0.05	0.6	22	0.14	4.8	170	0.60	0.4	845	0.3	69	240	8.8	0.
9	NE/NE Sec. 31	2.0	310	22	0.19	0.20	0.4	15	0.28	7.5	170	0.60	0.5	516	1.9	81	150	7.9	0.
10	NW/SE Sec. 34	1.6	320	28	0.08	0.10	1.2	23		4.6	150	0.50	0.4	695	0.3	59	205	8.1	0.

Table 2c. Trace Constituents (in mg/l)

Sample Number	Location	Al	Mn	Fe	Ni	Cu	Zn	As	Se	Sb	Hg	N (NH_3)	P (PO_4)	Calculated Dissolved Solids
1	NE/NE Sec. 25	0.002	< 0.02	< 0.05	< 0.05	< 0.03	0.045	0.02		< 0.1	< 0.0001	0.13	1.0	202
2	SW/NW Sec. 13	0.006	0.24	0.15	0.10	0.07	0.44	0.74	0.005	< 0.1	< 0.0001	0.40	0.15	1660
3	NE/NE Sec. 25	0.060	< 0.02	< 0.05	< 0.05	0.02	< 0.01				0.0013	0.50		1510
4	SW/NW Sec. 32		< 0.02	0.05	< 0.05	< 0.03	0.19	2.2	0.001	0.2	0.0001	0.40	0.18	1710
5	SW/NW Sec. 35	0.057	< 0.02	< 0.05	< 0.05	0.02	0.045	0.34	0.004	0.3	0.0003	0.15	0.71	1570
6	NE/NW Sec. 13	0.003	< 0.02	< 0.05	< 0.05	< 0.03	< 0.01	0.02	0.002	< 0.1	0.0001	0.35	0.15	235
7	SW/SW Sec. 21	0.002	0.10	0.23	< 0.05	0.04	0.18	0.46	0.005	< 0.1	< 0.0001	0.20	0.28	1590
8	SE/NE Sec. 23	0.003	0.08	< 0.05	< 0.05	0.03	0.12	0.34	0.004	< 0.1	0.0001	0.10	0.46	1810
9	NE/NE Sec. 31	0.006	< 0.02	< 0.05	< 0.05	< 0.03	0.02	0.84		< 0.1	0.0001	0.09	0.43	1290
10	NW/SE Sec. 34	< 0.002	0.085	0.45	< 0.05	< 0.03	0.10	0.36		< 0.1	< 0.0001	0.15	0.18	1500

Other trace constituents measured but below limit of detection:

Cd < 0.01
Co < 0.06
Au < 0.1
Pb < 0.1
Ag < 0.04

Table 2d. Calculated Temperatures, Long Valley (in °C)

Sample Number	Location	Quartz Solubility		Na/K	Na, K, Ca		Measured Temperature
		(regular)	(with steam loss)		(B = 1/3)	(B = 4/3)	
1	NE/NE Sec. 25	109		259	187	82	11
2	SW/NW Sec. 13	143		150	171	138	79
3	NE/NE Sec. 25	161	153	131	191	257	90 (boiling)
4	SW/NW Sec. 32	219	200	201	238	344	94 (boiling)
5	SW/NW Sec. 35	209	192	140	189	225	60 (evaporation)
6	NE/NW Sec. 13	114		86	117	52	10
7	SW/SW Sec. 21	196		205	200	166	56
8	SE/NE Sec. 28	193		192	200	183	49
9	NE/NE Sec. 31	161		147	175	157	58
10	NW/SE Sec. 34	182		169	183	155	41

Table 3a. Sierra Valley, Artesian Wells and Spring

Sample Number	Location	Owner	Date Sampled (mo/dy/yr)	Depth (m)	Altitude (m)	Water Temperature (°C)	pH	Conductivity (mmho/cm)	Discharge (1/min)	δO^{18}(‰)	δH^{2}(‰)
1	NW/SE Sec. 13 T. 22N., R. 14E., M.D.	Marble Hot Springs	6/20/73	104	1486	73.2	8.19	3.87	100		
2	SW/SE Sec. 13 T. 22N., R. 14E., M.D.	Marble Hot Springs	6/20/73	99	1486	70.3	7.96	3.74	80		
3	NW/NE Sec. 32 T. 22N., R. 15E., M.D.	W. Hagge	6/27/73	213	1486	39.8	7.61	2.39	2.5		
4	NW/NE Sec. 32 T. 22N., R. 15E., M.D.	W. Hagge	6/28/73	182	1486	38.6	7.48	1.62	2		
5	NE/SW Sec. 32 T. 22N., R. 15E., M.D.	G. Filipini	6/20/73	335	1487	94.2	7.97	4.72	50		
6	SE/SE Sec. 32 T. 22N., R. 15E., M.D.	W. Hagge	6/28/73	274	1487	44.1	8.00	2.65	4		
7	SW/NW Sec. 5 T. 21N., R. 15E., M.D.	G. Filipini	6/22/73	244	1489	51.3	7.42	2.71	8		
8	SW/SW Sec. 9 T. 21N., R. 15E., M.D.	A. Genasci	6/22/73	122	1498	18.2	7.68	0.198	12		
9	NW/NE Sec. 19 T. 20N., R. 15E., M.D.	Campbell Hot Springs	6/19/73	spring	1530	36.8	10.13	0.596	1		

Table 3b. Sierra Valley, Chemical Constituents (in mg/l)

Sample Number	Location	Cations									Anions					Others		Calculated Dissolved Solids
		Li	Na	K	Rb	Cs	Mg	Ca	Mn	Fe	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
1	NW/SE Sec. 13	0.42	410	7.6	0.06	0.2	0.1	37	0.022	< 0.06	2.2	460	41	0	340	60	7.4	1370
2	SW/SE Sec. 13	0.40	400	7.4	0.06	0.2	0.1	38	0.03	< 0.06	2.2	460	51	1	330	62	7.3	1360
3	NW/NE Sec. 32	0.50	400	6.3	0.05	0.1	1.3	26	0.10	0.63	1.5	440	76	0	270	80	7.8	1310
4	NW/NE Sec. 32	0.36	300	5.3	0.03	0.1	1.4	12	0.075	1.43	1.0	300	87	0	190	77	6.2	980
5	NE/SW Sec. 32	0.65	450	13	0.11	0.2	0.1	39	0.01	< 0.06	2.6	540	50	1	370	98	8.3	1570
6	SE/SE Sec. 32	0.43	420	8.5	0.05	0.2	0.6	20	0.06	< 0.06	1.9	450	72	1	270	92	6.2	--
7	SW/NW Sec. 5	0.38	380	5.6	0.04	0.1	0.6	20	0.09	0.09	1.8	390	103	0	220	85	7.4	1210
8	SW/SW Sec. 9	< 0.01	38	3.9	< 0.01	< 0.05	4.0	5.5	0.013	0.15	< 0.1	5.8	130	1	13	65	0.07	266
9	NW/NE Sec. 19	0.06	92	1.1	< 0.01	< 0.05	< 0.1	2.0	< 0.01	< 0.06	< 0.1	52	86	25	27	82	1.6	369

Trace Constituents Below Detection:

Co < 0.04
Ni < 0.04
Cu < 0.01
Zn < 0.01
Cd < 0.01
Pb < 0.06

Table 3c. Calculated Temperatures, Sierra Valley (in ^{o}C)

Sample Number	Location	Quartz Solubility (regular)	Quartz Solubility (with steam loss)	Na/K	Na, K, Ca (B = 1/3)	Na, K, Ca (B = 4/3)	Measured Temperature
1	NW/SE Sec. 13	111		46	112	92	73.2
2	SW/SE Sec. 13	112		46	111	90	70.3
3	NW/NE Sec. 32	125		37	107	93	39.8
4	NW/NE Sec. 32	123		44	113	102	38.6
5	NE/SW Sec. 32	136	132	74	131	112	94.2 (boiling)
6	SE/SE Sec. 32	133		51	120	112	44.1
7	SW/NW Sec. 5	128		34	106	95	51.3
8	SW/SW Sec. 9	115		187	167	85	18.2
9	NW/NE Sec. 19	126		23	95	76	36.8

Table 4a. Honey Lake Valley Wells and Springs

Sample Number	Location	Name	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (^{o}C)	pH	Conductivity (mmho/cm)	Discharge (l/min)	δO^{18}(‰)	δH^{2}(‰)
1	NE/NE Sec. 6 T. 29N., R. 12E., M.D.	Roosevelt Swimming Pool	7/18/73	90 (?)	1295	35.8	8.01	0.254	pumped		
2	SE/NE Sec. 6 T. 29N., R. 12E., M.D.	Latter Day Saints Church	7/18/73	169-181	1268	48.8	7.87	1.07	800 pumped		
3	SW/SE Sec. 23 T. 29N., R. 15E., M.D.	Wendel Hot Springs	7/17/73	spring	1231	95.6	8.38	3.34	1200		
4	NE/SW Sec. 30 T. 29N., R. 16E., M.D.	Southern Pacific Railroad	7/17/73	93	1223	28.2	8.33	0.332	300 pumped		
5	NW/NE Sec. 8 T. 28N., R. 16E., M.D.	Amedee Hot Springs	7/17/73	spring	1219	95.1	8.43	2.86	500		

Table 4b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations								Anions					Others		Calculated Dissolved Solids
		Li	Na	K	Rb	Mg	Ca	Zn	F	Cl	HCO_3	CO_3	SO_4		SiO_2	B	
1	NE/NE Sec. 6	<0.01	20	3.8	<0.01	3.4	19	0.043	<0.1	2.0	120	1	11		53	<0.02	233
2	SE/NE Sec. 6	0.05	140	4.6	0.02	1.6	24	0.009	1.2	64	68	1	190		62	1.4	556
3	SW/SE Sec. 23	0.12	280	7.5	0.04	<0.1	18	0.015	4.1	190	50	1	360		120	5.5	1040
4	NE/SW Sec. 30	0.01	58	8.0	0.01	2.2	6.0	<0.005	0.2	17	112	1	32		42	0.22	279
5	NW/NE Sec. 8	0.08	250	5.5	0.02	<0.1	14	<0.005	4.4	160	44	2	300		95	4.0	879

Trace Constituents Below Detection:

Cs <0.1, Mn <0.01, Fe <0.06, Cd < 0.01, Co <0.05, Cu <0.02, Ni <0.04, Pb <0.1

Table 4c. Calculated Temperatures, Honey Lake Valley (in ^{o}C)

Sample Number	Location	Quartz Solubility			Na, K, Ca		Measured Temperature
		(regular)	(with steam loss)	Na/K	(B = 1/3)	(B = 4/3)	
1	NE/NE Sec. 6	105		273	177	53	35.8
2	SE/NE Sec. 6	112		83	123	73	48.8
3	SW/SE Sec. 23	148	142	69	126	104	95.6 (boiling)
4	NE/SW Sec. 30	94		225	190	115	28.2
5	NW/NE Sec. 8	134	130	56	113	98	95.1 (boiling)

Table 5a. Surprise Valley Springs and Artesian Wells

Sample Number	Location	Name	Date Sampled (mo/dy/yr)	Depth (m)	Altitude (m)	Water Temperature (°C)	pH	Conductivity (mmho/cm)	Discharge (l/min)	δO^{18} (‰)	δH^{2} (‰)
1	NW/NE Sec. 17 T. 46N., R. 16E., M.D.	Fort Bidwell Reservation	7/26/73		1414	45.1	7.85	0.733	400		
2	SW/NE Sec. 24 T. 44N., R. 15E., M.D.	Lake City Mud Explosion	8/16/73	pool	1366	96.5	7.44	3.74	0		
3	NW/NW Sec. 12 T. 43N., R. 16E., M.D.	Seyferth Hot Springs	7/26/73	spring	1417	85.4	7.66	3.28	500		
4	NE/NE Sec. 13 T. 43N., R. 16E., M.D.	Leonards Hot Springs	7/25/73	spring	1390	61.8	7.82	2.59	150		
5	NE/SW Sec. 6 T. 42N., R. 17E., M.D.	Hot Springs Motel	7/27/73	27	1372	98.1	8.40	2.66	300		
6	NE/NE Sec. 7 T. 39N., R. 17E., M.D.	Menlo Hot Springs	8/23/73	spring	1384	57.4	8.91	0.808	500		

Table 5b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations								Anions					Other		Calculated Dissolved Solids
		Li	Na	K	Rb	Mg	Ca	Mn	Zn	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
1	NW/NE Sec. 17	0.03	110	9.5	0.01	0.1	4.2	< 0.01	< 0.005	2.2	31	131	1	86	82	0.61	458
2	SW/NE Sec. 24	0.24	320	15	0.08	< 0.1	7.7	< 0.01	< 0.005	7.6	220	112	0	320	200	6.3	1210
3	NW/NW Sec. 12	0.15	300	9.0	0.04	< 0.1	28	0.01	< 0.005	5.4	220	63	0	370	110	7.6	1110
4	NE/NE Sec. 13	0.13	330	8.5	0.03	0.6	26	0.09	< 0.005	5.2	220	82	1	390	110	7.6	1180
5	NE/SW Sec. 6	0.10	280	5.5	0.03	< 0.1	16	< 0.01	0.014	5.1	200	57	2	320	100	5.7	991
6	NE/NE Sec. 7	< 0.02	100	1.4	< 0.01	< 0.1	5.1	< 0.01	< 0.05	3.8	25	27	34	120	53	0.93	370

Trace Constituents Below Detection:

Cs < 0.1
Fe < 0.06
Cd < 0.01
Co < 0.05
Cu < 0.02
Ni < 0.04
Pb < 0.1

Table 5c. Calculated Temperatures, Surprise Valley (in ^{o}C)

Sample Number	Location	Quartz Solubility			Na, K, Ca		Measured Temperature
		(regular)	(with steam loss)	Na/K	(B = 1/3)	(B = 4/3)	
1	NW/NE Sec. 17	126		167	179	141	45.1
2	SW/NE Sec. 24	180	168	110	160	161	96.5 (boiling)
3	NW/NW Sec. 12	143		76	129	101	85.4
4	NE/NE Sec. 13	143		66	124	102	61.8
5	NE/SW Sec. 6	137	133	50	115	96	98.1 (boiling)
6	NE/NE Sec. 7	105		31	96	65	57.4

Table 6a. Modoc Plateau Hot Springs and Artesian Well

Sample Number	Location	Name	Date Sampled (mo/dy/yr)	Producing Depth (m)	Altitude (m)	Water Temperature (°C)	pH	Conductivity (mmho/cm)	Discharge (1/min)	δO^{18} (‰)	δH^2 (‰)
1	NE/NW Sec. 29 T. 42N., R. 10E., M.D.	Kelley Hot Spring	7/23/73	spring	1326	91.5	8.08	2.77	1250		
2	SW/NW Sec. 31 T. 40N., R. 13E., M.D.	Williams Ranch Well	7/24/73	30-38	1347	43.8	8.40	0.333	pumped		
3	NW/SW Sec. 9 T. 39N., R. 5E., M.D.	Little Hot Springs	8/22/73	spring	1082	75.7	7.59	2.49	300		
4	NW/NE Sec. 29 T. 39N., R. 14E., M.D.	West Valley Reservoir Hot Spring	7/24/73	spring	1460	77.3	7.79	2.98	12		
5	NW/SE Sec. 12 T. 38N., R. 7E., M.D.	Bassett Hot Spring	8/14/73	spring	1265	79.0	8.53	2.33	200		
6	SW/SE Sec. 15 T. 38N., R. 8E., M.D.	Kellog Hot Spring	8/22/73	spring	1277	78.4	8.63	2.59	15		
7	NW/SW Sec. 25 T. 37N., R. 1W., M.D.	Hunt Hot Springs	8/21/73	spring	503	57.6	8.75	2.55	32		

Table 6b. Chemical Constituents (in mg/l)

Sample Number	Location	Cations						Anions					Others		Calculated Dissolved Solids
		Li	Na	K	Rb	Mg	Ca	Mn	F	Cl	HCO_3	CO_3	SO_4	SiO_2	B	
1	NE/NW Sec. 29	0.15	250	6.5	0.02	< 0.1	20	< 0.01	2.1	160	45	1	300	110	3.8	899
2	SW/NW Sec. 31	< 0.01	49	3.4	< 0.01	< 0.1	4.2	< 0.01	0.4	11	80	3	28	52	0.22	231
3	NW/SW Sec. 9	0.17	230	5.2	0.02	0.2	44	0.01	1.9	120	49	0	400	87	3.9	941
4	NW/NE Sec. 29	0.40	330	11	0.06	< 0.1	19	0.012	4.0	150	63	0	510	130	4.5	1220
5	NW/SE Sec. 12	0.10	220	3.2	0.01	< 0.1	30	< 0.01	2.0	93	30	1	370	68	2.5	820
6	SW/SE Sec. 15	0.12	240	5.9	0.02	< 0.1	30	< 0.01	2.6	110	31	2	370	85	3.2	880
7	NW/SW Sec. 25	0.12	300	4.3	0.02	< 0.1	52	< 0.01	3.6	140	49	6	520	47	12.8	1130

Constituents Below Detection:

Cs < 0.1
Fe < 0.06
Cd < 0.01
Co < 0.05
Cu < 0.02
Ni < 0.04
Pb < 0.1
Zn < 0.005

Table 6c. Calculated Temperature, Modoc Plateau (in ^{o}C)

Sample Number	Location	Quartz Solubility (regular)	Quartz Solubility (with steam loss)	Na/K	Na, K, Ca (B = 1/3)	Na, K, Ca (B = 4/3)	Measured Temperature
1	NE/NW Sec. 29	143	137	67	123	95	91.5 (boiling)
2	SW/NW Sec. 31	104		145	154	90	43.8
3	NW/SW Sec. 9	130		58	111	69	75.7
4	NW/NE Sec. 29	152		84	138	120	77.3
5	NW/SE Sec. 12	117		33	96	62	79.0
6	SW/SE Sec. 15	128		63	117	82	78.4
7	NW/SW Sec. 25	99		32	96	63	57.6

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IDAHO

Summary

At least 380 hot springs and wells are known to occur throughout the central and southern parts of Idaho. One hundred twenty-four of these were inventoried as a part of a study by Young and Mitchell (1973). Thermal waters flow from rocks ranging in age from Precambrian to Holocene and from a wide range of rock types--igneous, metamorphic, and both consolidated and unconsolidated sediments. Twenty-eight sites occur on or near fault zones, while a greater number probably related to faulting. Most are low temperature with no steam. Idaho is underlain by large areas of granitic rocks of the Idaho Batholith (of Cretaceous age), where most of the springs occur, and by Tertiary volcanic rocks of the Snake River Plain. Heat flow in the state averages 2.0 HFU, which is similar to the Basin and Range Province as a whole. Most geothermal water (with the exception of that southeast of the Snake River Plain) has a specific conductance of less than 1,500 microhms/cm at 25°C. Virtually all spring and well water is alkaline, with pH's ranging from about 7 to more than 9. More than 200 homes in Boise are heated by hot water (77°C [170°F]) and there are two KGRA's in the state. Typical chemical content of water from granitic rocks in most areas north of the Snake River Plain as averaged by Ross, (1972).

SiO_2-62 ppm
calcium - 4 ppm
magnesium - 0.3 ppm
sodium - 60 ppm
potassium - 1.3 ppm
carbonate - 22 ppm
total dissolved solids - 224 ppm

carbonate - 22 ppm
bicarbonate - 59 ppm
sulfate - 14 ppm
chloride - 9 ppm
fluoride - 12.1 ppm
nitrate - 0.2 ppm
pH - 9.2

Hottest springs:

Vulcan Hot Spring
Maximum temperature - 89°C (192°F)

Discharge - 450 gpm
Dissolved solids (calculated) - 362 ppm
pH - 8.5

Boiling Springs
Maximum temperature 85°C (185°F)
Discharge - 165 gpm
Dissolved solids-270 ppm
PH - 8.8

Bonneville Hot Springs
Maximum temperature 85°C (185°F)
Discharge-363 ppm
Dissolved solids - 306 ppm
pH - 8.1

Big Creek Hot Springs
Maximum temperature 93°C (199°F)
Discharge - 75 gpm
Dissolved solids - 727 ppm
pH - 7.5

Bridge Spring
Maximum temperature 93°C (199°F)
Discharge - 26 gpm

Water quality of geothermal water in Idaho is good except in the southeastern part of the state, where the waters are uniformly high in total dissolved

Measured water temperatures at 124 wells and springs inventoried ranged from 12° to 93°C and averaged 50°C. Estimated aquifer temperatures, calculated using the silica and the sodium-potassium-calcium geochemical thermometers, range from 5° to 370°C and averaged 110°C. Estimated aquifer temperatures in excess of 140°C exist at 42 sites. No areal patterns to the distribution of temperatures either at the surface or subsurface are apparent.

Generally, the quality of the thermal waters is good. Dissolved solids concentrations range from 14 to 13,700 ppm and averaged 812 ppm, with higher values occurring in the southeastern part of the state.

At the Frazier KGRA in Raft River Valley, water temperatures at the surface are above 90°C at two wells. Geochemical thermometers indicate temperatures of 135° to 145°C may exist at depths. Dissolved solids concentrations in waters issuing from the two wells were 1720 and 3360 ppm. The minerals being deposited by these waters consist chiefly of halite ($NaCl$) and calcite ($CaCO_3$).

Well and Spring Numbering System

The numbering system used by the U.S. Geological Survey in Idaho indicates the location of wells or springs within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and a numeral, which indicate the quarter section, the 40-acre tract, the 10-acre tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from the northeast quarter of each section (Fig. 2). Within the quarter sections, 40-acre and 10-acre tracts are lettered in the same manner. Well 6S-5E-10ddd1 is in the SE1/4 SE1/4 SE1/4 sec.10, T.6S., R.5E., and was the first well inventoried in that tract. Springs are designated by the letter "S" following the last numeral; for example, 4S-13E-30adb1S.

Generalized Geologic Setting of Idaho

The state of Idaho is underlain by rocks of igneous, metamorphic, and sedimentary origins. These formations range in age from Precambrian to Holocene and represent a varied and complex geologic history. Large scale igneous activity has occurred throughout most of the state. Cenozoic lava flows ranging in composition from rhyolite to basalt are exposed in most of the western, central, and southern parts of the state, while Mesozoic and Cenozoic granitic rocks are the predominant rock type of large areas of central Idaho. Marine sedimentary rocks of Paleozoic age are the principal rock type of southeastern Idaho, while metamorphic rocks of Precambrian age are exposed in northern and east-central Idaho.

Although the occurrence of thermal activity and its association to a particular rock type in Idaho is obscure, known thermal anomalies are limited to the central and southern parts of the state. The occurrence and associated rock type of sampled springs and wells is discussed in the following sections.

A brief description of the geology, including the age and lithology of the spring vent or aquifer and, where possible, the controlling structure and the active deposition at each spring and well is given in Table 1. These descriptions indicate that thermal springs and wells throughout the state issue from a great diversity of rock types of nearly all ages. However, the lithology and age of the spring vent or aquifer may not be indicative of the aquifer from which the thermal waters originate. Many thermal springs in central Idaho occur in association with fault zones in Cretaceous and Tertiary granitic and related rocks, whereas springs and wells along the margins of the Snake River Plain occur in Cenozoic basaltic and rhyolitic lava flows and associated sedimentary rocks. In southeastern Idaho, springs and wells are primarily associated with fault zones in Paleozoic marine sedimentary rocks that may in places be overlain by unconsolidated valley fill.

Although nearly one-fifth of the sampled springs issue from known faults, a greater number are thought to be associated with faulting.

Active deposition of minerals from water discharged by thermal springs and wells occurs throughout the state. Minerals deposited include: gypsum, halite, various carbonates, and silicates. Carbonate deposits were identified using diluted hydrochloric acid, while siliceous deposits were identified by hardness and visual examination.

Water Chemistry

The chemical analyses of thermal spring and well waters sampled by Young and Mitchell (1973) are given in Table 2. The aquifer temperatures estimated by the silica method are given in Table 3.

Most thermal waters in Idaho are low in dissolved solids, with concentrations in sampled waters ranging from 14 to 13,700 ppm. Thermal waters in the southeastern part of Idaho are higher in dissolved solids than thermal waters in other parts of the state. Waters which are high in dissolved solids generally give high Na-K-Ca temperatures relative to silica temperatures (Table 3), whereas waters low in dissolved solids give high silica temperatures relative to low Na-K-Ca temperatures.

Measured temperatures of sampled waters ranged from 12°C in northern Fremont County to 93.0°C in Cassia and Lemhi Counties and averaged 50°C for all sampled springs and wells. Examination of the temperature data collected does not reveal any correlation of temperature with location, rock type, or structure.

Estimated aquifer temperatures for the waters sampled ranged from 5° to 370°C, as estimated by the sodium-potassium-calcium geochemical thermometer and from less than 35° to 170°C, as estimated by the silica geochemical thermometer.

Estimate aquifer temperatures in excess of 140°C were found at 42 sites. Generally, for waters high in dissolved solids, the Na-K-Ca geochemical thermometer indicated higher aquifer temperatures than did the silica geochemical thermometer; whereas for waters low in dissolved solids, the silica geochemical thermometer indicated highest temperatures.

TABLE 2

CHEMICAL ANALYSES OF THERMAL WATERS FROM SELECTED SPRINGS AND WELLS IN IDAHO

(Chemical constituents in milligrams per liter)

Analyses by: U. S. Geological Survey

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Carbonate (CO3)	Sulfate (SO4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness		Specific Conductance	pH (field)	Alkalinity as CaCO3	Percent Sodium	Sodium Absorption Ratio	Area No. Fig. 6
																			as CaCO3	Non-carbonate						
ADA COUNTY																										
5N 1E 35acal		5-31-72	22	40.0	33	4.3	0	49	3.2	112	1	23	0.03	4.9	11	0.05	193	0.26	11	0	285	7.5	94	89	7.4	
4N 2E 29acdl	1,195	5-31-72	-	47.0	46	4.5	.3	55	2.4	145	2	21	.02	4.4	10	.06	225	.31	14	0	311	7.1	122	89	7.1	
3N 2E 12cddl	400	5-31-72	-	75.0	78	2	0	75	1.3	141	4	23	.01	9.3	24	.08	299	.41	9	0	386	7.3	122	95	13	
ADAMS COUNTY																										
White Licks Hot Springs 16N 2E 33bcclS		6-29-72	30	65.0	110	39	.3	420	17	71	0	660	.05	150	8.8	.07	1,440	1.96	99	40	2,030	7.6	58	88	18	1
Zim's Resort Hot Springs 20N 1E 26ddblS		6-29-72	-	65.0	64	12	.1	190	3.6	47	9	330	.03	32	2.3	.07	666	.91	30	0	940	8.5	54	92	15	
Krigbaum Hot Springs 19N 2E 22ccalS		6-29-72	40	43.0	73	5.3	.2	140	3.3	81	9	190	.03	26	2.8	.05	490	.67	14	0	668	8.8	81	94	16	
Starkey Hot Springs 18N 1W 34dbblS		6-27-72	130	56.0	56	4.5	0	86	1.6	60	6	150	.03	14	.9	.05	369	.50	12	0	502	8.6	58	94	12	
BANNOCK COUNTY																										
5S 34E 26dabl	582	7-27-72	15	40.5	20	70	25	150	21	478	0	95	0	87	3.2	.02	706	.96	280	0	1,170	7.7	392	52	3.9	2
Lava Hot Springs 9S 38E 21ddalS		8-15-72	-	44.5	32	120	32	170	39	542	0	110	.04	190	.7	.38	962	1.31	430	0	1,580	6.6	445	43	3.6	3
Downata Hot Springs 12S 37E 12cdclS		5-17-72	[a]490	43.0	29	43	15	20	9.1	214	0	18	0	20	.4	.5	262	.36	170	0	413	6.7	176	19	.7	
BEAR LAKE COUNTY																										
Bear Lake Hot Springs 15S 44E 13ccalS		5- 9-72	-	47.5	35	210	55	180	61	256	0	800	.01	79	7.1	.56	1,560	2.12	750	540	2,040	6.6	210	32	2.9	4
BLAINE COUNTY																										
1S 17E 23aabl	260	6-21-72	15	70.5	100	22	1.3	330	19	766	0	60	.04	83	13	.06	1,010	1.37	60	0	1,500	6.4	628	89	19	5
Guyer Hot Springs 4N 17E 15aaclS		7-11-72	[a]1,000	70.5	86	2.9	0	84	2.1	51	25	72	.02	11	16	.06	324	.44	7	0	421	8.0	83	95	14	
Clarendon Hot Springs 3N 17E 27dcblS		7-11-72	100	47.0	80	2.2	.1	81	1.7	29	30	68	.01	11	15	.06	303	.41	6	0	400	8.2	74	96	15	
Hailey Hot Springs 2N 18E 18dbblS		7-11-72	70	[b]59.0	85	2	0	68	1.5	88	0	51	.02	10	12	.07	273	.37	5	0	337	8.7	72	96	13	
Condie Hot Springs 1S 21E 14ddlS		8- 8-72	346	52.0	28	56	11	63	17	360	0	28	.01	14	1.7	.05	396	.54	190	0	653	7.3	295	40	2	
1S 22E 1dalS		8- 8-72	[a]20	44.0	26	60	12	48	8.9	294	0	63	.03	6.5	2.3	.03	371	.5	200	0	591	7.3	241	33	1.5	
BOISE COUNTY																										
Bonneville Hot Springs 10N 10E 31clS		8-18-72	363	85.0	100	2.2	.1	67	2.9	58	21	52	.03	7.2	17	.02	306	.42	6	0	377	8.1	53	94	13	6

Table extracted from: Yours, H. W. and Mitchell, J. C., Geothermal Investigations in Idaho, Idaho Department of Water Administration, Bulletin No. 30, Part 1, 43 pgs., (1973)

TABLE 2 (Cont'd.)

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness		Specific Conductance	pH (field)	Alkalinity as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio	Fio Area No. Fig. 6
																			as $CaCO_3$	Non-carbonate						
BOISE COUNTY (Cont'd.)																										
9N 3E 25bac1S		8- 4-72	20	80.0	120	4.5	0	130	4.8	160	0	79	0.02	34	13	0.04	464	0.63	11	0	600	8.1	131	94	17	7
Kirkham Hot Springs 9N 8E 32cac1S		7-14-72	$_a$250	65.0	69	1.9	.1	66	1.3	46	21	45	.02	3	15	.06	245	.33	5	0	322	7.8	73	95	13	
8N 5E 1bcb1S		6- 8-72	$_a$2	40.0	48	2.4	.1	66	.9	85	1	42	.01	5.1	3.1	.25	216	.29	6	0	317	8.8	71	95	11	
8N 5E 10bdd1S		8-13-72	70	55.0	59	1.9	0	68	1.1	40	30	38	.02	5.6	14	.04	237	.32	5	0	336	8.6	83	96	14	
BONNEVILLE COUNTY																										
1N 43E 9cbb1S		8-10-72	$_a$70	25.0	11	440	96	1,110	120	1,200	0	390	.04	1,900	1.7	.05	4,650	6.32	1,500	510	7,950	6.3	984	59	12	8
BUTTE COUNTY																										
3N 25E 32cdd1	360	8- 9-72	12	41.0	55	74	24	72	21	322	0	170	.02	21	3.2	.12	599	.81	280	19	898	6.3	264	34	1.9	
3N 27E 9abb1	475	8- 9-72	-	$_b$35.0	33	64	24	31	7.7	315	0	56	.02	22	.8	.96	398	.54	260	0	648	7.2	258	20	.8	
CAMAS COUNTY																										
Wardrop Hot Springs 1N 13E 32abb1S		6-20-72	193	66.0	73	1.4	0	54	3	51	37	12	.03	5.1	4.1	.07	215	.29	4	0	252	8.0	103	94	13	5
Worswick Hot Springs 3N 14E 28ca1S		7-10-72	466	81.0	96	1.8	0	69	1.9	51	28	35	.02	5	15	.07	277	.38	5	0	328	7.3	88	96	14	
Elk Creek Hot Springs 1N 15E 14ada1S		6-21-72	$_a$15	53.5	63	2.3	0	87	1.4	82	15	48	.02	25	19	.06	302	.41	5	0	441	8.2	92	96	17	
1S 12E 31cbc1	400	6-20-72	15	31.0	36	.6	0	32	.3	31	26	3.3	.04	2.1	.8	.03	116	.16	2	0	150	9.2	69	97	11	
1S 13E 27ccb1	190	6-20-72	4	35.0	76	3.2	.1	92	1.3	216	0	6.4	.04	12	11	.04	308	.42	8	0	413	7.4	177	95	14	
Barron's Hot Springs 1S 13E 34bcc1S		6-20-72	31	70.0	77	3.6	.1	99	2.5	226	0	13	.04	15	14	.08	337	.46	10	0	471	7.3	185	94	14	
CANYON COUNTY																										
2N 2W 34abc1	318	6- 9-72	$_a$700	51.0	38	3.5	.1	110	.8	279	0	59	.04	11	4.1	.13	384	.52	9	0	589	7.5	229	97	19	
CARIBOU COUNTY																										
6S 41E 19baa1S		5-15-72	$_a$1,300	42.0	24	660	260	94	240	2,500	0	980	.05	40	1.9	.04	3,530	4.8	2,700	670	4,590	6.8	2,050	6	.8	9
Soda Springs 9S 41E 12add1S		8-15-72	-	31.0	29	640	170	12	23	2,290	0	800	.07	4.9	.5	.03	3,120	4.24	3,000	1,110	3,990	6.3	1,880	1	.1	
CASSIA COUNTY																										
15S 26E 23bbc1	414	5-18-72	58	93.0	90	53	.4	560	22	55	0	57	0	900	5.7	.54	1,720	2.34	130	89	3,050	7.4	45	88	21	10
15S 26E 23ddc1	540	5-18-72	60	$_b$90.0	97	130	.4	1110	35	36	0	61	.01	1,900	14	.57	3,360	4.57	330	300	6,090	7.7	30	67	27	10
11S 25E 11cca1	447	7-26-72	2,090	60.0	60	8.2	.5	110	3.9	125	0	59	0	55	14	0	372	.51	25	0	574	7.7	103	90	10	
14S 21E 34bdc1		7-26-72	$_a$50	43.0	47	14	1.1	44	9.6	144	0	15	.01	7	1.3	.01	210	.29	39	0	282	8.0	118	65	3	
Oakley Warm Spring 14S 22E 27dcb1S		10-26-72	$_a$10	47.0	70	2.7	0	87	2.2	43	29	22	.03	53	8	.04	295	.4	7	0	421	9.6	84	95	15	
15S 24E 22ddb1	500	7-25-72	100	38.0	44	37	9.3	70	3.1	169	0	33	.03	80	2.9	.56	365	.5	130	0	606	7.4	139	53	2.7	
CLARK COUNTY																										
Warm Springs 11N 32E 25aac1S		8-28-72	1,920	29.0	17	54	19	9.9	2.9	209	0	62	.02	5.3	1	.12	274	.37	210	42	457	7.0	171	9	.3	

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness		Specific Conductance	pH (Field)	Alkalinity as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio	Area No. Fig. 6
																			as $CaCO_3$	Non-carbonate						
												CLARK COUNTY (Cont'd.)														
Lidy Hot Springs 9N 33E 2bbc1S		8-25-72	$_a$250	$_b$50.0	34	87	16	27	15	179	0	190	0.03	8	6	0.02	471	0.64	260	140	691	6.3	147	16	0.7	
												CUSTER COUNTY														
8N 17E 32bca1S		7-12-72	$_a$25	51.0	43	21	5.5	100	13	234	0	94	.02	26	8.4	.06	425	.58	72	0	651	6.7	192	71	5.1	11
14N 19E 34daa1	3,000	7-12-72	50	40.0	23	55	21	45	7.6	226	0	130	.01	4	1.1	.1	398	.54	220	38	625	7.3	185	30	1.3	
Sunbeam Hot Springs 11N 15E 19c1S		7-12-72	444	76.0	91	1.5	0	85	2.4	119	0	54	.02	12	15	.06	320	.44	4	0	413	8.5	98	96	19	
Sullivan Hot Springs 11N 17E 27bdd1S		7-12-72	70	41.0	38	49	11	170	15	554	0	26	.02	57	1.8	.06	640	.87	170	0	1,070	7.0	454	66	5.7	
Barney Hot Springs 11N 25E 23cab1S		7-13-72	170	b28.5	18	37	20	9	1.5	181	0	35	.03	4	.5	.25	215	.29	170	26	364	7.8	148	10	.3	
Stanley Hot Springs 10N 13E 3cab1S		7-12-72	110	41.0	55	2.2	.1	60	.5	30	28	31	.01	5	14	.05	211	.29	6	0	293	8.8	71	95	11	
Slate Creek Hot Springs 10N 16E 30a1S		7-11-72	185	50.0	86	8.1	.1	83	4.5	110	0	110	.02	7	8.7	.03	362	.49	21	0	437	8.0	90	87	[illegible]	
												ELMORE COUNTY														
5S 8E 34bdc1	1,320	7- 5-72	2	34.0	58	9.1	1	320	11	797	0	6.5	.04	59	2.2	.04	859	1.17	27	0	1,340	7.7	654	94	27	12
Neinmeyer Hot Springs 5N 7E 24b1S		8-17-72	349	76.0	100	1.1	.1	67	1.8	5	51	31	.03	2.9	10	.02	267	.36	3	0	293	8.5	59	96	16	
Dutch Frank's Spring 5N 9E 7b1S		8-17-72	$_a$300	65.0	72	2.2	.2	57	1.2	17	40	30	.03	2.4	10	.02	223	.3	6	0	268	8.6	81	94	9.9	
Paradise Hot Springs 3N 10E 33bd1S		8-29-72	-	56.0	69	1.5	.1	50	1	45	35	17	.03	2.6	3.1	.04	200	.27	4	0	232	9.2	94	96	11	
3S 8E 36cda1	600	8-14-72	$_a$700	68.0	86	1.5	0	87	.8	74	50	14	.04	4.5	17	.06	297	.4	4	0	362	8.5	144	98	20	
Latty Hot Springs 3S 10E 31ddb1S		7- 5-72	-	$_b$55.0	100	.4	0	54	1.7	90	33	10	.04	2.7	7	.07	248	.34	1	0	243	8.4	117	98	29	
4S 8E 36bba1	1,900	6- 6-72	8	38.0	86	3.2	.2	160	3.7	447	0	5.4	.05	10	3	.06	491	.67	10	0	703	7.8	364	96	22	
4S 9E 8ab1	1,003	8-29-72	-	62.0	85	.9	0	82	.8	81	41	14	.03	3.2	16	.05	283	.38	2	0	387	9.2	135	98	24	
5S 10E 7acd1	1,300	6-19-72	-	32.0	42	2.5	0	79	.9	115	16	12	.03	6.1	20	.03	235	.32	6	0	367	8.5	121	96	14	
5S 10E 32bdb1	935	6-22-72	54	37.5	46	2.5	.2	130	.9	270	8	2.5	.03	29	13	.06	363	.5	6	0	590	7.9	235	97	22	
												FRANKLIN COUNTY														
Maple Grove Hot Springs 13S 41E 7aca1S		5-10-72	350	76.0	55	89	24	490	110	491	0	260	.04	630	1.1	.07	1,900	2.58	320	0	3,160	7.3	403	70	12	13
14S 39E 36ada1	40	5-11-72	-	44.5	80	25	7.1	360	24	524	0	15	.05	320	10	1.5	1,110	1.51	92	0	1,890	7.3	430	87	16	13
Wayland Hot Springs 15S 39E 8bdc1S		5- 9-72	$_a$900	77.0	80	160	16	3,100	660	699	0	50	.06	5,400	12	.81	9,830	13.4	470	0	16,400	7.0	573	84	63	13

TABLE 2 (Cont'd.)

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness as $CaCO_3$	Hardness Non-carbonate	Specific Conductance	pH (Field)	Alkalinity as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio	Area No. Fig. 6
FRANKLIN COUNTY (Cont'd.)																										
15S 39E 17bcd1	22	5-10-72	25	82.0	130	250	23	4,300	680	733	0	54	0.08	7,700	7	1.6	13,700	18.6	720	120	22,200	7.8	601	84	70	13
FREMONT COUNTY																										
Ashton Warm Springs 9N 42E 23dab1S		8-28-72	[a]2	41.0	110	1.1	.1	36	1.6	92	0	4.7	.05	2.9	2.2	.24	205	.28	3	0	166	7.6	75	94	8.8	14
Big Springs 14N 44E 34bbb1S		8-28-72	92,000	12.0	47	5.6	.6	14	3	46	0	3.2	.03	2.5	3.1	.05	102	.14	16	0	102	6.4	38	60	1.5	
Lily Pad Lake 10N 45E 35abc1S		8-30-72	-	[b]17.5	.1	2.6	.4	.5	1	11	0	2.2	.03	1.1	.1	.44	14	.02	8	0	19	7.2	9	10	.1	
7N 41E 35cdd1	350	8- 9-72	-	36.0	75	28	6.3	78	8.6	240	0	33	.02	24	5.4	.79	380	.52	96	0	538	7.9	197	61	3.5	
GEM COUNTY																										
Roystone Hot Springs 7N 1E 8dda1S		11-24-72	[a]20	[b]55.0	120	8.7	.6	160	7.7	187	0	110	.04	62	16	0	577	.78	24	0	799	7.5	153	91	14	15
7N 1E 9cdc1S		8- 4-72	-	45.0	94	15	2.4	99	5.3	169	0	57	.02	30	8	.67	397	.54	47	0	529	7.6	139	80	6.3	
GOODING COUNTY																										
4S 13E 26ab1	160	6-21-72	-	[b]47.0	92	9.8	1.2	100	5.9	278	0	19	.05	8.2	12	.49	373	.51	30	0	497	7.0	207	85	7.9	
White Arrow Hot Springs 4S 13E 30adb1S		5-26-72	826	65.0	97	1.2	0	91	1.6	141	22	15	.03	6.6	12	.11	316	.43	3	0	407	7.5	152	98	23	
5S 12E 3aaa1	692	6-19-72	-	43.0	62	1.6	.1	90	.8	83	42	19	.03	8.4	19	.17	284	.39	4	0	413	8.6	138	97	19	
IDAHO COUNTY																										
Weir Creek Hot Springs 36N 11E 13b1S		8-23-72	[a]40	47.5	49	3.3	0	29	.5	21	22	15	.03	2.1	2.2	.03	134	.18	8	0	145	8.5	54	85	4.4	
Jerry Johnson Hot Springs 36N 13E 15a1S		8-23-72	[a]300	48.0	49	2.7	.2	37	.4	24	25	25	.04	1.9	1.6	.03	155	.21	8	0	186	8.7	61	91	5.9	
Red River Hot Springs 28N 10E 3d1S		8-21-72	35	55.0	76	2.7	0	81	1.6	36	36	44	.01	4.4	23	.04	266	.39	6	0	380	8.6	89	95	14	
Riggins Hot Springs 24N 2E 14dac1S		8- 1-72	[a]50	42.0	72	6.2	.1	160	3.4	11	25	300	.02	8	2.1	.02	582	.79	16	0	612	8.6	51	95	17	
Burgdorf Hot Springs 22N 4E 15dc1S		8- 1-72	162	45.0	73	2.3	0	49	.8	19	41	18	.02	3	2	.03	199	.27	6	0	218	8.1	84	94	8.9	
JEFFERSON COUNTY																										
Heise Hot Springs 4N 40E 25dcb1S		7-27-72	[a]60	[b]49.0	30	450	82	1,500	190	1,100	0	740	.04	2,400	3.1	.1	5,940	8.08	1,500	560	8,940	6.7	902	66	17	8
LEMHI COUNTY																										
Big Creek Hot Springs 23N 18E 22c1S		7-13-72	[a]75	93.0	150	5.3	.2	220	14	488	0	53	.05	29	15	.07	727	.99	14	0	1,010	7.5	400	94	26	16
Salmon Hot Springs 20N 22E 3abd1S		8-24-72	145	45.0	33	23	11	190	28	565	0	34	.04	50	1.8	.03	649	.88	100	0	1,060	6.3	463	75	8.2	17

TABLE 2 (Cont'd.)

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness		Specific Conductance	pH (field)	Alkalinity as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio	Area No. Fig. 6
																			as $CaCO_3$	Non-carbonate						
LEMHI COUNTY (Cont'd.)																										
Sharkey Hot Springs 20N 24E 34ccc1S		8-24-72	8	[b]52.0	91	7.3	0.6	270	17	470	0	160	0.02	51	12	0.08	840	1.14	21	0	1,270	7.4	386	93	26	17
16N 21E 18adc1S		8-24-72	[a]20	46.0	37	11	1.4	160	11	339	0	66	.04	26	7	.06	486	.66	33	0	757	7.4	278	88	12	18
MADISON COUNTY																										
Green Canyon Hot Springs 5N 43E 6bca1S		8- 9-72	-	[b]44.0	25	140	32	3.9	3.6	167	0	330	.01	1.7	1.6	.13	621	.84	480	340	846	6.8	137	2	.1	
ONEIDA COUNTY																										
14S 36E 27cda1S		5-16-72	44	25.0	19	240	79	1,200	210	958	0	25	0	2,100	.4	.95	4,350	5.92	920	140	7,590	6.5	786	69	17	19
Pleasantview Warm Springs 15S 35E 3aab1S		5-16-72	3,810	25.0	21	110	33	280	29	331	0	110	0	470	.7	1.5	1,220	1.66	410	140	2,190	6.8	271	58	6	19
Woodruff Hot Springs 16S 36E 10bbc1S		5-11-72	-	27.0	29	130	45	910	87	454	0	58	.03	1,600	.6	1.4	3,090	4.2	510	140	5,370	7.3	372	76	18	19
12S 34E 36bcb1S		5-17-72	189	24.0	33	56	19	15	4.3	226	0	18	0	35	.3	.73	295	.40	220	33	479	6.7	165	13	.4	
OWYHEE COUNTY																										
4S 2E 32bcc1	2,704	6- 6-72	30	42.0	94	4.1	.7	150	8.8	390	0	7.1	.08	15	7.7	.05	479	.65	13	0	659	8.2	320	93	15	20
5S 3E 26bcb1	3,000	6-12-72	[a]280	84.5	110	1.6	0	90	1.5	74	38	74	.02	14	30	.06	416	.57	4	0	522	7.6	124	98	24	20
6S 3E 2ccc1	1,940	6-12-72	489	55.0	92	1.3	0	90	3.9	149	29	25	.02	17	17	.05	369	.05	3	0	506	8.1	171	97	28	20
6S 5E 10ddd1	1,667	6-14-72	4	38.5	70	2.5	.1	120	4.5	165	21	24	.04	15	28	.12	366	.50	6	0	549	8.6	170	96	22	20
6S 5E 29dcc1	1,560	6-14-72	3	34.0	100	6.8	0	92	7	140	0	56	.07	15	15	.03	361	.49	17	0	459	8.0	115	89	9.7	20
6S 6E 12ccd1	990	6-15-72	-	37.0	100	10	.5	170	14	460	0	3.6	.06	18	5.6	.06	548	.75	27	0	833	7.3	377	89	14	20
7S 5E 7abb1	1,625	6-14-72	-	39.0	81	6.3	.1	50	7.2	96	1	18	.04	8.3	9.7	.33	230	.31	16	0	278	8.1	80	81	5.4	20
Indian Bathtub Hot Springs 8S 6E 3bdd1S		7- 3-72	458	39.0	76	5.9	.4	54	7.3	124	2	15	.04	8	8.8	.79	242	.33	16	0	287	8.2	105	82	5.8	20
Murphy Hot Springs 16S 9E 24bb1S		5-23-72	[a]70	51.0	83	.6	0	30	2.0	67	1	4.7	.1	2.3	3.6	.64	163	.22	2	0	137	7.1	57	94	11	21
1N 4W 12dbb1	640	6-13-72	410	35.5	40	2.2	0	110	.3	214	0	8.6	.01	28	7.9	.04	302	.41	5	0	483	7.2	176	98	20	
1S 2W 7ccb1	1,700	6- 5-72	169	45.5	32	1.9	0	120	1.2	187	12	45	.01	19	11	.04	334	.45	5	0	545	8.7	173	95	24	
4S 1E 34bad1	2,960	6- 6-72	-	75.0	83	1.1	.2	98	.7	105	33	40	.03	12	12	.05	333	.45	4	0	454	7.9	144	98	23	
5S 1E 24ad1	3,120	7-24-72	1,060	66.0	82	1.2	.1	100	.8	105	31	45	.25	13	14	.04	339	.46	3	0	459	7.9	138	98	24	
5S 2E 1bbc1	1,800	6- 7-72	30	49.5	68	1.5	0	87	.6	60	54	20	.02	11	5.8	.04	277	.38	4	0	394	8.2	139	98	20	
7S 6E 9bad1	910	6-15-72	153	50.0	93	1.6	0	99	2.8	72	40	27	.06	9.7	22	.05	331	.45	4	0	446	8.2	126	97	22	
Indian Hot Springs 12S 7E 33c1S		6- 2-72	1,730	69.0	75	1.5	0	75	.6	67	30	24	.04	8.4	14	.06	262	.36	4	0	360	8.0	105	97	17	
POWER COUNTY																										
Indian Springs 8S 31E 18dab1S		7-27-72	1,540	32.0	20	76	19	110	10	254	0	19	.02	220	.7	.13	600	.62	270	60	1,100	7.5	208	46	2.9	
10S 30E 13cdc1S		7-27-72	418	38.0	22	92	33	62	14	160	0	23	.02	250	.6	.02	576	.78	370	230	1,110	7.6	131	26	1.4	
TWIN FALLS COUNTY																										
Miracle Hot Springs 8S 14E 31acb1S		5-24-72	[a]350	54.0	93	2.2	0	120	1.5	63	54	29	.03	35	20	.50	386	.53	5	0	560	9.0	142	97	22	

TABLE 2 (Cont'd.)

Spring or Well Identification Number	Reported Well Depth Below Land Surface (feet)	Sample Collection Date	Discharge (gpm)	Temperature (°C)	Silica (Si)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Phosphate (P)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved Solids (Calculated)	Dissolved Solids (tons per ac-ft)	Hardness		Specific Conductance	pH (field)	Alkalinity as $CaCO_3$	Percent Sodium	Sodium Absorption Ratio	Area No. Fig. 6
																			as $CaCO_3$	Non-carbonate						
TWIN FALLS COUNTY (Cont'd.)																										
8S 14E 33cba1	210	5-24-72	60	59.0	97	1.1	0	100	1.5	88	38	26	0.03	27	15	0.54	351	0.48	3	0	479	8.5	135	98	26	
11S 19E 33ddd1	620	5-25-72	1,930	33.0	63	27	3.9	17	8.6	118	0	12	.04	15	.3	1	209	.28	83	0	266	6.6	97	28	.8	
Nat-Poo-Paw Warm Springs 12S 17E 31bab1S		7-25-72	30	36.0	19	34	14	43	11	266	0	18	.01	8	1.9	.02	280	.38	140	0	469	7.6	218	37	1.6	
12S 18E 1bba1	775	7-25-72	543	38.0	67	18	2	16	6	95	0	9.3	.26	8	.6	.63	176	.24	53	0	198	7.6	78	36	1	
Magic Hot Springs 16S 17E 31ac1S		5-23-72	385	45.5	23	30	8.9	13	4.5	162	0	15	.03	3.8	.3	.42	180	.24	110	0	281	6.4	133	19	.5	
VALLEY COUNTY																										
Vulcan Hot Springs 14N 6E 11bda1S		8- 2-72	[a]500	87.0	120	1.8	.1	94	3	120	0	43	.02	17	24	.05	362	.49	5	0	451	8.5	98	96	18	22
Hot Creek Springs 15N 3E 13bbc1S		8- 2-72	798	[b]34.0	60	1.3	.1	60	.6	17	45	16	.02	16	7.6	0	210	.29	4	0	279	9.8	89	97	14	
Molly's Hot Springs 15N 6E 14acc1S		8- 2-72	[a]20	59.0	87	2	0	70	1.5	48	30	17	.02	10	17	.03	258	.35	5	0	326	7.7	89	96	14	
14N 3E 36abd1	50	8- 3-72	-	42.5	45	1.6	0	58	.4	62	22	17	.04	15	3.8	.09	194	.26	4	0	275	9.2	87	97	13	
Cabarton Hot Springs 13N 4E 31cab1S		8- 3-72	[a]70	70.5	78	1.7	0	100	1.9	70	26	46	.02	49	11	.05	348	.47	4	0	511	7.7	101	97	21	
Boiling Springs 12N 5E 22bbc1S		8- 3-72	165	85.0	94	1.9	.1	71	1.7	81	24	12	.02	12	13	.04	270	.37	5	0	331	8.8	106	95	14	
WASHINGTON COUNTY																										
14N 3W 3ddc1	925	6-28-72	-	25.5	70	2.6	.2	73	6.8	157	16	15	.04	3.8	1	.04	266	.36	7	0	309	8.7	155	91	12	1
13N 3W 8ccc1	963	6-28-72	-	28.0	84	8.7	.8	73	23	225	0	14	.04	3.1	.7	.04	318	.43	25	0	338	8.3	185	74	6.4	1
11N 6W 10cca1	400	6-28-72	1/3	70.0	170	2.7	0	160	5.1	92	19	150	.03	55	4.6	.07	612	.83	7	0	698	8.2	107	96	27	23
11N 3W 7bdb1S		6-30-72	10	87.0	170	27	.7	300	19	198	0	270	.31	190	2.9	.06	1,080	1.47	70	0	1,480	6.8	162	87	16	23
14N 3W 19cbd1S		6-27-72	58	50.0	55	8	.8	80	1.9	81	1	110	.05	15	.8	.30	314	.43	23	0	406	8.5	68	87	7.2	
14N 2W 6bba1S		6-28-72	431	70.0	72	17	.1	200	3.8	24	20	200	.09	140	1.9	.06	667	.91	43	0	1,000	7.8	53	90	13	
13N 4W 13bac1	1,350	6-28-72	-	28.0	73	3.5	.2	86	.7	188	20	14	.03	3.2	.7	.04	294	.4	10	0	375	8.5	188	95	12	

[a] Discharge estimated.

[b] Measured temperature is probably lower than at point of discharge.

TABLE 3

ESTIMATED AQUIFER TEMPERATURES AND ATOMIC RATIOS OF SELECTED CHEMICAL CONSTITUENTS

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers °C (rounded to 5°C)		Atomic Ratios							Area Number Fig. 6
			[a]Silica	[b]Sodium-Potassium-Calcium	Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO_3)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate ($Cl/HCO_3 + CO_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{Calcium}$ / Sodium $\sqrt{(Ca/Na)}$	
ADA COUNTY												
5N 1E 35aca1	22	40.0	85	85	26.0	0.058	-	19.9	0.075	0.239	0.154	
4N 2E 29acd1	-	47.0	95	80	39	.047	0.11	21.3	.051	.236	.14	
3N 2E 12cdd1	-	75.0	125	80	98.1	.022	-	65.4	.11	.208	.068	
ADAMS COUNTY												
White Licks Hot Springs 16N 2E 33bcc1S	30	65.0	145	145	42	.836	.013	18.8	3.64	9.13	.054	1
Zim's Resort Hot Springs 20N 1E 26ddb1S	-	65.0	115	85	89.8	.389	.014	27.6	.981	7.46	.066	
Krigbaum Hot Springs 19N 2E 22cca1S	40	43.0	120	95	72.1	.1	.062	46	.496	4.98	.06	
Starkey Hot Springs 18N 1W 34dbb1S	130	56.0	110	70	91.4	.114	-	33.3	.364	8.34	.09	
BANNOCK COUNTY												
5S 34E 26dab1	15	40.5	65	185	12.1	.223	.589	3.74	.313	14.6	.203	2
Lava Hot Springs 9S 38E 21dda1S	-	44.5	80	210	7.41	.337	.439	2.47	.603	145	.234	3
Downata Hot Springs 12S 37E 12cdc1S	[c]490	43.0	80	60	3.74	.306	.575	.811	.161	26.8	1.19	
BEAR LAKE COUNTY												
Bear Lake Hot Springs 15S 44E 13cca1S		47.5	85	230	5.02	1.25	.432	1.49	.531	5.96	.292	4
BLAINE COUNTY												
1S 17E 23aab1	15	70.5	135	160	29.5	.044	.097	26.1	.186	3.42	.052	5
Guyer Hot Springs 4N 17E 15aac1S	[c]1,000	70.5	130	90	68	.087	-	50.5	.248	.368	.074	
Clarendon Hot Springs 3N 17E 27dcb1S	100	47.0	125	85	81	.115	.075	64.2	.318	.393	.066	
Hailey Hot Springs 2N 18E 18dbb1S	70	[d]59.0	130	85	77.1	.035	-	59.3	.196	.447	.076	
Condie Hot Springs 1S 21E 14dd1S	346	52.0	80	90	6.3	.237	.324	1.96	.067	4.41	.431	
1S 22E 1da1S	[c]20	44.0	75	65	9.17	.311	.33	1.39	.038	1.51	.586	

TABLE 3 (Cont'd.)

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers °C (rounded to 5°C)		Atomic Ratios							Area Number Fig. 6
			[a]Silica	[b]Sodium-Potassium-Calcium	Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO$_3$)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate (Cl/HCO$_3$ + CO$_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{\text{Calcium}}$ / Sodium $\sqrt{(\text{Ca}/\text{Na})}$	
					BOISE COUNTY							
Bonneville Hot Springs 10N 10E 31c1S	363	85.0	135	140	39.3	0.058	0.075	53.1	0.156	0.227	0.08	6
9N 3E 25bac1S	20	80.0	150	140	46.1	.043	-	50.4	.366	1.4	.059	7
Kirkham Hot Springs 9N 8E 32cac1S	[c]250	65.0	115	80	86.3	.063	.087	60.6	.077	.107	.076	
8N 5E 1bcb1S	[c]2	40.0	100	65	125	.043	.069	47.9	.102	.882	.085	
8N 5E 10bdd1S	70	55.0	110	75	105	.072	-	62.4	.137	.214	.074	
					BONNEVILLE COUNTY							
1N 43E 9cbb1S	[c]70	25.0	35	190	15.6	.558	.36	4.36	2.72	599	.069	8
					BUTTE COUNTY							
3N 25E 32cdd1	12	41.0	105	90	5.83	.35	.534	1.7	.112	3.52	.434	
3N 27E 9abb1	-	[d]35.0	85	55	6.85	.309	.618	.844	.12	14.7	.937	
					CAMAS COUNTY							
Wardrop Hot Springs 1N 13E 32abb1S	193	66.0	120	155	30.6	.042	-	67.2	.099	.667	.06	5
Worswick Hot Springs 3N 14E 28ca1S	466	81.0	135	95	61.8	.054	-	66.8	.108	.179	.071	
Elk Creek Hot Springs 1N 15E 14ada1S	[c]15	53.5	115	80	106	.043	-	65.9	.442	.705	.063	
1S 12E 31cbc1	15	31.0	85	50	181	.029	-	93	.063	1.41	.068	
1S 13E 27ccb1	4	35.0	120	70	120	.023	.052	50.1	.096	.585	.071	
Barron's Hot Springs 1S 13E 34bcc1S	31	70.0	125	90	67.3	.024	.046	47.9	.114	.574	.07	
					CANYON COUNTY							
2N 2W 34abc1	[c]700	51.0	85	55	234	.019	.047	54.8	.068	1.44	.062	
					CARIBOU COUNTY							
6S 41E 19baa1S	[c]1,300	42.0	70	370	.666	.402	.649	.248	.028	11.3	.993	9
Soda Springs 9S 41E 12add1S	-	31.0	80	35	.887	.425	.438	.033	.004	5.25	7.66	
					CASSIA COUNTY							
15S 26E 23bbc1	58	93.0	135	145	43.3	1.47	.012	18.4	28.2	84.6	.047	10
15S 26E 23ddc1	60	[d]90.0	135	140	53.4	5.5	.005	14.8	96.8	72.7	.038	10
11S 23E 11cca1	2,090	60.0	110	90	48	.10	.1	23.4	.757	2.11	.095	
14S 21E 34bdc1	[c]50	43.0	95	95	7.79	.146	.129	5.48	.084	2.89	.309	
Oakley Warm Spring 14S 22E 27dcb1S	[c]10	47.0	115	90	67.3	.096		56.2	1.26	3.55	.069	

TABLE 3 (Cont'd.)

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers °C (rounded to 5°C)		Atomic Ratios							Area Number Fig. 6
			$_{a}$Silica	$_{b}$Sodium-Potassium-Calcium	Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO$_3$)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate (Cl/HCO$_3$ + CO$_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{\text{Calcium}}$ / Sodium $\sqrt{(Ca/Na)}$	
					CASSIA COUNTY (Cont'd.)							
15S 24E 22ddb1	100	38.0	95	45	38.4	0.333	0.414	3.3	0.815	14.8	0.316	
					CLARK COUNTY							
Warm Springs 11N 32E 25aac1S	1,920	29.0	60	25	5.81	.393	.58	.32	.044	2.84	2.7	
Lidy Hot Springs 9N 33E 2bbc1S	$_{c}$250	$_{d}$50.0	85	65	3.06	.74	.303	.541	.077	.714	1.25	
					CUSTER COUNTY							
8N 17E 32bca1S 14N 19E 34daa1	$_{c}$25 50	51.0 40.0	90 70	185 60	13.1 10.1	.137 .371	.432 .629	8.3 1.43	.191 .03	1.66 1.95	.166 .598	11
Sunbeam Hot Springs 11N 15E 19c1S	444	76.0	135	130	60.2	.019	-	98.8	.174	.429	.052	
Sullivan Hot Springs 11N 17E 27bdd1S	70	41.0	85	100	19.3	.135	.37	6.05	.177	17	.15	
Barney Hot Springs 11N 25E 23cab1S	170	$_{d}$28.5	60	15	10.2	.311	.891	.424	.038	4.29	2.45	
Stanley Hot Springs 10N 13E 3cab1S	110	41.0	105	45	204	.112	.075	47.5	.147	.191	.09	
Slate Creek Hot Springs 10N 16E 30a1S	185	50.0	130	90	31.4	.112	.02	17.9	.11	.431	.125	
					ELMORE COUNTY							
5S 8E 34bdc1	2	34.0	110	145	49.5	.017	.181	61.3	.127	14.4	.034	12
Neinmeyer Hot Springs 5N 7E 24b1S	349	76.0	135	125	63.3	.335	.15	106	.068	.155	.057	
Dutch Frank's Spring 5N 9E 7b1S	$_{c}$300	65.0	120	70	80.8	.197	.15	45.2	.072	.129	.094	
Paradise Hot Springs 3N 10E 33bd1S	-	56.0	115	75	85	.051	.11	58.1	.056	.449	.089	
3S 8E 36cda1	$_{c}$700	68.0	130	70	185	.031	-	101	.062	.142	.051	
Latty Hot Springs 3S 10E 31ddb1S	-	$_{d}$55.0	135	135	54	.007	-	235	.038	.207	.043	
4S 8E 36bba1 4S 9E 8ab1 5S 10E 7acd1 5S 10E 32bdb1	8 - - 54	38.0 62.0 32.0 37.5	130 130 90 95	125 80 65 70	73.5 174 149 246	.011 .017 .033 .014	.103 - - .132	87.2 159 55.1 90.7	.038 .045 .08 .179	1.79 .107 .163 1.2	.041 .042 .073 .044	
					FRANKLIN COUNTY							
Maple Grove Hot Springs 13S 41E 7aca1S	350	76.0	105	235	7.58	.276	.444	9.6	2.21	307	.07	13
14S 39E 36ada1	-	44.5	125	170	25.5	.073	.468	25.1	1.05	17.1	.05	13

TABLE 3 (Cont'd.)

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers °C (rounded to 5°C)		Atomic Ratios							Area Number Fig. 6
			[a]Silica	[b]Sodium-Potassium-Calcium	Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO$_3$)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate (Cl/HCO$_3$ + CO$_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{\text{Calcium}}$ / Sodium $\sqrt{(Ca/Na)}$	
					FRANKLIN COUNTY (Cont'd.)							
Wayland Hot Springs 15S 39E 8bdc1S	[c]900	77.0	125	270	7.99	0.348	0.165	33.8	13.3	241	0.015	13
15S 39E 17bcd1	25	82.0	155	270	8.31	.519	.152	30.	18.1	589	.013	13
					FREMONT COUNTY							
Ashton Warm Springs 9N 42E 23dab1S	[c]2	41.0	145	90	38.3	.018	.15	57.1	.054	.706	.106	14
Big Springs 14N 44E 34bbb1S	92,000	12.0	95	65	7.94	.185	.177	4.36	.094	.432	.614	
Lily Pad Lake 10N 45E 35abc1S	-	[d]17.0	<35	20	.85	.36	.254	.335	.172	5.89	11.7	
7N 41E 35cdd1	-	36.0	120	85	15.4	.178	.371	4.86	.172	2.38	.246	
					GEM COUNTY							
Roystone Hot Springs 7N 1E 6dda1S	[c]20	[d]55.0	150	150	35.5	.071	.114	32.1	.571	2.08	.067	15
7N 1E 9cdc1S	-	45.0	135	85	31.8	.135	.264	11.5	.305	2.01	.142	
					GOODING COUNTY							
4S 13E 28ab1	-	[d]47.0	135	100	28.8	.054	.202	17.8	.051	.366	.114	
White Arrow Hot Springs 4S 13E 30adb1S	826	65.0	135	115	96.7	.013	-	132	.07	.295	.044	
5S 12E 3aaa1	-	43.0	115	70	191	.029	.103	98.1	.115	.237	.051	
					IDAHO COUNTY							
Weir Creek Hot Springs 36N 11E 13b1S	[c]40	47.5	100	35	98.6	.239	-	15.3	.083	.512	.227	
Jerry Johnson Hot Springs 36N 13E 18a1S	[c]300	48.0	100	35	157	.171	.122	23.9	.066	.636	.161	
Red River Hot Springs 28N 10E 3d1S	35	55.0	120	80	86.1	.114	-	52.3	.104	.103	.074	
Riggins Hot Springs 24N 2E 14dac1S	[c]30	42.0	120	95	80	.858	.027	45	.378	2.04	.057	
Burgdorf Hot Springs 22N 4E 1bdc1S	162	45.0	120	55	104	.184	-	37.1	.095	.804	.112	
					JEFFERSON COUNTY							
Heise Hot Springs 4N 40E 25dcb1S	[c][illegible]	[d]49.0	80	205	13.4	.623	.3	5.81	3.75	415	.051	8

TABLE 3 (Cont'd.)

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (^{o}C)	Aquifer Temperatures from Geochemical Thermometers ^{o}C (rounded to 5^{o}C) [a]Silica	[b]Sodium-Potassium-Calcium	Atomic Ratios: Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO_3)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate ($Cl/HCO_3 + CO_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{\text{Calcium}}$ / Sodium ($\sqrt{Ca}/Na$)	Area Number Fig. 6
LEMHI COUNTY												
Big Creek Hot Springs 23N 15E 22c1S	[c]75	93.0	160	175	26.7	0.017	0.062	72.4	0.102	1.04	0.038	16
Salmon Hot Springs 20N 22E 3abd1S	145	45.0	80	205	11.5	.062	.788	14.4	.152	14.9	.092	17
Sharkey Hot Springs 20N 24E 34ccc1S	8	[d]52.0	135	175	27	.024	.135	64.5	.187	2.28	.036	17
16N 21E 18adc1S	[c]20	46.0	85	165	24.7	.049	.21	25.3	.132	1.99	.075	18
MADISON COUNTY												
Green Canyon Hot Springs 5N 43E 6bca1S	-	[d]44.0	70	5	1.84	1.28	.377	.049	.018	.569	11	
ONEIDA COUNTY												
14S 36E 27cda1S	44	25.0	65	230	9.72	.381	.542	8.72	.377	2,810	.047	19
Pleasantview Warm Springs 15S 35E 3aab1S	3,810	25.0	65	175	16.4	.506	.494	4.44	2.44	360	.136	19
Woodruff Hot Springs 16S 36E 10bbc1S	-	27.0	80	190	17.8	.436	.57	12.2	6.06	1,430	.046	19
12S 34E 36bcb1S	189	24.0	85	35	5.93	.377	.559	.467	.267	62.5	1.81	
OWYHEE COUNTY												
4S 2E 32bcc1	30	42.0	135	165	29	.016	.281	63.8	.066	1.04	.049	20
5S 3E 26bcb1	[c]280	84.5	145	90	102	.037	-	87.2	.214	.25	.054	20
6S 3E 2ccc1	489	55.0	135	150	39.2	.013	-	121	.164	.536	.046	20
6S 5E 10ddd1	4	38.5	115	145	45.4	.023	.066	85.7	.139	.287	.048	20
6S 5E 29dcc1	3	34.0	135	165	22.4	.074	-	23.6	.184	.536	.103	20
6S 6E 12ccd1	-	37.0	135	175	20.6	.033	.082	29.6	.067	1.72	.068	20
7S 5E 7abb1	-	39.0	125	190	11.8	.1	.026	13.8	.147	.459	.182	20
Indian Bathtub Hot Springs 8S 6E 3bdd1S	458	39.0	120	185	12.6	.072	.112	16	.109	.487	.163	20
Murphy Hot Springs 16S 9E 24bb1S	[c]70	51.0	125	160	25.5	.014	-	87.2	.058	.342	.094	21
1N 4W 12dbb1	410	35.5	85	40	624	.016	-	87.2	.225	1.9	.049	
1S 2W 7ccb1	169	45.5	80	85	170	.015	-	110	.164	.926	.042	
4S 1E 34bad1	-	75.0	125	75	238	.016	.3	155	.146	.536	.039	
5S 1E 24ad1	1,060	66.0	125	80	213	.017	.137	145	.164	.498	.04	
5S 2E 1bbc1	30	49.5	115	65	247	.038	-	101	.165	1.02	.051	
7S 6E 9bad1	153	50.0	135	130	60.1	.034	-	106	.148	.236	.046	
Indian Hot Springs 12S 7E 33c1S	1730	69.0	120	60	213	.034	-	87.2	.148	.322	.059	

TABLE 3 (Cont'd.)

Spring or Well Identification Number	Discharge (gpm)	Water Temperature at Surface (°C)	Aquifer Temperatures from Geochemical Thermometers °C (rounded to 5°C)		Atomic Ratios							Area Number Fig. 6
			[a]Silica	[b]Sodium-Potassium-Calcium	Sodium / Potassium (Na/K)	Calcium / Bicarbonate (Ca/HCO$_3$)	Magnesium / Calcium (Mg/Ca)	Sodium / Calcium (Na/Ca)	Chloride / Bicarbonate plus Carbonate (Cl/HCO$_3$ + CO$_3$)	Chloride / Fluoride (Cl/F)	$\sqrt{\text{Calcium}}$ / Sodium $\sqrt{(Ca/Na)}$	
POWER COUNTY												
Indian Springs 8S 31E 18dab1S	1,540	32.0	65	70	18.7	0.456	0.412	2.52	1.49	168.0	0.288	
10S 30E 13cdc1S	418	38.0	70	70	7.53	.875	.591	1.17	2.69	167	.562	
TWIN FALLS COUNTY												
Miracle Hot Springs 8S 14E 31acb1S	[c]350	54.0	135	85	136	.053	-	95.1	.511	.938	.045	
8S 14E 33cba1	60	59.0	135	110	113	.019	-	158	.367	.965	.038	
11S 19E 33ddd1	1,930	33.0	115	70	3.36	.348	.238	1.1	.219	26.8	1.11	
Nat-Poo-Paw Warm Springs 12S 17E 31bab1S	30	36.0	65	80	6.65	.195	.679	2.2	.052	2.26	.492	
12S 13E 1bba1	543	38.0	115	65	4.54	.288	.183	1.55	.145	7.14	.963	
Magic Hot Springs 16S 17E 31ac1S	385	45.5	70	45	4.91	.282	.489	.755	.04	6.79	1.53	
VALLEY COUNTY												
Vulcan Hot Springs 14N 6E 11bda1S	[c]500	87.0	150	135	53.3	.023	.092	91	.244	.38	.052	22
Hot Creek Springs 15N 5E 13bbc1S	798	[d]34.0	110	60	170	.116	.127	80.5	.439	3.3	.069	
Molly's Hot Springs 15N 6E 14acc1S	[c]20	59.0	130	85	79.4	.063	-	61	.219	.315	.073	
14N 3E 36abd1	-	42.5	95	45	247	.039	-	63.2	.306	2.12	.079	
Cabarton Hot Springs 13N 4E 31cab1S	[c]70	70.5	125	100	89.5	.037	-	103.0	.874	2.39	.047	
Boiling Springs 12N 5E 22bbc1S	165	85.0	135	90	71	.036	.087	65.1	.196	.495	.07	
WASHINGTON COUNTY												
14N 3W 5ddc1	-	25.5	115	180	18.3	.025	.127	48.9	.038	2.04	.08	1
13N 3W 8ccc1	-	28.0	130	240	5.4	.059	.152	14.6	.024	2.37	.147	1
11N 6W 10cca1	1/3	70.0	170	140	53.4	.045	-	103	.85	6.41	.037	23
11N 3W 7bdb1S	10	87.0	170	165	26.9	.208	.043	19.4	1.65	35.1	.063	23
14N 3W 19cbd1S	58	50.0	105	65	71.6	.15	.165	17.4	.315	10	.128	
14N 2W 6bba1S	431	70.0	120	80	89.5	1.08	.01	20.5	5.43	39.5	.075	
13N 4W 13bac1	-	28.0	120	50	209	.028	.094	42.8	.026	2.45	.079	

[a] Using curve A (equilibrium with quartz) Fournier and Truesdell, 1970.

[b] Fournier and Truesdell, 1973.

[c] Discharge estimated.

[d] Measured temperature is probably lower than temperature at point of discharge.

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MONTANA

Summary

The western third of the state is block faulted and composed in part of Tertiary granitic and volcanic rocks where the thermal springs occur. Approximately 40 thermal springs occur in the state, and their temperatures range up to 80°C. There is one KGRA near Yellowstone National Park in the southern part of the state. Flow rates range up to 50,000 gpm. The water quality is good in the areas underlain by granitic rocks of the Idaho Batholith, but water quality is variable in the region of Yellowstone Park.

The steepest geothermal gradient measured is in the area around Marysville, where conducted heat flow range is from 3.2 to 19.5 u cal/cm^2 sec. At one locality, a temperature of 58°C was measured at a depth of only 220 meters. Drilling has indicated that the immediate source of the high heat flow is an unexposed reservoir of thermal fluids rather than a shallow still cooling magma chamber. No water of substantial quantity has been located. The drilling confirms the convective circulation of water within the fractured granite to depths of 6000 feet, and thus casts doubts on the relative abundance of hot "dry" geotherman systems. Reference: Blackwell, D. D. and Baag, C. G., Heat Flow in a "Blind" Geothermal Area near Marysville, Montana, Geophysics, Vol. 38, No. 5, p. 941-956 (1973).

NEVADA

Summary

The chemical composition and minimum thermal reservoir temperatures of 55 hot springs in northern and central Nevada are described in a U.S.G.S. open file report issued in May, 1974 (Mariner, et.al.).

Major element constituents: sodium, potassium, calcium and silica suggest minimum thermal aquifer temperatures of 140°C or more at 16 of the hot spring complexes. At least five of the hot springs issue mixed waters, and true thermal aquifer temperatures may be significantly higher than indicated by the water chemistry.

Sodium is the principal cation in these waters, while the anions may be bicarbonate, chloride or a mixture of chloride, bicarbonate and sulfate. The pH values range from 6.47 to 9.38. Boron content ranges from less than .02 ppm to 47 ppm, with 18 springs having less than 1.0 ppm and eight springs having from 1.0 to 2.0 ppm. Boron was not reported for 13 springs. Specific conductance values range from 321 to 6,910. The sampled hot springs have chemical compositions characteristic of hot water-dominated systems.

Most of the thermal springs are along permeable zones associated with faults. Quaternary alluvium and fine-grained sediments cover the fault lines along which many of the springs issue.

Thirteen KGRA's have been designated in Nevada, and most of the northwestern part of the state is of potential geothermal importance.

Geologic Setting

Nevada, part of the Basin and Range Province, consists of roughly parallel fault-block mountain ranges separated by alluvial-filled valleys. Exposed rocks range in age from Precambrian to Quaternary. Precambrian and Paleozoic rocks crop out in the mountain ranges of eastern Lander, Eureka and southern Elko Counties (Montgomery, 1965). Mesozoic sedimentary and volcanic rocks are widespread in Pershing and southeastern Humboldt Counties; Mesozoic granitic intrusive rocks are common in western Pershing and northern Humboldt Counties, as well as near the Sierra Nevada of California. Cenozoic volcanic rocks and related sedimentary rocks are predominant in Washoe, northern Humboldt, northern Elko, Churchill, western Lander and Nye Counties.

The types and ages of rock exposed near the springs, as well as selected references on the geology of the area around the spring, are listed in Table 4. Most of the thermal springs are along permeable zones associated with faults. Quaternary alluvium and lacustrine rocks cover the fault lines along which many of the springs issue.

Eight of the thermal springs having estimated thermal-aquifer temperatures of 140°C or more have a poorly-developed regional trend. This regional trend extends from Wabuska Hot Springs in Lyon County, northeast through Churchill, Pershing, and into southeastern Humboldt County. The Stillwater Range of Churchill County and East Range of Pershing County parallel this trend.

Tabular Data

Table 1 lists the springs by name, location and topographic map coverage.

Table 2 contains measured temperature, specific conductance, pH values and major chemical constituents.

Table 3 contains the estimated thermal-aquifer temperatures and flow rates. The underlined values represent the "best" estimate of thermal-aquifer temperature.

Table 4 lists the types and ages of rock exposed near the springs and selected references on the geology of the surrounding areas.

Water Chemistry

The chemical analyses (Table 2) show that most of the thermal springs discharge sodium bicarbonate water. However, thermal springs along the western side of the state, Washoe County, discharge sodium chloride waters. Some sodium-mixed anion waters occur around the Black Rock Desert in Humboldt County. Sodium and calcium occur in approximately equal molar amounts in the water from Diana's Punch Bowl, the springs at Potts Ranch and East Ruby Marsh, and Walti Hot Springs. Water from Nile Spring is a calcium magnesium bicarbonate type.

The waters range in pH from 6.47 at Walti Hot Springs to 9.38 at the Beowawe "steam" well. Specific conductance is highest for sodium chloride waters, such as the discharge from Great Boiling Spring at Gerlach, and lowest for the sodium calcium bicarbonate or calcium magnesium bicarbonate waters mentioned above.

Thermal-Aquifer Temperature Estimates

Thermal-aquifer temperatures estimated from the chemical analyses indicate 16 different spring complexes where the waters have circulated through rock having a temperature of at least 140°C. The flowing well in Stillwater, Beowawe Hot Springs, Wabuska Hot Springs, Leach Hot Springs, Great Boiling Spring and Steamboat Springs all have estimated minimum thermal-aquifer temperatures of at least 140°C and are in areas designated as known geothermal resource areas by Godwin and others (1971). Other areas of geothermal potential not in known geothermal resource areas are: Lee Hot Springs and Dixie Valley Hot Springs in Churchill County, Sulphur Hot Springs and two unnamed hot springs near Wells in Elko County, Pinto Hot Springs, Baltazor Hot Spring, and an unnamed hot spring (Hot Springs Ranch) in Humboldt County, an unnamed hot spring (Smith Creek Valley) in Lander County, as well as Kyle Hot Springs and an unnamed hot spring (Jersey Valley) in Pershing County. Dixie Valley Hot Springs, Mineral Hot Springs, an unnamed hot spring (near Wells), Double Hot Spring and Dyke Hot Spring may be mixed waters. The thermal-aquifer temperatures estimated from the water compositions may be significantly below the true thermal-aquifer temperature.

SUMMARY OF TEMPERATURE DATA

The major portion of Nevada's hot springs are found in the northern 1/2 of the state. The Basin and Range physiographic province has the highest heat flow, and the west central and north central portions of the state have the highest hot spring temperatures. The Battle Mountain high in north-central Nevada has a heat flow of 3 HFU. The average heat flow for Nevada is general is 2 HFU. Spring temperatures range up to 208°F(98°C).
Discharge ranges up to 12,000 gpm.

Hottest areas:

Steamboat Springs
Max. Spring Temp - 203°F (95°C)
Max Well Temp - 369°F (187°C)
Hot water present with 5-10% steam flashover.
Numerous homes are heated from warm water wells in the Reno area.

The Needles (Pyramid Lake)
Max. Spring Temp - 208°F (98°C)
Max. Well Temp - 240°F (116°C)
Large flow

Wards Hot Springs (Fly Ranch)
Max Spring Temp - 203°F (95°C)
Max. Well Temp - 220°F (104°C)
Largest hot springs in northwestern Nevada

Beowawe Geysers
Max Spring Temp - 205°F (96°C)
Max Well Temp - 414°F (212°C)
Hot water with 5-10% steam flashover.
Problems of scaling and cold water inflow.

Wabuska Hot Springs
Max Spring Temp - 162°F (72°C)
Max Well Temp - 222°F (106°C)
Hot water used for greenhouse heating

Darrough Hot Springs
Max Spring Temp - 207°F (97°C)
Max Well Temp - 265°F (129°C)
Very large flow of hot water,little steam.

Brady's Hot Springs
Max Spring Temp - 194°F (90°C)
Max Well Temp - 418°F (214°C)
Hot water with 5% steam flashover.
Problem of scaling.

Stillwater
Max Well Temp - 240°F (116°C)
Some water wells drilled in this area encountered hot water and steam which have been used for space heating. No springs or other surface features.

TABLE I
Exploratory geothermal drilling in Nevada through 1973[1]

Operator	Name	API No.[2]	Location	Depth	Maximum Spring Temp. (°F)	Maximum Well Temp. (°F)	Completion Date	Remarks
1. Steamboat Hot Springs					203	369		
Nevada Thermal Power Co.	Steamboat No. 1[3]	27-031-90000	NW/4,NE/4,S28,T18N,R20E	1830			1954	Hot water present with 5-10% steam flashover. Eight core holes drilled by the U. S. Geological Survey (1950), for a total footage of 3316 feet. Also several wells for hot water baths, etc. Numerous homes are heated from warm water wells in the Reno area. For more information see White (1968).
Nevada Thermal Power Co.	Steamboat No. 2[3]	27-031-90001	SE/4,SW/4,S28,T18N,R20E	964			1959	
Nevada Thermal Power Co.	Steamboat No. 3[3]	27-031-90002	NW/4,NE/4,S32,T18N,R20E	1263			1960?	
Nevada Thermal Power Co.	Steamboat No. 4[3]	27-031-90003	NE/4,NW/4,S32,T18N,R20E	520?			1960	
Nevada Thermal Power Co.	Steamboat No. 5[3]	27-031-90004	NW/4,NW/4,S32,T18N,R20E	826			1961	
Nevada Thermal Power Co.	Steamboat No. 6[3]	27-031-90005	NW/4,NW/4,S32,T18N,R20E	716			1961	
2. The Needles (Pyramid Lake)					208	240		
Western Geothermal Inc.	Needles No. 1	27-031-90006	NW/4,SW/4,SW/4,S6,T26N,R21E	5888			1965	Large flow of hot water.
Western Geothermal Inc.	Needles No. 2(?)[3]	27-031-90007	C,W/2,NE/4,S12,T26N,R21E	~4000?			1964	
Western Geothermal Inc.	Needles No. 3(?)[3]	27-031-90008	NW/4,SW/4,SW/4,S6,T26N,R21E	?			1964	
3. Wards Hot Springs (Fly Ranch)					203	>220		
Western Geothermal Inc.	Fly Ranch No. 1(?)[3]	27-031-90009	SW/4,S2,T34N,R23E	1000+			1964	Largest hot springs in northwestern Nevada.
Western Geothermal Inc.	Granite Creek Ranch No. 1(?)[3]	27-031-90010	S35(?),T34N,R23E	800			1965?	
4. Monte Neva Hot Springs					193	190		
Magma Power Co.	Monte Neva No. 1(?)[3]	27-033-90000	S24(?),T21N,R63E	402			1965	Melvin (Goodrich) Hot Springs
5. Beowawe Geysers					205	414		
Magma Power Co.	Beowawe No. 1	27-011-90000	NE/4,SE/4,NW/4,S17,T32N,R48E	1918			1959?	Hot water with 5-10% steam flashover. Problems of scaling and cold water inflow.
Magma Power Co.	Beowawe No. 2	27-011-90001	SE/4,SW/4,NW/4,S17,T32N,R48E	715			1959?	
Vulcan Thermal Power Co.	Vulcan No. 1	27-011-90002	NW/4,SW/4,NW/4,S17,T32N,R48E	715?			1961	
Vulcan Thermal Power Co.	Vulcan No. 2	27-011-90003	C,SE/4,NW/4,S17,T32N,R48E	655?			1961	
Vulcan Thermal Power Co.	Vulcan No. 3	27-011-90004	NE/4,SW/4,NW/4,S17,T32N,R48E	795 or 715			1961	
Vulcan Thermal Power Co.	Vulcan No. 4	27-011-90005	S17?,T32N,R48E	767			1961	
Vulcan Thermal Power Co.	Vulcan No. 5	27-011-90006	S17?,T32N,R48E	237			1963?	
Vulcan Thermal Power Co.	Vulcan No. 6	27-011-90007	NW/4,SW/4,NE/4,S17,T32N,R48E	478			1963	
Sierra Pacific Power Co.(?)[3]	Sierra No. 1	27-011-90008	S17?,T32N,R48E	927			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 2	27-011-90009	S17?,T32N,R48E	397			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 3	27-011-90010	NW/4,SE/4,NW/4,S17,T32N,R48E	2052			1964?	
Sierra Pacific Power Co.(?)[3]	Sierra No. 4	27-011-90011	NW/4,NE/4,NW/4,S17,T32N,R48E	1005			1964?	
Chervon-American Thermal Res.	Ginn No. 1-13	27-015-90000	C,SE/4,SE/4,S13,T31N,R47E	–			–	
6. Hot Springs Point (Crescent Valley)					122	166		
Magma Power Co.	Hot Springs Point No. 1(?)[3]	27-011-90012	S1,2, or 11,T29N,R48E	410			1965	Hot water.

Table extracted from: Garside, L. J., Geothermal Exploration and Development in Nevada through 1973, Mackay School of Mines at University of Nevada, Report #21, 12 pgs. (1974).

TABLE 1 (Continued)
Exploratory geothermal drilling in Nevada through 1973[1]

Operator	Name	API No.[2]	Location	Depth	Maximum Spring Temp. (°F)	Maximum Well Temp. (°F)	Completion Date	Remarks
7. Wabuska Hot Springs					162	222		
Magma Power Co.	Wabuska No. 1	27-019-90000	S16?,T15N,R25E	488			1959	Hot water used for greenhouse heating.
Magma Power Co.	Wabuska No. 2	27-019-90001	SE/4,NE/4,SW/4,S16,T15N,R25E	532?			1959	
Magma Power Co.	Wabuska No. 3	27-019-90002	NE/4,SE/4,SE/4,S16,T15N,R25E	2223			1959	
8. Fernley (Hazen)					?	270		
Magma Power Co.	Hazen No. 1(?)[3]	27-019-90003	SW/4,S18?,T20N,R26E	750			1962	Patua Hot Springs.
Magma Power Co.	Hazen No. 2(?)[3]	27-019-90004	S18?,T20N,R26E	∿300?			1962	
Magma Power Co.	Hazen No. 3(?)[3]	27-019-90005	S18?,T20N,R26E	∿300?			1962	
9. Hind's Hot Springs					144	?		
U. S. Steel Corp.	Hind's No. 1(?)[3]	27-019-90006	SW/4,SE/4,S16,T12N,R23E	?			1962?	Hot water in wells cooler than springs at surface.
U. S. Steel Corp.	Hind's No. 2(?)[3]	27-019-90007	SW/4,SE/4,S16,T12N,R23E	?			1962?	
U. S. Steel Corp.	Hind's No. 3(?)[3]	27-019-90008	SW/4,SE/4,S16,T12N,R23E	?			1962?	
10. Darrough Hot Springs					207?	265		
Magma Power Co.	Darrough No. 1(?)[3]	27-023-90000	S17?,T11N,R43E	812			1962	Very large flow of hot water, little steam.
11. Brady's Hot Springs					194	418		
Magma Power Co.	Brady No. 1	27-001-90000	NE/4,NE/4,SW/4,S12,T22N,R26E	700?			1959?	Hot water with 5% steam flashover. Problem of scaling.
Magma Power Co.	Brady No. 2	27-001-90001	NE/4,NE/4,SW/4,S12,T22N,R26E	241			1959?	
Magma Power Co.	Brady No. 3	27-001-90002	SE/4,SE/4,NW/4,S12,T22N,R26E	610			1961?	
Magma Power Co.	Brady No. 4	27-001-90003	SE/4,SE/4,NW/4,S12,T22N,R26E	723			1961?	
Magma Power Co.	Brady No. 5	27-001-90004	NW/4,SW/4,NE/4,S12,T22N,R26E	593			1961?	
Magma Power Co.	Brady No. 6	27-001-90005	NW/4,SW/4,NE/4,S12,T22N,R26E	770			?	
Magma Power Co.	Brady No. 7	27-001-90006	NW/4,SW/4,NE/4,S12,T22N,R26E	250			?	
Earth Energy Inc.	R. Brady EE No. 1	27-001-90007	S12?,T22N,R26E	5062?			1964	
Earth Energy Inc.	Brady Pros. No. 1	27-001-90008	S12?,T22N,R26E	1758?			1965?	
12. Stillwater					–	240		
O'Neill Geothermal, Inc.	Joseph I. O'Neill, Jr. Reynolds No. 1	27-001-90009	NE/4,SW/4,SW/4,S6,T19N,R31E	∿4200?			1964	Some water wells drilled in this area encountered hot water and steam which have been used for space heating. No springs or other surface features.
13. Wally's Hot Springs					160	181		
U. S. Steel Corp.	Wally's No. 1	27-005-90000	SE/4,NW/4,NW/4,S22,T13N,R19E	1268			1962	Twenty-six shallow holes were also drilled to measure the temperature gradient.
U. S. Steel Corp.	Wally's No. 1	27-005-90001	SW/4,SW/4,NW/4,S22,T13N,R19E	499			1962	

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[1] Listing does not include thermal water wells or wells drilled to exploit thermal waters for spas, swimming pools, space heating, etc.

[2] The American Petroleum Institute Unique well number system has been applied to geothermal wells as well as oil and gas wells, and is recommended for the unique identification of wells by all agencies of industry and government.

[3] Name assigned by Nevada Bureau of Mines and Geology; original name unknown.

Table 1.--Location and topographic map coverage of selected hot springs and wells

	Spring or well	Location	Topographic map coverage
		Churchill County	
1	Lee Hot Springs	Unsurveyed (lat. 39°12' N., long. 118°43' W.)	Allen Springs, Nev. (15'); Reno, Nev. (2°)
2	Dixie Valley Hot Springs	SE 1/4 sec. 5 and NE 1/4 sec. 8, T. 22N., R. 35E.	Dixie Hot Springs, Nev. (15'); Reno, Nev. (2°)
3	Flowing well in Stillwater	SW 1/4 sec. 7, T. 19N., R. 31E.	Stillwater, Nev. (15'); Reno, Nev. (2°)
		Douglas County	
1	Walleys Hot Springs	NE 1/4 sec. 22, T. 13N., R. 19E.	Minden, Nev.-Calif. (7-1/2'); Walker Lake, Calif.-Nev (2°)
		Elko County	
1	Hot Hole	NE 1/4 sec. 21, T. 34N., R. 55E.	Elko, west, Nev. (7-1/2'); Elko, Nev.-Utah (2°)
2	Sulphur Hot Springs	NW 1/4 sec. 11, T. 31N., R. 59E.	Lamoille, Nev. (15'); Elko, Nev.-Utah (2°)
3	Unnamed hot spring (Hot Creek)	NW 1/4 sec. 12, T. 28N., R. 52E	Pine Valley, Nev. (15'); Winnemucca, Nev. (2°)
4	Nile Spring	SW 1/4 sec. 30, T. 47N., R. 70E.	Goose Creek, Nev.-Utah-Idaho (15'); Wells, Nev.-Utah-Idaho (2°)
5	Mineral Hot Spring	sec. 16, T. 45N., R. 64E.	Delaplain, Nev.-Idaho (15'); Wells, Nev.-Utah-Idaho (2°)
6	Unnamed hot spring near Wells	sec. 20, T. 38N., R. 62E	Oxley Peak, Nev. (7-1/2'); Wells, Nev.-Utah-Idaho (2°)
7	Unnamed hot spring near Wells	NE 1/4 sec. 17, T. 38N., R. 62E.	Oxley Peak, Nev. (7-1/2'); Wells, Nev.-Utah-Idaho (2°)
8	Unnamed hot spring (Wild Horse Reservoir)	SE 1/4 sec. 4, T. 43N., R. 55E.	Wild Horse, Nev. (15'); Wells, Nev.-Utah-Idaho (2°)
9	Unnamed hot spring (SSE Patsville)	Unsurveyed (lat. 41°5' N., long. 115°55' W.)	Mountain City, Nev.-Idaho (15'); Wells, Nev. Utah-Idaho (2°)
10	Hot Sulphur Springs	NE 1/4 sec. 8, T. 41N., R. 52E.	Tuscarora, Nev. (15'); McDermitt, Nev.-Ore.-Idaho (2°)
11	Unnamed hot spring near Carlin	sec. 33, T. 33N., R. 52E.	Carlin, Nev. (15'); Winnemucca, Nev. (2°)
12	Unnamed hot spring near Ruby Marsh	NW 1/4 sec. 2, T. 27N., R. 58E.	Ruby Lake NW, Nev. (7-1/2'); Elko, Nev.-Utah (2°)
		Eureka County	
1	Walti Hot Springs	SW 1/4 sec. 33, T. 24N., R. 48E.	Walti Hot Spring, Nev. (15'); Millet, Nev. (2°)
2	Hot Springs Point	NE 1/4 sec. 11, T. 29N., R. 48E.	Crescent Valley, Nev. (15'); Winnemucca, Nev. (2°)
3	Beowawe "steam" well	NW 1/4 sec. 17, T. 31N., R. 48E.	Dunphy, Nev. (15'); Winnemucca, Nev. (2°)
4	Beowawe Hot Spring	SE 1/4 sec. 8, T. 31N., R. 48E.	Dunphy, Nev. (15'); Winnemucca, Nev. (2°)
5	Bartholomae Hot Springs	SE 1/4 sec. 28, T. 18N., R. 50E.	Antelope Peak, Nev (15'); Millett, Nev. (2°)

Table 1.--Location and topographic map coverage of selected hot springs and wells Continued

Spring or well	Location	Topographic map coverage
	Humboldt County	
1 Unnamed hot spring (Hot Springs Ranch)	SE 1/4 sec. 5, T. 33N., R. 40E.	Edna Mtn., Nev. (15'); Winnemucca, Nev. (2°)
2 Unnamed hot spring near Golconda	SE 1/4 sec. 29, T. 36N., R. 40E.	Edna Mtn., Nev. (15'); Winnemucca, Nev. (2°)
3 Double Hot Springs	sec. 4, T. 36N., R. 26E.	; Vya, Nevada-Oregon (2°)
4 Unnamed hot springs in Soldier Meadows	sec. 23, T. 40N., R. 24E.	; Vya, Nevada-Oregon (2°)
5 West Pinto Hot Spring (well)	Unsurveyed (lat. 41°20'N., long. 118°48'W)	; Vya, Nevada-Oregon (2°)
6 East Pinto Hot Spring	Unsurveyed (lat. 41°21'N., long. 118°47'W)	; Vya, Nevada-Oregon (2°)
7 Dyke Hot Spring	SE 1/4 sec. 25, T. 43N., R. 30E.	Duffer Peak, Nev. (15'); Vya, Nevada-Oregon (2°)
8 Flowing well near Baltazor Hot Spring	NW 1/4 sec. 13, T. 46 N., R. 28E.	Denio, Nev.-Ore. (15'); Vya, Nevada-Oregon (2°)
9 Baltazor Hot Spring	NW 1/4 sec. 13, T. 46N., R. 28E.	Denio, Nev.-Ore. (15'); Vya, Nevada-Oregon (2°)
10 Bog Hot Springs	NW 1/4 sec. 18, T. 46N., R. 28E.	Railroad Point, Nev.-Ore. (15'); Vya, Nevada-Oregon (2°)
11 Hot Pot	SW 1/4 sec. 11, T. 35N., R. 43E.	Hot Pot, Nev. (7-1/2'); Winnemucca, Nev. (2°)
12 Howard Hot Spring	NE 1/4 sec. 4, T. 44N., R. 31E.	Duffer Peak, Nev. (15'); Vya, Nevada-Oregon (2°)
13 The Hot Springs	NE 1/4 sec. 20, T. 41N., R. 41E.	Hot Springs Peak, Nev. (15'); McDermitt, Nev.-Ore.-Idaho (2°)
	Lander County	
1 Spencer Hot Springs	Unsurveyed (lat. 39°49' N., long. 116°51' W)	Spencer Hot Springs, Nev. (15'); Millet, Nev. (2°)
2 Unnamed hot spring (Valley of the Moon)	NE 1/4 sec. 23, T. 27N., R. 43E.	The Cedars, Nev. (15'); Winnemucca, Nev. (2°)
3 Unnamed hot spring (Smith Creek Valley)	sec. 11, T. 17N., R. 39E.	; Millet, Nev. (2°)
4 Buffalo Valley Hot Springs	SE 1/4 sec. 23, T. 29N., R. 41E.	Buffalo Springs, Nev. (15'); Winnemucca, Nev. (2°)
	Lyon County	
1 Wabuska Hot Springs	SE 1/4 sec. 16, T. 15N., R. 25E.	Wabuska, Nev. (15'); Tonopah, Nev. (2°)
2 Nevada Hot Springs	SE 1/4 sec. 16, T. 12N., R. 23E.	Wellington, Nev. (15'); Walker Lake, Calif.-Nev. (2°)
	Mineral County	
1 Soda Springs	SE 1/4 sec. 29, T. 6N., R. 35E.	Sodaville, Nev. (7-1/2'); Walker Lake, Calif.-Nev. (2°)
	Nye County	
1 Darrough "steam" well	sec. 8, T. 11N., R. 43E.	; Tonopah, Nev. (2°)
2 Darrough Hot Springs	sec. 8, T. 11N., R. 43E.	; Tonopah, Nev. (2°)
3 Diana's Punch Bowl	SE 1/4 sec. 22, T. 14N., R. 47E.	Diana's Punch Bowl, Nev. (15'); Millet, Nev. (2°)
4 Hot spring near Diana's Punch Bowl	SE 1/4 sec. 22, T. 14N., R. 47E.	Diana's Punch Bowl, Nev. (15'); Millet, Nev. (2°)
5 Pott's Ranch Hot Spring	NE 1/4 sec. 2, T. 14N., R. 47E.	Diana's Punch Bowl, Nev. (15'); Millet, Nev. (2°)
6 Unnamed warm spring near Warm Springs	SW 1/4 sec. 20, T. 4N., R. 50E.	Warm Springs, Nev. (15'); Tonopah, Nev. (2°)

Table 1.--Location and topographic map coverage of selected hot springs and wells--Continued

Spring or well	Location	Topographic map coverage
	Pershing County	
1 Unnamed hot spring (Jersey Valley)	SW 1/4 sec. 28, T. 27N., R. 40E.	Mt. Moses, Nev. (15'); Winnemucca, Nev. (2°)
2 Kyle Hot Springs	SW 1/4 sec. 1, T. 29N., R. 36E.	Kyle Hot springs, Nev. (15'); Winnemucca, Nev. (2°)
3 Sou Hot Springs	SE 1/4 sec. 29, T. 26N., R. 38E.	Cain Mtn., Nev. (15'); Winnemucca, Nev. (2°)
4 Unnamed hot spring (Lower Ranch)	NW 1/4 sec. 16, T. 25N., R. 39E.	Cain Mtn., Nev. (15'); Winnemucca, Nev. (2°)
5 Unnamed hot spring near Trego	Unsurveyed (lat. 40°46' N., long. 119°7'W)	; Lovelock, Nev.-Calif. (2°)
6 Unnamed hot spring near Black Rock	Unsurveyed (lat. 40°57'N., long. 118°58W)	; Lovelock, Nev.-Calif. (2°)
7 Leach Hot Springs	SE 1/4 sec. 36, T. 32N., R. 38E.	Leach Hot Springs, Nev. (15'); Winnemucca, Nev. (2°)
	Washoe County	
1 Steam Geyser (Needle Rocks)	Unsurveyed (lat. 40°9'N., long. 119°40'W)	The Needle Rocks, Nev. (7-1/2'); Lovelock, Nev.-Calif. (2°)
2 Great Boiling Spring	NW 1/4 sec. 15, T. 32N., R. 23E.	Gerlach, Nev. (15'); Lovelock, Nev.-Calif (2°)
3 Flowing well near Gerlach	sec. 2, T. 34N., R. 23E.	; Lovelock, Nev.-Calif. (2°)
4 Steamboat Springs	NE 1/4 sec. 33, T. 18N., R. 20E.	Steamboat, Nev. (7-1/2'); Reno, Nev. (2°)

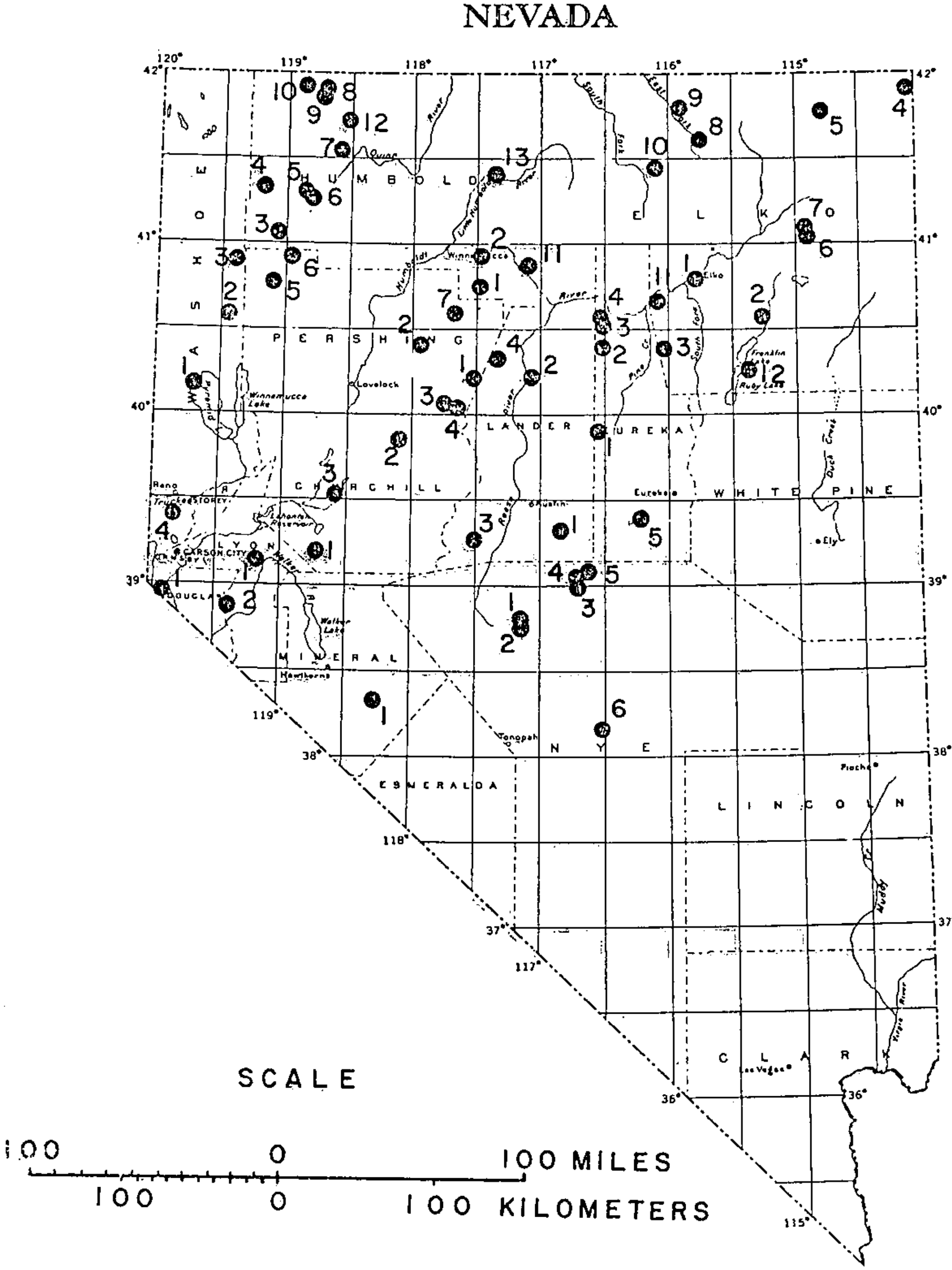

Figure 1. Map of the State of Nevada showing the location of sampled thermal springs and wells. The numbered dots correspond to sampled springs and wells listed by county in tables 1, 2, 3, and 4 of the text.

Table 2.--Chemical analyses of selected hot springs and wells

[Concentrations in milligrams per liter; parentheses indicate supplementary samples; n.a. indicates not available]

Spring or well	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Churchill County															
1 Lee Hot Springs	88	7.36	2,430	180	44	0.6	450	26	0.70	114	<1	470	380	7.9	2.4
2 Dixie Valley Hot Springs	72	8.59	914	115	3.6	.02	190	6.5	.38	111	11	111	126	16.3	.89
3 Flowing well in Stillwater	96	7.57	6,910	170	108	1.7	1,480	42	1.94	90	<1	190	2,200	5.0	15
Douglas County															
1 Walleys Hot Springs	61	8.77	726	58	10	.01	145	3.6	.20	50	9	235	44	4.9	1.2
Elko County															
1 Hot Hole	56	7.21	908	65	60	15.5	120	39	.33	488	1	72	16	1.9	.70
2a Sulphur Hot Springs	93	8.53	601	210	1.0	.03	135	8.9	.46	244	15	40	23	17.7	.20
2b Sulphur Hot Springs	45	8.63	652	230	1.6	.02	150	9.8	.51	247	12	40	4	19.0	.23
3 Unnamed hot spring (Hot Creek)	26	7.30	408	20	46	23.5	10	2.1	.02	226	1	27	4.6	<0.1	.03
(4) Nile Spring	43	7.2	321	31	40	11.5	10	5.6	<.2	149	--	37	8.7	.4	<.02
(5) Mineral Hot Spring	60	9.1	344	83	1.6	<.01	75	2.2	<.2	108	--	45	15	8.9	.47
(6) Unnamed hot spring near Wells	50	7.3	753	165	12	.3	160	16	.8	345	--	61	22	10	1.2
(7) Unnamed hot spring near Wells	61	7.3	1,650	105	75	37	300	31	.8	1,135	--	32	27	7.2	.89
(8) Unnamed hot spring (Wild Horse Reservoir)	54	7.2	818	40	48	12	130	22	.5	482	--	40	14	5.2	.67
(9) Unnamed hot spring (SSE Patsville)	41	7.4	624	23	29	7.7	110	8.3	.4	380	--	36	4.4	3.4	.22
(10) Hot Sulphur Springs	90	7.0	1,760	84	49	13	390	41	.7	1,180	--	18	40	7.2	.77
(11) Unnamed hot spring near Carlin	79	7.6	625	70	60	15	45	16	n.a.	335	--	52	12	n.a.	n.a.
(12) Unnamed hot spring near Ruby Marsh	65	8.0	600	50	45	12	58	14	n.a.	377	--	24	6.5	n.a.	n.a.
Eureka County															
1 Walti Hot Springs	72	6.47	592	68	56	12	44	14	.3	264	<1	64	12	2.5	.12
2 Hot Springs Point	54	6.63	1,730	67	53	35	230	58	1.1	913	<1	7	1	6.6	2.1
3 Beowawe "steam" well	--	9.38	1,490	500	1.3	.2	250	38	2.1	505	81	64	70	<.05	2.5
4 Beowawe Hot Spring	98	8.98	1,020	320	1.0	<.1	230	16	1.3	321	32	130	69	17	2.1

Table 2.--Chemical analyses of selected hot springs and wells--Continued

Spring or well	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
(5) Bartholomae Hot Springs	54	9.25	295	85	1	<0.1	64	0.7	n.a.	144	--	18	6.3	n.a.	n.a.
				Humboldt County											
1 Unnamed hot spring (Hot Springs Ranch)	85	8.36	1,060	125	16	.9	200	18	1.2	385	--	140	41	n.a.	2.6
2 Unnamed hot spring near Golconda	74	6.53	810	66	33	6.8	130	22	.36	429	<1	56	18	1.8	1.1
3 Double Hot Springs	80	7.93	902	105	4.8	.1	180	4.5	.06	261	2	120	59	10	1.8
4 Unnamed hot springs in Soldier Meadows	54	8.55	363	63	3.1	<.1	74	1.1	.17	92	3	41	18	12	.64
5 West Pinto Hot Spring (well)	92	7.65	1,520	160	4.6	.1	320	25	.45	436	2	130	160	14	6.9
6 East Pinto Hot Spring	93	7.14	1,560	150	14	.4	330	23	.45	495	1	120	160	12	7.5
7 Dyke Hot Spring	66	8.86	666	85	1.8	<.1	150	4.3	.09	243	17	82	21	8.0	1.0
8 Flowing well near Baltazor Hot Spring	90	7.50	934	150	10	.1	180	8.2	.22	156	<1	230	47	6.8	2.1
9 Baltazor Hot Spring	80	8.00	947	160	8.4	<.1	180	8.7	n.a.	139	2	220	48	7.1	2.9
10 Bog Hot Springs	54	9.05	356	57	.2	<.1	81	1.0	.03	116	11	45	15	1.7	.91
(11) Hot Pot	58	8.0	1,400	80	29	5	288	33	.72	823	--	60	28	n.a.	n.a.
(12) Howard Hot Spring	56	9.2	400	85	3	<.1	88	1.7	n.a.	127	--	62	10	n.a.	n.a.
(13) The Hot Springs	58	8.0	1,340	55	10	8	296	36	n.a.	881	--	36	26	n.a.	n.a.
				Lander County											
1 Spencer Hot Springs	72	6.49	1,180	77	43	9.4	200	36	1.8	672	<1	51	22	4.7	2.6
(2) Unnamed hot spring (Valley of the Moon)	53	8.0	700	40	20	9	118	21	n.a.	333	--	64	21	n.a.	n.a.
3 Unnamed hot spring (Smith Creek Valley)	86	7.72	737	110	4.8	.06	170	8.4	.38	246	5	102	22	8.9	.66
4 Buffalo Valley Hot Springs	49	6.53	1,530	80	45	4.9	250	34	.80	813	<1	110	29	4.8	2.3
				Lyon County											
(1) Wabuska Hot Springs	97	8.5	1,550	115	38	.2	277	15	n.a.	70	--	580	46	n.a.	n.a.
2 Nevada Hot Springs	61	8.65	509	52	4.5	.01	102	2.5	.08	54	7	169	17	3.1	.19
				Mineral County											
1 Soda Springs	35	7.60	1,640	46	40	3.3	305	16	.65	112	<1	597	87	7.4	2.3

Table 2.--Chemical analyses of selected hot springs and wells--Continued

Spring or well	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Nye County															
1 Darrough "steam" well	94	8.29	499	105	1.4	0.1	110	2.9	0.3	165	3	55	12	15	0.24
2 Darrough Hot Springs	95	8.29	479	98	1.3	.1	110	2.6	.3	146	3	53	12	14	.22
3 Diana's Punch Bowl	59	7.14	605	46	50	11	55	15	.4	277	<1	59	8	2.8	.21
4 Hot spring near Diana's Punch Bowl	51	6.73	589	46	47	11	57	15	0.4	270	<1	59	8	2.8	0.23
5 Pott's Ranch Hot Spring	45	6.62	561	36	52	11	47	13	.3	249	<1	57	10	2.0	.17
(6) Unnamed warm spring near Warm Springs	61	8.1	1,250	60	43	24	175	24	n.a.	714	--	120	32	n.a.	n.a.
Pershing County															
1 Unnamed hot spring (Jersey Valley)	29	7.10	1,040	110	36	4.4	180	20	1.2	374	<1	150	40	7.8	1.9
2 Kyle Hot Springs	77	6.50	3,220	150	95	25.5	540	80	3.1	544	<1	51	770	5.7	3.8
(3) Sou Hot Springs	73	8.1	1,407	65	110	22	165	26	n.a.	312	--	370	75	n.a.	n.a.
(4) Unnamed hot spring (Lower Ranch)	40	8.1	850	42	31	15	143	12	n.a.	456	--	63	29	n.a.	n.a.
(5) Unnamed hot spring near Trego	86	8.4	2,300	85	25	.2	463	9.3	n.a.	154	--	86	520	n.a.	n.a.
(6) Unnamed hot spring near Black Rock	90	8.1	6,590	120	35	4	1,500	20	n.a.	932	--	290	787	n.a.	n.a.
7 Leach Hot Spring	92	7.40	811	135	8.8	.5	160	13	1.7	366	1	53	29	7.8	1.2
Washoe County															
1 Steam Geyser (Needle Rocks)	56	8.43	6,200	110	260	.1	1,100	160	.61	24	1	340	1,900	3.0	6.1
2 Great Boiling Spring	86	7.15	7,610	165	68	1.2	1,400	130	1.6	83	<1	400	2,200	4.5	9.9
3 Flowing well near Gerlach	80	7.91	1,800	82	31	4.2	340	17	.46	458	4	46	240	7.0	1.9
4 Steamboat Springs	94	7.19	3,340	270	16	0.7	680	66	7.5	364	2	73	837	2.1	47

Table 3.--Estimated thermal-aquifer temperatures of selected hot springs

[Spring deposits: X, calcium carbonate or silica apron; T, traces of calcium carbonate or silica; --, calcium carbonate or silica not detected]

Spring or well	Spring temperature (°C)	Flow (lpm)	Spring deposits		Comments	Estimated reservoir temperatures			
			CaCO$_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca
					Churchill County				
1 Lee Hot Springs	88	130	X	X	High chloride, near boiling	173	162	128	162
2 Dixie Valley Hot Springs1/	72	200	--	--	Low calcium, moderate chloride, moderate silica	145	139	86	144
3 Flowing well in Stillwater	96	--	--	--	High chloride, boiling	169	159	72	140
					Douglas County				
1 Walleys (Genoa) Hot Springs	61	75	X	--	Na-K-4/3Ca estimate near the spring temperature	109	109	64	119
					Elko County				
1 Hot Hole (Elko Hot Springs)	56	75	X	--	Calcite ppt., Na-K-Ca meaningless	114	113	380	234
2a Sulphur Hot Springs	93	75	--	X	Boiling spring, low chloride and calcium	183	171	140	181
2b Sulphur Hot Springs2/	45	500	--	X	May be boiling at the orifice (?), large lake with a large cooling surface	190	176	139	178
3 Unnamed hot spring (Hot Creek)	26	6,000	--	--	Na-K-4/3Ca estimate near the spring temperature	63	69	282	161
4 Nile Spring	43	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	81	84	543	220
5 Mineral Hot Spring1/	60	Supplementary sample			Low calcium, magnesium, and chloride (?), moderate silica	127	124	75	129
6 Unnamed hot spring near Wells 1/	50	Supplementary sample			Low calcium and chloride (?), high silica	167	158	184	184
7 Unnamed hot spring near Wells	61	Supplementary sample			High calcium and magnesium, low chloride, mixed (?)	140	135	188	181
8 Unnamed hot spring (Wild Horse Reservoir)	54	Supplementary sample			High calcium and bicarbonate, low chloride	92	94	255	197
9 Unnamed hot spring (SSE Patsville)	41	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	69	74	153	156
10 Hot Sulphur Springs	90	Supplementary sample			High calcium and bicarbonate, low chloride, mixed (?)	128	125	190	191
11 Unnamed hot spring near Carlin	79	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	118	117	395	216
12 Unnamed hot spring near Ruby Marsh	65	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	102	102	314	202
					Eureka County				
1 Walti Hot Springs	72	300	X	--	Na-K-4/3Ca estimate near the spring temperature	116	115	375	212
2 Hot Springs Point	54	125	X	--	High calcium, very low chloride, mixed water (?)	115	115	325	233
3 Beowawe "steam" well	--	--	--	X	Boiling, very low calcium	252	226	238	242

Table 3.--Estimated thermal-aquifer temperatures of selected hot springs--Continued

Spring or well	Spring temperature (°C)	Flow (lpm)	Spring deposits		Comments	Estimated reservoir temperatures (°C)				
			$CaCO_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca	Na-K-4/3Ca
4 Beowawe Hot Spring	98	100	--	X	Boiling, very low calcium, superheated	214	196	145	194	237
5 Bartholomae Hot Springs	54	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	128	125	19	92	73
					Humboldt County					
1 Unnamed hot spring (Hot Springs Ranch)	85	100	X	T	Calcite precipitating, mixed (?)	150	144	172	180	139
2 Unnamed hot spring near Golconda	74	750	X	--	High calcium, bicarbonate, and magnesium, possible mixing (?)	115	114	255	201	121
3 Double Hot Spring[1/]	80	175	T	T	Low calcium, bicarbonate, and magnesium, mixed	140	135	64	127	113
4 Unnamed hot springs in Soldier Meadows	54	50	--	--	Na-K-4/3Ca estimate near the spring temperature	112	112	34	98	65
5 West Pinto Hot Spring (well)	92	100	X	X	Low calcium and magnesium, spring near boiling	165	156	157	192	208
6 East Pinto Hot Spring	93	500	X	X	Low calcium and magnesium, spring near boiling	162	153	145	176	163
7 Dyke Hot Spring[1/]	66	100	T	--	Low calcium and magnesium, spring not boiling	128	126	73	137	136
8 Flowing well near Baltazor Hot Spring	90	25	--	--	Low calcium, nearly boiling, low flow rate	162	153	107	148	118
9 Baltazor Hot Spring	80	100	T	T	Low calcium, may be a mixed water although chloride and magnesium are low	165	156	111	152	100
10 Bog Hot Spring	54	4,000	--	--	Low TDS, deep circulation meteoric or mixed (?)	108	109	25	109	128
11 Hot Pot	58	Supplementary sample			High calcium, bicarbonate, calcite ppt. (?), indeterminate	125	122	200	195	155
12 Howard Hot Spring	56	Supplementary sample			Na-K-4/3Ca estimate near the spring temperature	128	125	49	110	81
13 The Hot Springs	58	Supplementary sample			Calcite ppt. (?), low chloride, indeterminate	106	106	208	209	197
					Lander County					
1 Spencer Hot Springs	72	50	X	--	Low flow rate, low chloride, high calcium and bicarbonate	123	121	264	210	141
2 Unnamed hot spring (Valley of the Moon)	53	Supplementary sample			Very low silica, probably deep circulation meteoric	92	94	263	207	132
3 Unnamed hot spring (Smith Creek Valley)	86	75	T	--	Spring near boiling, low calcium, low chlorite (?)	143	137	114	157	139
4 Buffalo Valley Hot Springs	49	10	T	--	High calcium and bicarbonate, low flow rate	125	122	223	198	140

Table 3.--Estimated thermal-aquifer temperatures of selected hot springs--Continued

Spring or well	Spring temperature (°C)	Flow (lpm)	Spring deposits		Comments	Estimated reservoir temperatures (°C)				
			CaCO$_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca	Na-K-4/3Ca
					Lyon County					
1 Wabuska Hot Springs	97	Supplementary sample			Boiling	145	139	120	152	111
2 Nevada Hot Springs	61	200	X	--	Na-K-4/3Ca estimate near the spring temperature	104	104	64	119	86
					Mineral County					
1 Soda Springs	35	100	T	--	High calcium, deep circulation meteoric or mixed water (?)	98	99	122	154	116
					Nye County					
1 Darrough "steam" well	94	300	--	--	Boiling	140	135	68	131	122
2 Darrough Hot Springs	95	350	X	T	Boiling	136	132	61	127	120
3 Diana's Punch Bowl	59	--	X	--	Na-K-4/3Ca estimate near the spring temperature	99	100	341	208	86
4 Hot springs near Diana's Punch Bowl	51	200	X	--	Na-K-4/3Ca estimate near the spring temperature	99	100	334	207	88
5 Pott's Ranch Hot Spring	45	125	X	--	Na-K-4/3Ca estimate near the spring temperature	91	92	344	205	79
6 Unnamed warm spring near Warm Springs	61	Supplementary sample			High calcium, magnesium, and bicarbonate, probably low temperature	110	110	225	192	122
					Pershing County					
1 Unnamed hot spring (Jersey Valley)	29	20	X	X	Low flow rate, qualitatively high aquifer temperature	142	137	196	182	119
2 Kyle Hot Springs	77	20	X	T	Low flow rate, qualitatively high aquifer temperature	171	161	199	194	154
3 Sou Hot Springs	73	Supplementary sample			Na-K-4/3Ca estimate near spring temperature	114	113	244	190	100
4 Unnamed hot spring (Lower Ranch)	40	Supplementary sample			High calcium, magnesium, and bicarbonate	94	96	162	164	100
5 Unnamed hot spring near Trego	86	Supplementary sample			High chloride, near boiling, flow rate (?)	128	125	51	120	111
6 Unnamed hot spring near Black Rock	90	Supplementary sample			High chloride, near boiling, flow rate (?)	148	142	28	117	151
7 Leach Hot Springs	92	200	T	T	Near boiling, low calcium and magnesium	155	147	161	176	139

Table 3.--Estimated thermal-aquifer temperatures of selected hot springs--Continued

Spring or well	Spring temperature (°C)	Flow (lpm)	Spring deposits		Comments	Estimated reservoir temperatures (°C)				
			$CaCO_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca	Na-K-4/3Ca
					Washoe County					
1 Steam Geyser (Needle Rocks)	56	--	X	--	High chloride, calcium, calcite ppt. (?), boiling in well (?)	143	137	232	214	184
2 Great Boiling Spring	86	--	T	X	Boiling, high chloride	167	158	175	205	230
3 Flowing well near Gerlach	80	500	X	--	Calcite ppt., Na-K-Ca estimate too high	125	124	115	154	125
4 Steamboat Springs	94	50	--	X	Boiling, high chloride	201	186	180	208	233

[1] Mixed waters

[2] Temperature measured at the outlet of the lake not in the orifice of the spring

Table 4.--Age and type of rock near each spring

Spring or well	Age and type of rock	Geologic reference
	Churchill County	
1 Lee Hot Springs	Miocene to Pliocene volcanic rocks	Willden and Speed (1968)
2 Dixie Valley Hot Springs	Quaternary alluvium, Tertiary volcanic rocks, and possibly late Mesozoic intrusive and metamorphic rocks	Page (1965)
3 Flowing well in Stillwater	Quaternary alluvium and Tertiary basalt(?)	Willden and Speed (1968)
	Douglas County	
1 Walleys Hot Springs	Triassic and Jurassic metavolcanic rocks of greenschist facies	Moore (1969)
	Elko County	
1 Hot Hole	Tertiary limestone, lacustrine rocks and volcanic rocks	Granger, Mendell, Simmons, and Lee (1957)
2 Sulphur Hot Springs	Quarternary alluvium, late Mesozoic granites, and Paleozoic to Precambrian metamorphic rocks	Granger, Mendell, Simmons, and Lee (1957)
3 Unnamed hot spring (Hot Creek)	Paleozoic limestone	Smith and Ketner (1972)
4 Nile Spring	Tertiary lacustrine rocks	Granger, Mendell, Simmons, and Lee (1957)
5 Mineral Hot Spring	Tertiary lacustrine rocks, granite(?) and volcanic flows	Granger, Mendell, Simmons, and Lee (1957)
6 Unnamed hot spring near Wells	Tertiary lacustrine rocks	Granger, Mendell, Simmons, and Lee (1957)
7 Unnamed hot spring near Wells	Tertiary lacustrine rocks	Granger, Mendell, Simmons, and Lee (1957)
8 Unnamed hot spring (Wild Horse Reservoir)	Tertiary volcanic and lacustrine rocks	Granger, Mendell, Simmons, and Lee (1957)
9 Unnamed hot spring (SSE Patsville)	Tertiary volcanic rocks and Paleozoic limestone	Granger, Mendell, Simmons, and Lee (1957)
10 Hot Sulphur Springs	Tertiary volcanic rocks and Paleozoic limestone	Granger, Mendell, Simmons, and Lee (1957)
11 Unnamed hot spring near Carlin	Quaternary alluvium and Tertiary volcanic rocks	Granger, Mendell, Simmons, and Lee (1957)
12 Unnamed hot spring near Ruby Marsh	Quaternary alluvium and Paleozoic(?) marine sedimentary rocks	Granger, Mendell, Simmons, and Lee (1957)
	Eureka County	
1 Walti Hot Springs	Quaternary alluvium, late Mesozoic to early Cenozoic granite, and Paleozoic sedimentary rock	Roberts, Montgomery, and Lehner (1967)
2 Hot Springs Point	Late Miocene and early Pliocene basalts, and Ordovician quartzite and cherts	Gilluly and Gates (1965)
3 Beowawe "steam" well	Miocene basalt and andesite flows	Gilluly and Gates (1965)
4 Beowawe Hot Spring	Miocene basalt and andesite flows	Gilluly and Gates (1965); Stewart and McKee (1970)
5 Bartholomae Hot Springs	Quaternary alluvium and Tertiary volcanic rocks	Roberts, Montgomery, and Lehner (1967)

Table 4.--Age and type of rock near each spring--Continued

Spring or well	Age and type of rock	Geologic reference
	Humboldt County	
1 Unnamed hot spring near Hot Springs Ranch	Cambrian phyllitic shale	Willden (1964)
2 Unnamed hot spring near Golconda	Quaternary alluvium, Cambrian quartzite, and Tertiary volcanic rocks	Ferguson, Roberts, and Muller (1952)
3 Double Hot Springs	Quaternary alluvium, Tertiary basalt and ash-flow rhyolite	Willden (1964)
4 Unnamed hot spring in Soldier Meadows	Quaternary alluvium, Tertiary flows and tuffs	Willden (1964)
5 West Pinto Hot Spring (well)	Cretaceous or Tertiary granodiorite, and Tertiary basalt	Willden (1964)
6 East Pinto Hot Spring	Cretaceous or Tertiary granodiorite	Willden (1964)
7 Dyke Hot Spring	Quaternary alluvium, Triassic and Jurassic metamorphic rocks	Willden (1964)
8 Flowing well near Baltazor Hot Spring	Quaternary alluvium, Tertiary volcanic rocks, and Cretaceous to Tertiary granodiorite	Willden (1964)
9 Baltazor Hot Spring	Quaternary alluvium, Tertiary volcanic rocks, and Cretaceous to Tertiary granodiorite	Willden (1964)
10 Bog Hot Springs	Quaternary alluvium, Pliocene volcanic and sedimentary rocks	Willden (1964)
11 Hot Pot	Quaternary alluvium, Tertiary basalt(?), and Cambrian quartzite(?)	Willden (1964)
12 Howard Hot Spring	Quaternary alluvium and Tertiary flows	Willden (1964)
13 The Hot Springs	Tertiary sedimentary rocks and flows	Willden (1964)
	Lander County	
1 Spencer Hot Springs	Quaternary alluvium, Oligocene or Miocene ash-flow tuff, Jurassic "granite", Ordovician cherts or quartzites	Stewart and McKee (1970); McKee (1968)

Table 4.--Age and type of rock near each spring--Continued

Spring or well	Age and type of rock	Geologic reference
2 Unnamed hot spring (Valley of the Moon)	Quaternary alluvium covering Tertiary volcanic rocks	Stewart and McKee (1970)
3 Unnamed hot spring (Smith Creek Valley)	Quaternary alluvium, Oligocene or Miocene (?) ash-flow rhyolites	McKee (1968)
4 Buffalo Valley Hot Springs	Quaternary alluvium, Quaternary basalts, and Tertiary tuffs	Stewart and McKee (1970)
	Lyon County	
1 Wabuska Hot Springs	Quaternary alluvium, Miocene to Pleistocene basalt and andesite, Triassic and Jurassic metavolcanic rocks	Moore (1969)
2 Nevada Hot Springs	Cretaceous intrusives of granitic to mafic composition	Moore (1969)
	Mineral County	
1 Soda Springs	Quaternary alluvium, Quaternary basalt, and Tertiary tuffaceous rocks	Ross (1961)
	Nye County	
1 Darrough "steam" well	Quaternary alluvium and Paleozoic rhyolite	Kleinhampl and Ziony (1967)
2 Darrough Hot Springs	Quaternary alluvium and Paleozoic rhyolite	Kleinhampl and Ziony (1967)
3 Diana's Punch Bowl	Quaternary alluvium and Tertiary ash-flow rhyolite	Kleinhampl and Ziony (1967)
4 Hot spring at Diana's Punch Bowl	Quaternary alluvium and Tertiary ash-flow rhyolite	Kleinhampl and Ziony (1967)
5 Pott's Ranch Hot Spring	Tertiary ash-flow rhyolite	Kleinhampl and Ziony (1967)
6 Unnamed warm spring near Warm Springs	Tertiary volcanics and Paleozoic sedimentary rocks	Kleinhampl and Ziony (1967)
	Pershing County	
1 Unnamed hot spring (Jersey Valley)	Quaternary alluvium, Tertiary tuffs and flows	Tatlock (1969)
2 Kyle Hot Springs	Quaternary alluvium and Paleozoic metamorphic rocks	Tatlock (1969)
3 Sou Hot Springs	Quaternary alluvium, Tertiary flows and volcanic derived sedimentary rocks	Tatlock (1969)
4 Unnamed hot spring (Lower Ranch)	Quaternary alluvium, Tertiary rhyolite, and metamorphosed Triassic rocks	Tatlock (1969)

Table 4.--Age and type of rock near each spring--Continued

Spring or well	Age and type of bedrock	Geologic reference
5 Unnamed hot spring (Trego)	Quaternary dune sands and Cretaceous granite	Tatlock (1969)
6 Unnamed hot spring (Black Rock)	Quaternary playa sediments, Tertiary volcanic and sedimentary rocks	Tatlock (1969)
7 Leach Hot Springs	Quaternary alluvium, Tertiary sedimentary rocks, basalt of unknown age, Paleozoic metamorphic rocks	Tatlock (1969)
	Washoe County	
1 Steam Geyser (Needle Rocks)	Quaternary tufa and alluvium, Tertiary olivine basalt	Bonham (1969)
2 Great Boiling Spring	Cretaceous or Tertiary granodiorite, Quaternary alluvium and lake sediments	Bonham (1969)
3 Flowing well near Gerlach	Quaternary alluvium, late Tertiary basalts, tuffs, and volcanic sandstone	Bonham (1969)
4 Steamboat Springs	Cretaceous graondiorite	Thompson and White (1964)

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NEW MEXICO

New Mexico has approximately 60 thermal areas above 90°F (32°C). Thermal areas are concentrated in the block-faulted volcanic terrain of the southwest and along the faulted western margin of the Rio Grande Rift Valley. Heat flow in this region is up to 2.77 HFU. The Rio Grande trough is bounded on the east and west by discontinuous fault zones. Warm and hot springs are found along the faults which border the trough; most are on the west side of the trough.

Average temperature 90-100°F (32-38°C); temperatures ranged up to 240°F (116°C)
Total solids average 1,000 to 2,000 ppm
pH average 7.5, except Sandoval County with a 1.9 average pH

Best potential areas:
Animas Valley in Hidalgo County
Cliff-Gila-Riverside area in Grant County
Southern Rio Grande trough
Upper Jemez River Basin

Lemonade Spring
150°F (66°C)
216 ppm SiO_2
pH 1.9
1,950 ppm total solids

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS
(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
Bernalillo															
Source: Spring ("Clear Water Spring") Location: 9N.4E.24.1															
Remarks: About 50 yards north of Iron Spring															
—	69	7-25-45	—	—	—	—	—	—	218	48	—	234		890	0
Catron															
Source: Spring Location: 2S.14W.17.410															
Remarks: Across road from old church and near court house upper end of Mangas															
450	72	7-17-63	—	—	—	—	—	—		<1	—	62		115	22
Source: Aragon Springs Location: 5S.16W.3.300															
Remarks: "a" taken upstream from springs; "b" taken several hundred yards downstream from springs. Numerous springs in meadow															
2000	70	11-20-52	44	—	—	—	—	—	—	—	—	20		138	0
1000	68	11- 8-54	42	0.1	0.05	0.00	—	—	21	6.6	—	19	3.3	139	0
1500	70	7-16-63		—	—	—	—	—	22	6	—	13		124	0
"a" small	—	7-16-63		—	—	—	—	—	22	6	—	24		154	0
"b" —	70	7-16-63		—	—	—	—	—	28	6	—	14		146	0
Source: Frisco Hot Springs (upper) Location: 5S.19W.34.200															
Remarks: Discharge from alluvium collected at old bath house (FRH); runs out of Gila Conglomerate about 100 ft above floor of San															
—	98	5-22-58	58	—	—	—	0.00	0.01	—	—	2.2	66	0.5	57	55
Source: Frisco Hot Springs (lower) Location: 12S.20W.23.100															
Remarks: Discharges from lava of late Tertiary age, at temperatures ranging from 80°-124°F (S); temperature=130°F (P)															
20+	117.0	5-16-53	85	—	—	—	—	—	—	—	—	333		130	0
—	109	6-13-58	76	—	—	—	0.00	0.00	—	—	0	280	16	132	0
—	115	7- 6-59	—	—	—	—	—	—	49	40	—	289	—	127	0
Dona Ana															
Source: Well Location: 19S.5E.5.100															
Remarks: Two dug wells 65 ft deep															
—	69	—	—	—	—	—	—	—	120	106	—	858		171	104
Source: Radium Springs (Radium Hot Springs) Location: 21S.1W.10.213															
Remarks: Springs issue at base of rhyolite hill on east border of lowland of the Rio Grande; temperatures = 168°, 185°F (S); rhyolite															
—	—	5-17-48	71	—	—	—	—	—	142	23	—	1160		427	—
—	128	11-17-54	75	0.1	0.15	0.40	—	—	126	12	—	1100	161	417	0
10	120+	4-14-58	66	—	—	—	0.0	0.25	—	—	0.0	1100	155	424	0
—	—	5- 4-62	—	—	0.0	0.1	—	—	131	15	—	1100	163	416	—
—	—	8-31-22	60	—	1.2	—	—	—	138	17	—	1164	111	429	0
Source: Well Location: 21S.1W.20.200															
Remarks: (3 miles SW of Radium Springs) Drilled well, 2½ inches in diameter, 250 ft deep, cased to 150 ft, water-bearing formation =															
8-9	"hot"	5-25-58	46	—	—	—	0.01	0.18	—	—	0.0	227	6.0	534	0
Source: Cleolas Spring Location: 21S.1E.23.200															
Remarks: Discharges from andesite tuff															
0.5	65	4-24-58	39	—	—	—	0.02	0.00	—	—	0.0	66	5.5	216	0
Source: Well Location: 21S.1W.31.200															
Remarks: Drilled well 2½ inches in diameter, 51 ft deep, cased to 24 ft, water level 24 ft below land surface, water-bearing formation 20-															
4	68	4-24-58	56	—	—	—	—	—	—	—	—	95	6.6	310	0
Source: Well Location: 23S.1W.31.400															
Remarks: Drilled well 1200 ft deep, water level at 597 ft below land surface, water sample from 1030-1200 ft															
13.2	90	2-19-55	19	0.02	—	—	—	—	110	1.1	—	928		55	—
Source: Wildcat oil well Location: 28S.2W.24.213															
Remarks: Water was struck at 675 ft; sample from waste water pumped by well during drilling; contains detergent and possibly other															
500	113	11-25-61	—	—	—	—	—	—	—	—	—	1380	—	934	0
Grant															
Source: Gila Hot Springs Location: 13S.13W.5.241															
Remarks: Discharge from lava (S)															
25	147	6-23-57	33	—	0.00	—	—	—	11	0.2	—	129		109	0
100	147	7-25-62	68	0.31	0.00	0.00	—	—	12	0	—	121	3.6	106	0
Source: Hot Spring Location: 13S.13W.10.121															
10	126	6-23-57	—	—	—	—	—	—	—	—	—	—	—	108	0

New Mexico tables extracted from: Summers, W. K., A Preliminary Report on New Mexico's Geothermal Energy Resources, State Bureau of Mines and Mineral Resources, New Mexico Institute of Mining and Technology, Circular 80, 41 pgs., (1965)

WELLS INCLUDING CHEMICAL ANALYSES

pc. million unless noted)

SO₄	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hard-ness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity ($\mu\mu$c/1)	Ra ($\mu\mu$c/1)	U (μg/1)	Ref.
County																	
93	300	—	—	—	—		1330		742	—	232	—	—	—	—	—	4086
County																	
2	1	—	—	—	—				0.0	—	304	9.3	—		—	—	FRH
along east edge of canyon floor (B); issues from lake beds—sand, gravel, clay—of extinct Lake San Agustin (S&B)																	
7.0	5	0.4	0.5	—	—			—	86	0	236	—	—	—	—	—	21145
2.9	4.5	0.6	1.5	—	0.04			175	80	—	234	8.2	—	<7	<0.1	1.1	S&B
2	3	—	—	—	—			—	78	—	235	7.6	—	—	—	—	FRH
2	3	—	—	—	—			—	80	—	267	7.4	—	—	—	—	FRH
2	3	—	—	—	—			—	94	—	264	7.9	—	—	—	—	FRH
Francisco River bed, 130°F at 30 gpm (Sc)																	
6.6	5.0	1.0	0.8	—	0.04				10	0	284	9.7	—	—	—	—	38851
45	512	1.6	1.5	—	—				157	50	1930	—	—	—	—	—	22690
4	434	1.8	1.3	—	0.32				142	34	1660	7.6	—	—	—	—	38864
	460	—	—	—	—			1020	286	182	1780	7.8	—	—	—	—	42605
County																	
241	1541	—	—	—	—	3019			174	—	—	—	—	—	—	—	M&H
dikes intruded into latitic tuffs overlain by alluvium (S&B)																	
265	1680	4.6	2.0	—	—			3540	449	—	6060	—	—	—	—	—	C
255	1650	4.8	1.1	—	—			3620	364	—	6100	7.2	—	170	0.6	18	S&B
277	1660	5.7	1.4	—	0.32			—	380	32	5540	7.2	—	—	—	—	38867
269	1677	5.3	0.26	—	—	3660			390	—	6100	7.2	—	—	—	—	NMPHL
253	1752	—	—	—	—	3738	3707		352	—	—	—	—	—	—	—	2058
ndesite breccia																	
126	32	2.2	28	—	0.13				142	0	1130	8.2	—	—	—	—	38863
100	42	1.0	0.3	—	0.04				188	11	627	7.8	—	—	—	—	38862
l ft = latite tuff																	
49	10	5.2	16	—	.17				126	—	612	7.8	—	—	—	—	38847
927	910	—	3.3	—	—	2930			279		4640	8.6	—	—	—	—	H&K
rilling chemical contaminants; lime of Cretaceous age																	
456	1610	—	—	—	—				736	0	7380	7.3	—	—	—	—	48858
ounty																	
46	104	12	0.5	—	0.07	369			28	—	653	8.2	—	—	—	—	36105
45	102	9	0.07	0.00	—		414	421	30	0	638	7.5	—	—	—	—	4897
22	59	—	—	—	—				15	0	432	8.1	—	—	—	—	36104

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
															Grant
Source: Drilled well Location: 15S.17W.27.111															
Remarks: Gila Conglomerate; water level 17.5 ft below surface; well 300 ft deep; producing from 75-85 ft and 170-180 ft															
10	92	7-14-62	48	—	0.00	—	—	—	3.0	0.1	—	150		130	24
Source: Spring Location: 15S.17W.30.224															
Remarks: Gila Conglomerate															
30	77	9-14-55	—	—	—	—	—	—	—	—	—	—	—	123	14
Source: Allen Springs Location: 16S.15W.26.412															
Remarks: Issues from fault zone in limestone															
80	77.5	4- 2-54	18	—	—	—	—	—	78	39	—	18		387	0
Source: Drilled well Location: 16S.17W.9.242															
Remarks: 36 ft deep, diameter 8″, cased to 36 ft; water level 19 ft below surface															
—	86	6- 8-55	40	—	0.09	—	—	—	7.5	1.0	—	126		241	0
Source: Well Location: 16S.17W.34.212															
Remarks: Pipe in orifice; volcanic rock (latite ?); water level +60 ft below surface															
90	84	4-26-55	32	—	0.04	—	—	—	18	3.0	—	92		232	0
Source: Spring Location: 16S.18W.34.314															
Remarks: Volcanic tuff of Tertiary age and sandstone															
0.75	68	7-28-55	—	—	—	—	—	—	—	—	—	—	—	212	0
Source: Spring Location: 16S:21W.20.300 (?)															
Remarks: Spring in bed of Bitter Creek															
1	69	9-20-41	—	—	—	—	—	—	536	67	—	62	—	164	0
Source: Ash Spring Location: 17S.15W.20.222															
Remarks: Granite of Precambrian age															
0.25	72	8- -54	15	—	—	—	—	—	71	21	—	11		200	0
Source: Spring Location: 17S.21W.18.200 (?)															
Remarks: Spring at fault															
1	69	9-17-41	—	—	—	—	—	—	56	93	—	83	—	415	12
Source: Spring Location: 18S.9W.31.340															
5	71.5	6-10-52	—	—	—	—	—	—	—	—	—	—	—	160	0
Source: Goat Spring Location: 18S.9W.34.124															
Remarks: Mimbres conglomerate; water issues from joints in conglomerate striking N. 45 W., dipping 30° S															
20	66	3-21-57	—	—	—	—	—	—	—	—	—	—	—	210	0
Source: Mimbres Hot Springs Location: 18S.10W.18.100															
Remarks: "a" spring upstream from Mimbres spring; "b," Green Horse Spring; "c," Mimbres Hot Spring. Discharge 100 gpm at 135° and															
"a"															
10	79	6- 5-52	—	—	—	—	—	—	—	—	—	—	—	83	14
"b"															
10	135.55	6- 5-52	—	—	—	—	—	—	—	—	—	—	—	75	20
"c"															
20	137	6- 5-52	53	—	—	—	—	—	12	2.6	—	86		113	—
Source: Faywood Hot Springs Location: 20S.11W.20.243															
Remarks: Several springs discharging 120 gpm @ 142°F from base of lava slope; issues from top of travertine mound 20 ft high (S); (see															
15-20	129.2	6- 5-52	—	—	—	—	—	—	—	—	—	91		282	0
50	128	4-19-57	43	0.0	0.1	0.00	—	—	38	7.3	—	85	7.8	278	0
Include with data below: Pb = 0.00															
50	128	11- 9-54	—	—	—	—	0.0	0.0	37	8.5	—	—	—	282	0
Source: Well Location: 23S.15W.31.110															
Remarks: Drilled well 470 ft deep, water level 443 ft below surface															
—	82	5-16-55	34	—	0.15	—	—	—	44	13	—	123		229	0
															Guadalupe
Source: Spring Location: 8N.21E.1.333															
Remarks: Blue Hole at outlet to U.S. Fish Hatchery at Santa Rosa; yield of 500-1000 gpm at 65.5°F (B)															
500-1000	65.5	5- 6-59	16	—	—	—	—	—	620	62	—	33		181	0
															Hidalgo
Source: Blowing" well Location: 22S.21W.3.312															
Remarks: Well of unknown depth with water level 446 ft below the land surface, discharges water from the Santa Fe formation (H&K);															
5	88	7- 8-55	—	—	—	—	—	—	—	—	—	—	—	431	—

ND WELLS INCLUDING CHEMICAL ANALYSES (cont)
er ion unless noted)

O_4	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hard-ness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity ($\mu\mu$c/1)	Ra ($\mu\mu$c/1)	U (μg/1)	Ref.
ounty (Continued)																	
103	18	21	0.1	—	—		431	435	8	0	665	9.0	—	—	—	—	50019
	5.2	—	—	—	—				72	0	256	8.7	—	—	—	—	31368
20	38	0.8	2.4	—	—		404		355	38	621	—	—	—	—	—	26035
51	16	8.0	1.6	—	—	363	370		22	0	551	7.9	—	—	—	—	29790
8	8.5	6.0	0.1	—	—	311	312		58	0	472	7.9	—	—	—	—	29750
—	8.8	—	—	—	—				158	0	389	7.2	—	—	—	—	31374
9	21	1.1	0.8	—	—	2288			1613	—	255	—	—	—	—	—	1559
10	4	1.2	1.2	—	—		332		264	100	526	—	—	—	—	—	27635
3	21	0.9	20	—	—		773		522	—	118	—	—	—	—	—	1569
	9.0	5.2	—	—	—				66	—	347	—	—	—	—	—	19655
	9.0	—	—	—	—				132	0	353	7.4	—	—	—	—	38212
F from Mimbres fault zone (S): about 30 springs with a combined flow of 100+ gpm from latite and rhyolite at the surface (EBu)																	
	17	16	—	—	—				11	—	451	—	—	—	—	—	19647
	16	16	—	—	—				9	—	450	—	—	—	—	—	19645
5	17	16	0	—	—		308		40	0	457	—	—	—	—	—	19646
o JoEBu)																	
0	18	7.0	0.1	—	—			—	129	0	606	—	—	—	—	—	19824
2	16	6.8	0.2	0.00	—			384	125	—	605	7.4	—	19	29	0.1	S&B
	17	—	—	—	—				128	0	600	—	—	—	—	—	27917
3	23	2.8	3.5	—	—		549	553	164		820	8.0	—	—	—	—	29797
unty																	
0	48	0.5	0.1	—	—		2460		1800	1650	2620	7.3	—	—	—	—	42376
un'																	
perature is 95°F, depth is 449 ft (R)																	
	102	—	—	—	—				128		1590	7.8	—	—	—	—	H&K

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS
(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
Hidalgo															
Source: Wells Location: 25S.19W.7.234															
Remarks: A group of three irrigation wells in alluvium, ranging from 83 to 106 ft deep with casings perforated 42-90, ?, & 50-82 ft, drilled															
—	—	2- 1-49	—	—	—	—	—	—	24	1.5	—	324		146	0
—	240	4-28-49	141	—	—	—	—	—	19	1.2	—	329		181	0
—	—	7-30-51	—	—	—	—	—	—	—	—	—	—	—	163	7
—	—	3-28-52	—	—	—	—	—	—	—	—	—	—	—	163	7
—	210	4-27-54	138	0.1	0.07	0.00	—	—	21	0.7	—	324	21	145	6
—	—	4-10-55	135	—	—	—	—	—	22	1.5	—	319		157	0
Rio Arriba															
Source: Springs at Ojo Caliente Location: 24N.8E.															
Soda Spring															
15	95	10- 1-47	60	—	—	—	—	—	23	8.7	—	1040		2200	0
Soda Spring															
—	—	10- 6-49	66	—	—	—	—	—	25	9.0	—	997	29	2180	0
Sodium Sulfate Spring															
0.25	90	10- 1-47	56	—	—	—	—	—	25	8.7	—	1040		2210	0
Soda Spring															
—	115	10- 6-49	60	0.3	1.2	—	—	—	23	9.5	Trace	996	31	2230	—
Bath House															
10	105	10- 6-49	63	—	0.02	—	—	—	24	7.6	—	933	34	2160	0
Arsenic Spring															
—	113	10- 6-49	63	—	0.01	—	—	—	25	8.9	—	928	30	2160	0
Source: Spring Location: 25N.8E.25															
Remarks: Three almost contingent springs; from Dakota Sandstone (?)															
Field 1															
—	97	9- 5-52	—	—	—	—	—	—	—	—	—	—	—	692	0
Field 2															
—	97	9- 5-52	—	—	—	—	—	—	—	—	—	—	—	698	0
Field 3															
—	97	9- 5-52	—	—	—	—	—	—	—	—	—	—	—	694	0
Field 4															
—	97	9- 5-52	22	—	—	—	—	—	145	59	—	187		698	0
Field 5															
—	65	9-15-52	15	—	0.01	—	—	—	44	11	—	11		73	0
Sandoval															
Source: Spring Location: 13N.4E.36.323															
Remarks: Seep in arroyo bottom at fault															
0.5	68	8- 9-62	—	—	—	—	—	—	—	—	—	10	1.2	291	0
Source: San Ysidro Warm Springs Location: 15N.1E.3, 9, and 10															
Remarks: A group of several springs north of Rio Salado, deposits of calcareous tufa around spring (Ri); several springs issuing from															
—	68	9-15-24	15	—	3.0	—	—	—	368	85	—	2219		1757	—
—	—	3- 6-45	—	—	—	—	—	—	322	84	—	1830		1780	0
—	—	3- 6-45	—	—	—	—	—	—	306	73	—	2080		2000	0
—	—	3- 2-45	—	—	0.48	—	—	—	324	85	—	1850		1820	0
5-10	72	9-29-48	16	—	—	—	—	—	300	74	—	2100		2020	0
Source: San Ysidro Hot Springs Location: 15N.1E.8.400															
Remarks: Issues from faulted beds of Triassic age (S); calcareous tufa around spring (Ri)															
—	86	9-15-24	15	—	2.0	—	—	—	497	91	—	3310		1969	—
Source: "Hot well" Location: 16N.1W.1 (unsurveyed)															
Remarks: Drilled well 12" in diameter, 550 ft deep (Ri), 2008 ft deep [Aqua Zarca, 600 ft; San Andres, 870 ft; Abo, 1535 ft; Magdalena,															
—	115	9-29-26	18	—	2.3	—	—	—	400	73	—	3450		1498	—
Include with data below: Mo = 0.00; Pb = 0.6; Li = 6.9; As = 0.60; Br = 0.3; I = 4.6; Se = 0.00															
1500	130	3-14-64	31	2.6	3.9	0.01	0.04	1.5	345	56	—	3550	87	1450	0
Source: Spring and oil test well Location: 16N.1W.1.410															
Remarks: The flowing abandoned well is an oil test, rich in H_2S and other gases; the oil test is 2000 ft deep															
—	180	4- 3-56	35	—	—	—	—	—	328	76	—	3500		1470	0
—	—	7-29-58	31	—	0.00	—	—	—	301	67	—	3590		1410	0
Well															
—	140	9-29-48	27	—	—	—	—	—	368	73	—	3640		1470	0
Source: Swimming pool spring Location: 16N.4E.20 (unsurveyed)															
—	70	9-14-24	30	—	0.60	—	—	—	260	70	—	2400		1301	—
Source: Indian Spring Location: 16N.2E.29.142															
2	95	8-30-62	48	—	0.03	—	—	—	100	8.6	—	1240		1280	0

D WELLS INCLUDING CHEMICAL ANALYSES (cont)

r million unless noted)

h	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity (μμc l)	Rn (μμc l)	U (μg l)	Ref.
unty (Continued)																	
to "hard rock" and "solid rock, very hot" (R)																	
9	87	—	5	—	—			1020	68	0	[illegible]	--	.		--	-	R
0	78	11	0.9	—	0.45			[illegible]	52	0	[illegible]	--	--		--	--	12254
—	81	—	—	—	—			—	—	0	1650		--		--		S
-	82	—	0.4	—	—			—	55	—	1600	8.2	--	-	—	--	R
74	83	9.9	0.3	—	—			1160	56	—	1580	8.4	—	12	0.3	0.2	S&B
59	80	13	0.2	—	—			1110	61	0	1510	7.6	—	—	—	—	R
ounty																	
58	238	16	1.6	—	1.7		2640		106	0	3890	—	—	—	—	—	8977
62	240	16	0.9	—	—		2620		100	0	3910	7.2	—	—	—	—	13378
65	245	16	1.7	—	4.6		2650		106	0	3890	—	—	—	—	—	8978
1	231	0.84	0.9	0.2	1.2				—	—	—	7.2	—	—	—	—	WH&W
56	238	16	0.5	—	1.7		2540		91	0	3920	6.9	—	—	—	—	13192
56	238	16	0.8	—	1.6		2530		99	0	3930	7.1	—	—	—	—	13193
—	107	—	—	—	—				—	—	1730	—	—	—	—	—	20032
-	111	—	—	—	—				—	—	1760	—	—	—	—	—	20033
-	108	—	—	—	—				—	—	1740	—	—	—	—	—	20034
70	110	1.4	0.2	—	—		1140		604	32	1740	—	—	—	—	—	20035
10	2.5	0.2	0.2	—	—		230		115	95	347	7.0	—	—	—	—	20119
unty																	
57	6.4	—	0.6	—	—				294	56	563	7.4	—	—	—	—	50288
ulted crest of anticline (S)																	
12	1940	—	Trace	—	—	7320			—	—	—	—	—	—	—	—	Ri
00	1710	—	—	—	BO_3=60		6020		1150	0	903	—	—	—	—	—	3478
0	1920	—	—	—	BO_3=60		6560		1060	0	980	—	—	—	—	—	3479
10	1700	—	—	—	—		6100		1160	0	896	—	—	—	—	—	3548
10	1880	3.8	5.1	—	10.3		6610		1050	0	9750	6.5	—	—	—	—	10983
01	2500	—	Trace	—	50	10960			1608	—	—	—	—	—	—	—	Ri
90 ft] (B)																	
15	2660	—	0	—	—			11120	1299	—	—	—	—	—	—	—	Ri
60	2990	2.8	0.2	—	4.8		11000		1090	0	15300	7.3	—	—	—	—	54144
20	2900	—	—	—	—		10900		1130	0	15000	6.6	—	—	—	—	32740
10	2970	4.5	8.1	—	6.6		11000		1030	0	14900	7.2	—	—	—	—	39231
10	3010	2.6	—	—	6.6		11400		1220	14	15400	6.8	—	—	—	—	10984
28	2330	—	Trace	—	—			7510	—	937	—	—	—	—	—	—	Ri
86	1140	7.3	0.3	—	6.1		3470		285	0	5680	8.0	—	—	—	—	50248

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
Sandoval															
Source: Spring at Ojo del Espiritu ranch house (CCC camp on San Ysidro quadrangle) Location: 17N.1W.15 (unsurveyed)															
—	60	9 22-24	30	—	0.30	—	—	—	90	12	12	12		259	
Source: Soda Dam springs (The Sulphurs) Location: 18N.2E.14 (unsurveyed)															
Remarks: Large tufa deposit in channel of Jemez River from flow of about 10 gpm at 75°-105°F (S); at contact of granite of Precambrian															
---	104	8-21-24	48	—	0.10	—	—	—	328	23	—	1000		1440	—
40	96	6-28-49	47	—	—	—	—	—	327	27	—	830		1400	0
Sulphur Pool															
—	100	8- 2-49	—	—	—	—	—	—	—	—	—	—	—	1500	0
Sulphur Pool															
10	102	6-24-49	47	—	—	—	—	—	330	29	—	1170		1540	0
Sulphur Pool															
1	—	1-20-50	42	—	—	—	—	—	221	29	—	1020	197	1200	0
Sulphur Pool															
—	—	12-20-49	—	—	—	—	—	—	—	—	—	—	—	1520	0
Geyser Spring															
—	—	10-10-50	—	—	—	—	—	—	—	—	—	—	—	1550	0
Geyser Spring															
—	—	6-20-50	—	—	—	—	—	—	—	—	—	—	—	1550	0
Geyser Spring															
—	110	8- 2-49	—	—	—	—	—	—	—	—	—	—	—	1580	0
Geyser Spring															
5	—	6-28-49	47	—	—	—	—	—	344	29	—	1140		1580	0
Geyser Spring															
—	—	12-20-49	—	—	—	—	—	—	—	—	—	—	—	1590	0
—	—	8-31-46	—	—	—	—	—	—	—	—	—	—	—	883	0
Hole-in-Rock Spring															
—	—	6-14-49	35	—	—	—	—	—	304	32	—	932		1560	0
Sulphur Pool															
—	—	8-31-49	48	—	0.04	—	—	—	332	33	—	1000	183	1530	0
—	104	8-21-24	48	—	0.10	—	—	—	328	23	—	1000		1440	0
2	81	6-26-49	43	—	—	—	—	—	326	30	—	1200		1550	0
25	95	8- 2-49	44	—	—	—	—	—	326	27	—	986		1440	0
—	—	8 31-46	—	—	—	—	—	—	346	33	—	1230		1530	0
—	—	8-31-46	—	—	—	—	—	—	314	32	—	989		1560	0
0.5	102	6-14-49	47	—	—	—	—	—	340	31	—	1170		1590	0
Well															
12.5	—	12-13-57	—	—	—	—	—	—	—	—	—	—	—	338	5
Dug Pit															
40	96	6-28-49	47	—	—	—	—	—	327	27	—	830		1400	0
Source: Jemez Hot Springs Location: 18N.2E.23 (unsurveyed)															
Remarks: About 10 springs flowing 200 gpm with temperatures ranging from 94° to 168°F from faults in redbeds of Permian age (S)															
Bath House															
--	125	8-21-24	91	—	1.2	—	—	—	166	9.0	—	645		791	—
—	160	4- 3-56	86	—	—	—	—	—	136	10	—	618	70	716	0
Main Spring No. 1															
—	—	4-15-47	47	—	0.04	—	—	—	18	6.2	—	12	3.6	94	0
Main Spring No. 2															
—	—	4-15-47	60	—	0.01	—	—	—	47	14	—	14	3.0	228	0
No. 3															
—	—	4-15-47	51	—	0.01	—	—	—	34	10	—	39	3.8	232	0
--	164	8- 1-47	64	—	0.0	—	—	—	137	4.4	—	701		750	0
25	—	6-14-49	91	—	—	—	—	—	137	9.0	—	677		740	0
Behind Bath House															
10	150	6-14-49	92	—	—	—	—	—	140	9.4	—	680		758	0
10	150	8-31-49	93	—	0.03	—	—	—	138	6.6	—	572	70	735	0
Behind Bath House															
20	152	10-24-51	—	—	—	—	—	—	—	—	—	—	—	727	0
Source: Hot spring (McCauley Spring) Location: 18N.3E.4															
Remarks: Issues at base of recent volcanic flow on contact with red beds of Permian age; no obvious mineralization															
110	98	8- 1-47	53	—	0	—	—	—	11	4.2	—	23		87	0
Source: Sulphur Springs on Sulphur Creek Location: 19N.3E.4 (unsurveyed)															
Remarks: Thermal waters issue from volcanics of late Tertiary age (Ri); about 8 springs discharging 500 gpm at 86°-167°F from andesites															
Ladies Bath House; Acidity as SO_4 = 2304															
—	110	8-31-24	276	195	369	—	Trace	—	321	24	—	304		0	0
Alum Spring; Acidity as SO_4 = 2328															
--	76	8 31-24	146	421	72	—	—	—	316	51	—	127		0	0
Alum Spring; Acidity as SO_4 = 2570															
—	61	8-13-47	170	501	2.8	—	—	—	256	35	—	—	—	0	0
Laxative Spring; Acidity as SO_4 = —															
—	—	8-31-49	42	—	0.64	—	—	—	168	23	—	14	—	0	0

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO_4	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity ($\mu\mu$c/1)	Ra ($\mu\mu$c/1)	U (μg/1)	Ref.
County (Continued)																	
99	4	—	0.25	—	—	396			274	—	—	—	—	—	—	—	Ri
and Magdalena Group (Ri) (see Jo)																	
40	1320	—	Trace	—	—	3458			914	—	—	—	—	—	—	—	Ri
51	1080	2.4	1.3	—	8.7		3060		927	—	5160	6.8	—	—	—	—	12208
39	1540	—	—	—	—				—	—	6610	—	—	—	—	—	12529
42	1540	3.2	1.0	—	14		3920		942	0	6600	6.9	—	—	—	—	12210
39	1510	3.3	4.3	—	—		3660		670	0	6150	—	—	—	—	—	13845
—	1530	—	—	—	—				—	—	6530	—	—	—	—	—	13484
—	1550	—	—	—	—				—	—	6620	—	—	—	—	—	15097
—	1550	—	—	—	—				—	—	6590	—	—	—	—	—	15096
40	1510	—	—	—	—				—	—	6590	—	—	—	—	—	12530
42	1500	3.2	1.3	—	13		3880		978	0	6520	6.9	—	—	—	—	12211
—	1520	—	—	—	—				—	—	6530	—	—	—	—	—	13485
912	1570	—	—	—	—				—	—	5970	—	—	—	—	—	7124
60	1110	3.2	1.6	—	9.8		3250		890	0	5410	6.9	—	—	—	—	12146
41	1550	3.6	1.4	—	12		3950		964	0	6570	6.9	—	—	—	—	13080
40	1320	—	Trace	—	BO_3=2.5		3471		914	—	3458	—	0	—	—	—	3227
40	1580	3.6	1.2	—	12		3990		937	0	6720	7.0	—	—	—	—	12209
5	1300	2.8	1.7	—	9.1		3440		924	0	5860	—	—	—	—	—	12531
263	1520	3.5	1.5	—	—		4150		999	0	651	—	—	—	—	—	7125
53	1220	2.8	1.4	—	—		3380		915	0	563	—	—	—	—	—	7126
37	1540	4.0	2.0	—	12.5		3950		976	0	6620	6.7	—	—	—	—	12147
—	9.0	—	—	—	—				266	0	563	8.3	—	—	—	—	—
51	1080	2.4	1.3	—	8.7		3060		927	0	5160	6.8	—	—	—	—	12208
(see also RiJoP)																	
42	820	—	5.0	—	2.5	2184			452	—	—	—	—	—	—	—	Ri, 3226
44	870	5.2	0.5	—	—		2190		380	0	3860	6.7	—	—	—	—	32741
15	4	0.8	0.4	—	0.0		153		70	0	1840	—	—	—	—	—	8252
15	4	0.8	0.3	—	0.0		270		175	0	3510	—	—	—	—	—	8253
17	4	0.8	0.3	—	BO_3=0.0		274		126	0	3640	—	—	—	—	—	8254
44	855	7.1	0.4	—	6.33		2180		360	0	3700	7.2	—	—	—	—	8928
51	835	4.9	1.7	—	—		2170		379	0	3640	7.6	—	—	—	—	12139
51	835	4.9	1.5	—	—		2190		388	0	3670	7.7	—	—	—	—	12140
49	795	5.2	0.8	—	11	2150	2090		372	0	3560	7.2	—	—	—	—	13079
—	—	—	—	—	—				—	—	3680	—	—	—	—	—	17772
8.0	8.0	1.6	0.4	—	BO_3=0		152		45	0	19.8	8.1	—	—	—	—	8929
and rhyolites of Tertiary age (S) (see also GPH)																	
3560	294	—	0	77	—	6270	5420		—	—	—	—	8.2	—	—	—	3224
3159	1.0	—	Trace	41	—	4344	4344		—	—	—	—	2.1	—	—	—	3221
	170	0.7	0.4	—	—				—	—	826	1.8	—	—	—	—	8937
614	8.0	0.0	0.4	—	—	967			514	514	1270	3.1	—	—	—	—	13257

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
															Sandoval
Source: Sulphur Springs on Sulphur Creek (cont)															
Lemonade Spring															
—	150	8-31-49	216	56	33	3.3	—	—	185	52	—	6.7	24	0	0
Men's Bath House															
—	110+	8-31-49	219	205	217	—	—	—	66	17	—	42		0	0
Bath House; As = 0.05; Li = 0.07; Pb = 0.12 Se = 0.03															
—	188	11- 4-63	190	36	115	0.33	—	—	6.9	9.7	—	24	31	0	0
Foot Bath															
—	99	8-31-24	259	90	252	—	—	—	41	16	—	52		0	—
Lemonade Spring															
—	115	8-13-47	162	—	1.8	—	—	—	150	73	—	—		0	0
Lemonade Spring															
1	130	7-28-49	—	—	—	—	—	—	—	—	—	—	—	—	—
Lemonade Spring; Se = 0.00															
—	—	1-20-50	—	—	—	—	—	—	—	—	—	—	—	—	—
Lemonade Spring															
—	—	10-24-51	—	—	—	—	—	—	—	—	—	—	—	—	—
Men's Bath House; Acidity as SO_4=5400															
—	—	8-31-24	324	303	1250	—	—	—	303	33	—	157		0	0
Ladies' Bath House															
—	—	8-31-49	237	172	93	—	—	—	110	11	—	24	—	0	0
Mud Bath															
—	99	7-28-49	—	—	—	—	—	—	—	—	—	—	—	—	—
Hot Sulphur Mud Bath															
—	80-98	8-13-47	—	694	22	1.1	—	—	154	42	—	—	12	—	—
Mud Foot Bath															
—	97	8-13-47	122	469	12	—	—	—	7.2	19	—	—	—	0	0
Footbath Spring															
—	72	7-28-49	—	—	—	—	—	—	—	—	—	—	—	—	—
Mud Bath															
—	105	8-31-49	174	104	92	—	—	—	45	12	—	13	—	0	0
Electric Spring															
—	97	8-13-47	166	—	3.4	—	—	—	140	161	—	—	—	0	0
Electric Spring															
15	102	7-28-49	—	—	—	—	—	—	—	—	—	—	—	—	—
Electric Spring															
1	—	8-31-49	206	194	81	—	—	—	101	23	—	9.6	42	0	0
Alum and Boric Spring															
—	72	8-13-47	—	364	17	—	—	—	372	43	—	—	47	—	—
Sulphur Creek below Sulphur Springs															
—	—	10-22-49	83	76	40	—	—	—	164	24	—	16	—	0	0
Source: Hot spring (Natural Bath-Tub) Location: 19N.3E.28.310															
Remarks: Issues at base of recent volcanic flow on contact with red beds of Permian age; no observable mineralization; elevation 7350 ft															
—	100	8- 1-47	71	—	0	—	—	—	7.5	2.2	—	56		139	0
Source: Steam well Location: 20N.3E.35 (unsurveyed)															
Remarks: Analyses reported to be of steam condensate which would enter stream as runoff															
—	—	6-13-63	—	—	12.6	0.5	—	—	28	0	—	83	27	623	—
—	—	6-18-63	—	—	1.05	0.03	—	—	2	1.2	—	83	31	854	—
Source: Alamo Canyon Spring Location: 20N.3E.35															
Remarks: Over area approximately 50 × 100 ft are numerous points evolving gas, some sulfurous gas but largely CO_2; elevation 8700 ft;															
—	—	8- 1-47	87	—	0.41	—	—	—	32	22	—	—	—	0	0
Source: Spring on Rio Antonio (warm spring) Location: 20N.4E.7 (unsurveyed)															
Remarks: Issues from rhyolite of Tertiary age (He); 50 gpm at 120°F (S) (see also P)															
25	101	8- 1-47	103	—	0	—	—	—	6.5	1.1	—	40		77	0
															San Miguel
Source: Spring Location: 16N.16E.6															
1	106	3-11-52	68	—	0.02	—	—	—	4.5	1.0	—	179		77	16
5	123	3-11-52	59	—	0.03	—	—	—	4.5	1.1	—	179		66	22
Source: Montezuma Hot Springs Location: 16N.16E.6															
—	—	5-16-39	—	—	—	—	—	—	14	8.3	—	141		—	—
—	130	7- 2-40	—	—	—	—	—	—	8.5	0.7	—	173		92	11
—	—	8-20-40	—	—	—	—	—	—	—	—	—	—	—	82	13
—	—	8-20-40	—	—	—	—	—	—	—	—	—	—	—	80	15
															Sierra
Source: Oil test, Victoria Land and Cattle Company No. 2 Location: 10S.2W.25.100															
Remarks: Flow from 1328 to 1347 ft from San Andres Limestone (H&K)															
900	94	—	—	—	—	—	—	—	—	—	—	—	—	636	—

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO₄	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids, (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (µmhos at 25°C)	pH	H_2S	Total β-γ activity (µµc/1)	Ra (µµc/1)	U (µg/1)	Ref.
County (Continued)																	
1570	3.5	1.1	0	—	—	1950			676	0	4570	1.9	—	—	—	—	He, 13260
1250	45	0.9	0.5	—	—		3630		234	234	13900	1.4	—	—	—	—	13253
5100	24	1.2	0.0	2.4	—				57	57	13800	2.0	—	—	—	—	5300
2337	20	—	0	154	—	2562	3221		168	—	—	—	1.6	—	—	—	Ri, 3225
1190	65	1.0	0.3	—	—				—	—	—	2.0	—	—	—	—	8935
1590	—	—	—	—	—				—	—	4570	2.2	—	—	—	—	12524
—	—	—	—	—	—				—	—	3560	2.2	—	—	—	—	13558
—	—	—	—	—	—				—	—	2710	2.3	—	—	—	—	17774
6156	54	—	Trace	37	—	7887	8617		—	—	—	—	—	—	—	—	3223
2740	20	0.5	0.6	—	—	2690			320	320	8510	1.6	—	—	—	—	13254
550	—	—	—	—	—				—	—	6100	1.9	—	—	—	—	12520
430	241	—	—	—	—				—	—	1410	1.9	—	—	—	—	9171
190	649	—	0.3	—	—				—	—	1660	1.5	—	—	—	—	8934
230	—	—	—	—	—				—	—	13900	1.7	—	—	—	—	12519
1440	—	—	0.7	—	—	1730			162	162	4370	1.9	—	—	—	—	13258
15	410	1.5	0.3	—	—				—	—	1170	1.5	—	—	—	—	8936
880	—	—	—	—	—				—	—	12500	1.7	—	—	—	—	12522
820	2.5	1.0	0.0	—	—	3160			346	346	12700	1.4	—	—	—	—	13259
560	74	—	—	—	—		364		—	—	794	2.9	—	—	—	—	9172
1160	4.0	0.3	0.0	—	—	1600			508	508	2270	2.5	—	—	—	—	13262
17	11	0.8	0.2	—	0.8		234		28	0	28.3	7.3	—	—	—	—	8933
335	121	24	0.00	—	—	2970			70	—	2225	8.0	—	—	—	—	NMPHL
177	114	24	0.00	—	—	1700			10	—	2070	8.3	—	—	—	—	NMPHL
acidity as H_2SO_4 = 153																	
242	3.0	0.3	0.6	—	BO_3=0.2				—	—	72.1	2.9	—	—	—	—	8930
15	17	1.6	0.4	—	0		222	230	20	0	16.7	6.7	—	—	—	—	He
County																	
42	155	20	0.1	—	—	528	524		15	0	876	8.8	—	—	—	—	18610
42	155	20	0.1	—	—	530	515		16	0	876	9.0	—	—	—	—	18609
66	154	—	—	—	—	554			—	—	878	—	—	—	—	—	2083
49	158	—	0.2	—	—	537			—	—	870	—	—	—	—	—	4801
—	160	—	—	—	—	531			—	—	878	—	—	—	—	—	5233
	159	—	—	—	—	523			—	—	872	—	—	—	—	—	5233
County																	
1660	22	—	—	—	—				1850	—	1850	7.2	—	—	—	—	H&K

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
														Sierra	
Source: Warm spring Location: 12S.5W.28															
Remarks: In Cuchillo Canyon, 10 miles NW of T or C and 15 miles W of Cuchillo (Th)															
—	85.6	2-9/10-39	37	—	0.00	—	—	—	109	10	—	386	26	212	0
Source: Drilled wells at Truth or Consequences Location: 13S.4W.33															
Remarks: (for detailed location, see Th) Magdalena Limestone (Th); "discharge," respectively, from 27 ft, 105 ft, and 100 ft deep															
—	112.3	2-9/10-39	38	—	0.10	—	—	—	150	16	—	692	45	218	—
—	114	2-9/10-39	—	—	0.07	—	—	—	152	18	—	740	—	210	—
—	111.2	2-9/10-39	—	—	0.42	—	—	—	155	17	—	772	—	214	—
Source: Springs at Truth or Consequences Location: 13S.4W.33															
Remarks: Discharge from alluvium (for detailed description, see Th)															
1.3	103-106	9-9/10-39	36	—	0.1	—	—	—	154	14	—	731	39	215	0
1	99-103	2-9/10-39	37	—	0.08	—	—	—	148	16	—	678	36	212	0
Old Gov't Spring															
—	106	7-23-38	—	—	—	—	—	—	168	36	—	687	53	217	0
Source: Drilled well in Truth or Consequences Location: 13S.4W.34.310															
Remarks: Valley fill; well 120 ft deep (Th)															
—	70	2-9/10-39	18	—	3.30	—	—	—	460	76	—	661	21	152	—
Source: Palomas Spring Location: 13S.5W.31.130															
Remarks: Santa Fe Formation															
—	—	6-12-58	—	—	—	—	—	—	—	—	—	—	—	171	0
Source: Wells of Truth or Consequences Location: 14S.4W.4															
Remarks: (for detailed location, see Th) Magdalena Limestone (Th); "discharge," respectively, from 212 ft and 208 ft deep															
—	—	2-9/10-39	—	—	0.08	—	—	—	154	16	—	730	—	121	—
—	—	2-9/10-39	32	—	0.53	—	—	—	153	15	—	714	43	219	—
Source: Yucca Baths at Truth or Consequences (Ponce de Leon Spring) Location 14S.4W.4															
Remarks: (for detailed location, see Th) Alluvium samples from 14 ft deep drive point into spring head (Th)															
—	110	2-9/10-39	—	—	0.08	—	—	—	154	19	—	751	—	218	—
2	110	3-31-52	39	—	0.01	—	—	—	174	25	—	692		221	—
1.1	109	5-28-54	41	0.1	0.02	0.19	—	—	154	21	—	735	61	216	0
Well 14 ft deep															
—	109.4	4-28-43	—	—	—	—	—	—	—	—	—	—	—	—	—
0.5	—	7-12-54	—	—	—	—	—	—	156	20	—	749		220	0
0.75	110	8- 2-55	—	—	—	—	—	—	—	—	—	—	—	221	0
0.75	110.5	9-17-56	—	—	—	—	—	—	—	—	—	—	—	216	0
Flowing Well															
8.5	108	8- 5-57	—	—	—	—	—	—	—	—	—	—	—	228	0
Bath House Spring															
—	104	4-15-58	—	—	—	—	—	—	—	—	—	—	—	227	0
North Spring															
—	107	8- 3-59	—	—	—	—	—	—	—	—	—	—	—	221	0
—	104	4- 4-60	—	—	—	—	—	—	—	—	—	—	—	220	0
—	107.5	8-13-62	—	—	—	—	—	—	—	—	—	—	—	220	0
Source: City well No. 2 at Truth or Consequences Location: 14S.4W.6															
Remarks: (for detailed location, see Th) Alluvium; well 200 ft deep (Th)															
—	77	2-9/10-39	21	—	2.20	—	—	—	58	5	—	131	9	125	—
Source: Drilled well Location: 15S.6W.31.34															
Remarks: 193 ft deep, diameter 6"; alluvium; water level at 100 ft															
15	70.2	8-20-46	—	—	—	—	—	—	63	21	—	36		242	0
Source: Drilled well at Hot Springs Location: 16S.5W.22															
40	75	6-14-46	—	—	—	—	—	—	21	4.4	—	59		169	0
Source: Derry Warm Springs Location: 17S.4W.29.340															
Remarks: Issues from limestone bluff on east side of Rincon Valley (C); small dpeosits of travertine; flows approximately 50 gpm from 2															
50	93	4-17-48	—	—	—	—	—	—	52	19	—	303		370	0
5-10	93.2	5- 7-52	32	—	—	—	—	—	48	20	—	293		372	0
10-15	93	4-30-57	—	—	—	—	—	—	—	—	—	—	-	368	0
														Socorro	
Source: Springs Location: 1N.1E.31.320															
Remarks: Sand and gravel; flow in area may be as much as 100 gpm; (a) pipe from side of hill at pond on railroad near San Acacia; (b)															
(a) 25	70	7- 9-63	—	—	—	—	—	—	368	143	—	900		178	0
(b) <1	68	7- 9-63	—	—	—	—	—	—	320	118	—	900		163	0

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO_4	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (µmhos at 25°C)	pH	H_2S	Total β-γ activity (µµc/l)	Ra (µµc/l)	U (µg/l)	Ref.
County (Continued)																	
79	650	2.4	25.0	—	0.5	1428	1429		314	—	—	—	—	—	—	—	Th
102	1230	3.4	2	—	—	2486			441	—	—	—	—	—	—	—	Th
74	1280	2.6	—	—	—				—	—	—	—	—	—	—	—	Th
73	1330	3.2	—	—	—				457	—	—	—	—	—	—	—	Th
79	1300	3	10	—	—	2560	2472		442	—	452	—	—	—	—	—	Th
81	1210	3	5	—	—	2418	2318		236	—	429	—	—	—	—	—	Th
95	1314	—	—	—	—				—	—	459	—	—	—	—	—	684
1193	1120	1.6	4	—	—	3720			1462	—	—	—	—	—	—	—	Th
23	114	—	—	—	—				158	18	664	7.7	—	—	—	—	38787
75	1250	2.8	—	—	—				451	—	—	—	—	—	—	—	Th
105	1240	3.2	6.2	—	—	2437			444	—	—	—	—	—	—	—	Th
86	1290	3.2	—	—	—				463	—	—	—	—	—	—	—	Th
98	1240	2.8	2.7	—	—		2380	2640	537	—	4430	7.2	—	—	—	—	S&B
93	1290	3.3	2.0	—	—			2670	470	—	4510	7.3	--	100	0.7	3.3	S&B
—	1285	—	—	—	—				—	—	438	—	—	—	—	—	653
95	1290	—	—	—	—		2420		471	290	4420	—	—	—	—	—	27039
91	1300	—	—	—	—				490	309	4450	7.4	—	—	—	—	31082
91	1290	—	—	—	—				525	348	4450	7.4	—	—	—	—	33929
—	1280	—	—	—	—				470	283	4400	7.2	—	—	—	—	38827
—	1280	—	—	—	—				475	289	4460	7.2	—	—	—	—	38930
—	1290	—	—	—	—				—	—	4450	7.2	—	—	—	—	43037
96	1300	—	—	—	—				470	290	4450	7.5	—	—	—	—	44734
—	1310	—	—	—	—				510	330	4480	7.2	—	—	—	—	50301
52	212	0.6	1	—	—	556			166	—	—	—	—	—	—	—	Th
80	26	1.2	1.2	—	—		348		244	45	60.9	—	—	—	—	—	6870
36	13	1.2	0.8	—	0.0		219		70	0	36.0	—	—	—	—	—	6135
levels: (1) 5 ft above floor at 92°F, (2) 6 ft above at 66°F from alluvial material above Derry fault block																	
309	160	5.8	2.0	—	—		1030		208	—	1650	—	—	—	—	—	C
306	141	6	1.3	—	—		1030		207	0	1660	—	—	—	—	—	18725
303	158	—	—	—	—				192	0	1660	7.4	—	—	—	—	35977
County																	
bank of railroad just north of (a)																	
[illegible]	1816	—	—	—	—				1510	—	6970	7.4	—	—	—	—	FRH
920	1526	—	—	—	—				1284	—	6080	7.6	—	—	—	—	FRH

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
														Socorro	
Source: Spring Location: 1N.2W.7.100															
Remarks: Madera Limestone (see H&K)															
500	70	11-30-49	—	—	—	—	—	—	138	59	—	887		420	0
Source: Artesian spring Location: 1N.2W.7.132															
Remarks: (mouth of box on Rio Salado) Madera Limestone															
—	72	11-19-61	—	—	—	—	—	—	—	—	—	—	—	398	0
Source: Well Location: 1N.2E.34.130															
Remarks: 33 ft deep															
—	65	—	21	—	—	—	—	—	562	130	—	21		142	—
Source: Ojitos Springs Location: 2S.1W.19.431 and 2S.1W.19.414															
Remarks: A group of springs discharging from rhyolite breccia fault zone															
106	—	1952	—	—	—	—	—	—	50	12	—	67		308	—
—	68	7- 9-63	—	—	—	—	—	—	29	11	—	38		195	0
—	—	7- 9-63	—	—	—	—	—	—	40	14	—	76		332	0
Source: Cook Spring Location: 3S.1W.15.313; temperature in pond															
10-15	66	3-20-58	28	—	—	—	0.00	0.00	—	—	—	66	3.0	175	0
Include with data below: Li = 0.33															
—	70	9-24-64	26	—	0.58	—	—	—	13	4	—	68	3.4	158	3
Source: Well (Blue Canyon) Location: 3S.1W.16.323															
Remarks: Drilled well 300 ft deep, water level 210 ft below surface in rhyolite breccia															
20	90.4	7-24-56	26	—	—	—	—	—	—	—	—	53		145	8
—	88	12-20-61	—	—	—	—	—	—	18	5	—	55		166	0
—	89	4-10-65	27	—	—	—	—	—	20	4.6	—	56	3	163	0
Source: Socorro warm springs Location: 3S.1W.22.113															
Remarks: (S) Several springs flowing from lake beds of Tertiary age lying against lava hills flowing 500 gpm at 91°F (S&B); flow from															
—	—	2-17-36	—	—	—	—	—	—	19	4	—	55	5	168	—
—	—	12- 4-36	—	—	—	—	—	—	18	5	—	53		156	—
—	91	1952	—	—	—	—	—	—	19	5	—	53		163	—
353	90	1-24-57	27	0.00	0.00	0.00	—	—	18	3.9	—	52	2.8	154	0
220	90	3-20-58	39	—	—	—	0.00	0.04	—	—	1.6	55	3.0	160	5
—	91	12-12-61	—	—	—	—	—	—	18	5	—	50		163	0
—	91	2- 5-63	—	—	—	—	—	—	13	5	—	—	—	156	0
—	92	4-10-65	—	—	—	—	—	—	18	4.4	—	—	—	155	0
Source: Sedillo Spring Location: 3S.1W.22.131															
Remarks: Issues from rhyolite breccia															
240	90	3-20-58	27	—	—	—	0.00	0.04	—	—	0.00	54	2.9	159	0
—	88	12-12-61	—	—	—	—	—	—	18	5	—	50		154	5
Source: Ojo de las Cañas, east of Rio Grande Location: 3S.2E.19.323															
Remarks: Controlled by prominent east-dipping sandstone bed in Yeso Formation, with fault control downstream (FRH)															
—	79	6-13-62	—	—	—	—	—	—	552	141	—	38		193	0
10	—	3-15-63	—	—	—	—	—	—	488	141	—	—	—	142	0
Source: Well Location: 4N.2E.35.220															
Remarks: 187 ft deep															
—	73	2-24-50	32	—	—	—	—	—	24	6.3	—	34		115	—
Source: Well Location: 4N.3E.23.430															
Remarks: 370 ft deep															
—	72	3-29-50	17	—	—	—	—	—	20	6.0	—	28		98	—
Source: Well Location: 5S.1E.36.440															
Remarks: Alluvium															
—	80	10- 5-62	—	—	—	—	—	—	—	—	—	—	—	258	0
Source: Sawmill Spring Location: 5S.3W.4.231															
Remarks: Sawmill Canyon above Birris Ranch															
—	66	8- 7-63	—	—	—	—	—	—	33	3.9	—	6		124	0
Source: Spring Location: 6S.1W.6.440															
Remarks: (Diamond A Ranch) Volcanics in fault zone (?)															
25	70	6-18-63	—	—	—	—	—	—	22	2.4	—	22		112	0
Source: Springs Location: 8S.7W.31.300															
Remarks: Issues from Gila Conglomerate (?); (a) from developed spring area, below ruins, east of Alamosa River at Ojo Caliente; (b) from															
(a) 4-5	82	12-13-63	—	—	—	—	—	—	44.8	1.4	—	—	—	117.1	0.
(b) —	—	—	—	—	—	—	—	—	37.6	1.9	—	—	—	122	0.

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO_4	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity (μμc/l)	Ra (μμc/l)	U (μg/l)	Ref.
County (Continued)																	
611	1160	—	4.9	—	—		3110		714	—	5023	—	—	—	—	—	13430
—	1080	—	—	—	—				—	—	4750	7.6	—	—	—	—	48607
1770	10	0.6	10	—	—	2590			1940	—	2760	—	—	—	—	—	SP
38	20	—	—	—	—				174	—	—	—	—	—	—	—	—
20	14	—	—	—	—				118	—	499	7.7	—	—	—	—	FRH
20	22	—	—	—	—				158	—	703	8.2	—	—	—	—	FRH
44	14	1.0	1.1	—	0.08				62	0	393	8.1	—	—	—	—	38856
42	14	0.8	0.8	—	0.13		254	250	49	0	391	8.4	—	—	—	—	55434
37	14	0.6	1.0	—	0.76				78	—	380	—	—	—	—	—	33772
32	17	—	—	—	—				68	—	390	8.0	—	—	—	—	FRH
36	14	—	1.1	—	—				69	0	375	7.6	—	—	—	—	56677
rhyolite agglomerate (Sp, Sd, Ho, FRH, Jo)																	
30	14	—	1.3	—	—				63	—	340	—	—	—	—	—	Sd
	13	1.0	0.6	—	—				64	—	318	—	—	—	—	—	Sd
	13	—	—	—	—	234			70	—	—	8.2	—	—	—	—	
28	15	0.6	1.2	0.15	—			224	61	—	348	7.8	—	<11	0.2	1.8	S&B
33	16	0.7	1.1	—	0.06				74	0	362	8.4	—	—	—	—	38854
28	8	—	—	—	—				64	—	370	8.1	—	—	—	—	FRH
20	12	—	—	—	—				52	—	356	7.8	—	—	—	—	FRH
—	—	—	—	—	—				63	0	346	7.8	—	—	—	—	56678
33	14	0.8	1.3	—	0.05				63	0	318	8.2	—	—	—	—	38853
24	10	—	—	—	—				64	—	370	8.4	—	—	—	—	FRH
776	24	—	—	—	—				1960	—	3030	7.6	—	—	—	—	FRH
568	20	—	—	—	—				1800	—	2800	—	—	—	—	—	FRH
49	9	0.8	1.6	—	—	214			86	—	310	—	—	—	—	—	Sp
40	7	0.6	1.6	—	—	168			74	—	263	—	—	—	—	—	Sp
170	1060	—	—	—	—				1700	1490	6740	7.0	—	—	—	—	50501
4	4	—	—	—	—				98	—	246	7.0	—	—	—	—	FRH
12	4	—	2.2	—	—				66	—	244	7.9	—	—	—	—	FRH
p	ravine, east of Alamosa River at Ojo Caliente																
80	154.0	—	—	—	—				112	—	910	7.9	—	—	—	—	FRH
76.0	108.0	—	—	—	—				94	—	772	8.1	—	—	—	—	FRH

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS
(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
															Valencia
Source: Coyote Spring Location: 5N.3W.29.441															
Remarks: Issues from limestone at wide gap in hogback upstream from fault; precipitate covers estimated 30 acres of arroyo flow (Ti)															
3	64	1941	59	—	0.80	—	—	—	284	245	—	10000		2700	—
Source: Spring Location: 6N.2W.6.340															
Remarks: Issues from Magdalena Limestone; a Lucero fault zone spring (Wr)															
0.1	78	—	21	—	0.02	—	—	—	534	448	—	3650	38	1385	—
Source: Spring Location: 6N.3W.35.340															
Remarks: Issues from Magdalena Limestone; a Lucero fault zone spring (Wr); issues from limestone at gap in hogback upstream from															
—	71	1941	15	—	0.57	—	—	—	704	356	—	4570	79	2049	—
—	58	5- 1-57	16	—	—	—	—	—	823	460	—	5830		2990	0
10	15.3	11-30-63	18	—	0.01	—	—	—	809	419	—	5730	99	2420	0
Source: Laguna Pueblo springs Location: 7N.2W.6.210 & .444															
Remarks: .444 issues from limestone in gap in hogback upstream from fault; precipitate covers arroyo floor (Ti)															
(.210) 0.3	—	1941	—	—	—	—	—	—	227	185	—	11400		2050	—
(.444) —	68	4-30-57	25	—	—	—	—	—	681	314	—	7450		2440	—
Source: Springs Location: 7N.2W.6.400															
Remarks: Two springs with large travertine deposits issue from sandstone in fault zone															
0.5	80	1941	—	—	—	—	—	—	312	133	—	9460		2100	—
3	58	2-20-56	—	—	—	—	—	—	92	126	—	9670		2440	—
Source: Springs Location: 7N.2W.7.100 and .340															
Remarks: Issue from sandstone and shale along fault zone (Wr)															
(.100) 0.5	76	—	37	—	0.08	—	—	—	108	138	—	9760	283	1713	—
(.340) 0.05	—	—	—	—	—	—	—	—	324	152	—	—	—	2214	—
Source: Springs Location: 7N.2W.7.124 and .320															
Remarks: Issue from shale and sandstone at fault zone (Ti)															
(.320) 0.1	—	1941	—	—	—	—	—	—	324	152	—	9250		2210	—
(.124) 3	76	8-25-41	37	—	0.08	—	—	—	108	138	—	10000		1710	—
Source: Laguna Pueblo Seeps Location: 7N.2W.18.140, .312, and .313															
Remarks: Issue from sandstone and shale in fault zone (Ti)															
(.313) 0.02	82	1941	—	—	—	—	—	—	560	188	—	—	—	2030	—
(.312) 0.05	—	1941	—	—	—	—	—	—	560	188	—	—	—	2030	—
(.140) 0.2	—	1941	—	—	—	—	—	—	418	187	—	10700		1610	—
Source: Unnamed springs and seeps, Laguna Pueblo Location: 7N.2W.30															
Remarks: (see Wr and Ti for exact locations) A series of springs along the Lucero fault zone issuing from limestone, sandstone, and															
0.05	86	—	—	—	—	—	—	—	297	224	—	—	—	1374	—
0.35	75	1941	32	—	15	—	—	—	702	214	—	6470	165	2174	—
0.02	82	—	34	—	1.8	—	—	—	918	220	—	10950	283	2840	—
5	72	1941	20	—	0.09	—	—	—	516	163	—	6820		1340	—
Source: Spring Location: 7N.2W.31.140															
Remarks: Issues from sandstone in Abo Formation along fault zone (Wr; see also H&K)															
0.05	80	1941	20	—	0.18	—	—	—	603	271	—	5230	118	1615	—
Source: Spring Location: 7N.4W.3.430															
Remarks: Issues from shale and sandstone (Wr)															
0.01	65	—	—	—	—	—	—	—	606	150	—	—	—	408	—
Source: Spring Location: 7N.5W.20.340															
Remarks: Issues from sandstone and shale (Wr)															
3	68	—	—	—	—	—	—	—	604	130	—	—	—	428	—
Source: Ojo Escondido Spring· Location: 8N.2W.19.421															
Remarks: Issues from sandstone along fault zone (Ti)															
20	73	9- 8-41	12	—	0.02	—	—	—	33	20	—	23	5.6	220	—

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO_4	Cl	F	NO_3	PO_4	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as $CaCO_3$	Noncarb. hardness as $CaCO_3$	Sp. Cond. (μmhos at 25°C)	pH	H_2S	Total β-γ activity ($\mu\mu$c/1)	Ra ($\mu\mu$c/1)	U (μg/1)	Ref.
County																	
510	12500	1.6	—	—	—	29500			1720	0	—	—	—	—	—	—	Ti
2640	5160	1.0	—	—	—	13540			3170	—	—	—	—	—	—	—	Wr
fault; water cascades through dams built by precipitates (Ti)																	
2660	6210	—	—	—	—	15630			3220	1540	—	—	—	—	—	—	Wr-Ti
250	7900	1.8	—	—	—	19700			3940	1860	26700	6.5	—	—	—	—	Ti
210	7790	1.1	1.3	—	3.2		19300		3740	1760	26800	6.4	—	—	—	—	53068
7800	11600	—	—	—	—	32400			1330	—	—	—	—	—	—	—	Ti
490	9610	—	—	—	—	22700			2990	990	31000	7	—	—	—	—	Ti
380	9600	—	—	—	—	—	27100		1330	—	—	—	—	—	—	—	Ti
300	9400	—	—	—	—	—			748	—	35200	7.7	—	—	—	—	Ti
710	9940	5.8	—	—	—	29500			1716	—	—	—	—	—	—	—	Wr
670	9070	—	—	—	—	26700			—	—	—	—	—	—	—	—	Wr
870	9070	—	—	—	—	26700			1430	—	—	—	—	—	—	—	Ti
710	9940	5.8	—	—	—	27900			837	—	—	—	—	—	—	—	Ti
390	9210	—	—	—	—	27800			2180	521	—	—	—	—	—	—	Ti
90	9210	—	—	—	—	27800			2180	521	—	—	—	—	—	—	Ti
040	10200	—	—	—	—	30000			1810	492	—	—	—	—	—	—	Ti
ypsum (Ti)																	
710	8880	—	—	—	—	25700			1660	540	—	—	—	—	—	—	Wr-Ti
40	6560	2.8	—	—	—	20920			2630	853	—	—	—	—	—	—	Wr-Ti
10	11120	3.4	—	—	—	33900			3200	—	—	—	—	—	—	—	Wr-Ti
40	8170	4.3	—	—	—	20900			1960	860	—	—	—	—	—	—	Wr-Ti
80	5120	1.2	—	—	—	17540			2620	—	—	—	—	—	—	—	Wr
69	146	—	—	—	—	3440			—	—	—	—	—	—	—	—	Wr
10	113	—	—	—	—	3500			—	—	—	—	—	—	—	—	Wr
32	5.6	0.7	0.1	—	—	239			164	—	—	—	—	—	—	—	Ti, Wr

TABLE 3. INFORMATION ABOUT THERMAL SPRINGS

(All constituents in parts

gpm	°F	Date	SiO_2	Al	Fe	Mn	Cu	Zn	Ca	Mg	Ba	Na	K	HCO_3	CO_3
															Valencia
Source: Spring Location: 8N.2W.30.340															
Remarks: Issues from fault zone (Wr)															
0.03	73	. —	—	—	—	—	—	—	227	185	—	—	—	2017	—
0.3	72	9- 3-41	20	—	0.09	—	—	—	516	163	—	6630	194	1340	—
Source: Suwanee Spring (Laguna Pueblo) Location: 8N.3W.10.224															
Remarks: Issues from alluvium and lava-filled shallow valley (Ti)															
30	62	4- 2-58	29	—	—	—	—	—	258	99	—	558		224	—
Source: Dipping Vat Spring Location: 8N.3W.12.342															
Remarks: Issues from sandstone (Ti)															
400	60	4- 2-58	30	—	0.26	—	—	—	270	109	—	609		222	—
Source: Spring near Mesa Redondo Location: 8N.3W.15.413															
25	68.2	11-29-63	11	—	0.05	—	—	—	676	174	—	3500	116	2370	0
Source: Springs Location: 8N.3W.35.100															
Remarks: Issue from shale, sandstone, and basalt slump blocks (Ti)															
1	65	—	28	—	0.09	—	—	—	516	163	—	6630	194	1345	—
1	65	9- 3-41	28	—	0.02	—	—	—	65	18	—	43	3.9	377	0
Source: Ojo Caliente Spring Location: 8N.20W.21.140															
—	80	12-20-33	—	—	—	—	—	—	145	44	—	50		342	0
450	71	11-25-57	19	—	—	—	—	—	143	37	—	66		344	0
—	—	10-19-61	16	—	0.01	—	—	—	224	21	—	3.3	—	119	0
Source: Spring Location: 10N.3W.26.330 (?)															
Remarks: From uncontaminated Todilto gypsum (?)															
1/16	72	6-30-58	18	—	—	—	—	—	174	15	—	9.4		599	0

12345 = U.S. Geol. Surv. laboratory number; analyses probably previously unpublished
B = unpublished data in the files of the N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res.
Bu = Bushman, 1955
C = Conover, 1954
E = Elston, 1957
FRH = unpublished data from the files of Francis R. Hall (or Hall, 1963)
He = Hem, 1959
H&K = Hood and Kister, 1962

AND WELLS INCLUDING CHEMICAL ANALYSES (cont)
per million unless noted)

SO₄	Cl	F	NO$_3$	PO$_4$	B	Total solids	Total solids (sum)	Total solids (evap)	Hardness as CaCO$_3$	Noncarb. hardness as CaCO$_3$	Sp. Cond. (μmhos at 25°C)	pH	H$_2$S	Total β-γ activity ($\mu\mu$c/1)	Ra ($\mu\mu$c/1)	U (μg/1)	Ref.
County (Continued)																	
7800	11560	—	—	—	—	32400			—	—	—	—	—	—	—	—	Wr
6540	6170	4.3	—	—	—	20900			1960	—	—	—	—	—	—	—	H&K
1530	344	—	3.6	—	—	3020			1090	807	3790	7.7	—	—	—	—	Ti
1640	384	0.7	4.7	—	0.85	3270			1120	940	4030	7.7	—	—	—	—	Ti
4220	2740	2.3	0.7	—	6.3		12600		2400	458	15800	7.3	—	—	—	—	53069
6540	6170	4.3	—	—	—	20900			1958	—	—	—	—	—	—	—	Wr
13	3.1	0.2	0.83	—	—	355	361		236	—	—	—	—	—	—	—	Ti
310	34	0.0	0.10	—	—		752		543	—	—	—	—	—	—	—	12573
303	37	0.7	0.0	—	—	809	775		509	227	1120	7.1	—	—	—	—	38875
463	54	0.5	11	—	0.23		1120		644	—	1560	7.2	—	—	—	—	48325
13	5.5	0.6	2.3	—	—		533		496	4	906	7.7	—	—	—	—	40498

Jo=Jones, 1904
=Kelley and Silver, 1952
I=Meinzer and Hall, 1915
NMPHL=N. Mex. Pub. Health Lab.
P=Peale, 1886
R=Reeder, 1957
Ri=Renick, 1931

S=Stearns et al., 1937
Sc=Personal communication from the Work Unit Conservationists, U.S. Soil Conserv. Serv.
Sd=Schofield, 1938
Sp=Spiegel, 1957
S&B=Scott and Barker, 1962
Ti=Titus, 1963
Wr=Wright, 1946
WH&W=White et al., 1963

TABLE 2. INFORMATION ABOUT THERMAL SPRINGS AND WELLS FOR WHICH NO CHEMICAL ANALYSES ARE AVAILABLE

COUNTY	SOURCE	LOCATION	TEMP. (°F)	DISCHARGE (GPM)	DISCHARGE FROM (AQUIFER)	DEPTH (FEET)	REMARKS (*see* FOOTNOTES AT END OF TABLE)
Bernalillo	well	10N.2W.21.343	90	—	—	1180	U
	spring	11N.2W.32	68	3	Mancos Shale	—	S
Catron	spring	11S.12W.30.100	80	50	lava agglomerate	—	S
	spring	11S.14W.25	160	900	—	—	T
	spring	12S.13W.7	—	—	—	—	F
	spring	12S.13W.11	151	30	lava	—	S
	spring	12S.13W.14	100	—	—	—	P
	spring	12S.13W.24	—	—	—	—	F
Dona Ana	well	19S.2W.9.120	120	100	—	110	Sc
	Agua Caliente	23S.1E.7	—	—	—	—	P
	Kilbourne Hole	27S.1W.8	100	—	—	100	LRe
Grant	spring	12S.20W.26	—	—	—	—	U
	spring	13S.13W.20	—	30	lava	—	S
	spring	14S.16W.3	—	20	lava	—	S
	spring	14S.16W.16	—	20	lava	—	S
	hot spring area	15S.17W.9&10	—	—	—	—	U
	flowing well	15S.17W.29.442	68.5	2	—	410	U; cased to 40 ft
	warm spring	16S.12W.22	150	—	—	—	P
	well	16S.17W.9.223	85	—	—	22	U
	well	16S.17W.10.433	90	—	—	—	U
	well	16S.17W.19.213	67	—	—	180	U
	spring	17S.17W.34	—	30	Gila Conglomerate	—	Sc
	Hudson's Hot Spring	18S.10W.4.100	142	—	lava	—	S
	Apache Tejo Warm Spring	19S.12W.19.300	89, 97	2000	—	—	SPPa
	warm spring	20S.11W.18.300	—	dry	near rhyolite plug	—	PaU
	well	20S.19W.15.400	—	—	—	—	U
	Fuller's Ranch well	20S.19W.15.400	81	—	—	361	U
Guadalupe	Rock Lake	8N.21E.14	65	2700	—	—	T
Hidalgo	well	20S.19W.19.321	81	—	—	361	R
	well	21S.18W.18.180	83	—	—	—	R
	well	21S.20W.1.410	82	—	—	—	R
	well	22S.19W.23.130	85	—	—	—	R
	well	24S.18W.32	—	—	—	—	well used to heat greenhouse
	well	25S.19W.7.143	98	—	—	—	R
	well	25S.19W.7.134	84.5	—	—	74	R
	well	30S.19W.7	—	—	—	—	Sc; hot stock well
	spring	30S.19W.7	—	—	—	—	Sc; thermal pipe by road
	Humble Oil and Refining Co. No. 1	32S.16W.25	—	—	—	14588	BH 320°F
McKinley	spring	16N.18W.35	—	—	—	—	P
	Togay Spring	19N.15W.33	65	20	—	—	S
Sandoval	Spense Hot Springs	14N.3E.28	110	100	—	—	F
	spring	18N.1E.24	—	—	—	—	T
	San Antonio Spring	20N.3E.29	130	150	—	—	SBaSc
	Westates Petroleum No. 1	20N.3E.35	—	—	—	3675	BH 100+°F
San Juan	spring	24N.18W.3	—	—	—	—	PJo
	spring	25N.18W.34	65	3	—	—	S
	spring	25N.18W.	67	7	—	—	S

TABLE 2. INFORMATION ABOUT THERMAL SPRINGS AND WELLS FOR WHICH NO CHEMICAL ANALYSES ARE AVAILABLE (cont)

COUNTY	SOURCE	LOCATION	TEMP. (°F)	DISCHARGE (GPM)	DISCHARGE FROM (AQUIFER)	DEPTH (FEET)	REMARKS (*see* FOOTNOTES AT END OF TABLE)
	spring	28N.18W.10	68	3	—	—	SGPJo
San Miguel	well	16N.16E.5.211	—	—	granite	108	—
Sierra	Victoria Land and Cattle Co. No. 2	10S.1W.25	—	—	—	6059	BH 122°F
	Victoria Land and Cattle Co. No. 1	10S.1W.27	—	—	—	6352	BH 170°F
	16 wells	13S.4W.33	98.6-112.5	—	Magdalena Limestone	20-250	Th; Cl = 1320-1440
	spring	13S.4W.33	—	—	—	—	Th
	Ojo Caliente	14S.1W.28	—	—	—	—	P
	8 wells	14S.4W.4	107-116	—	Magdalena Limestone	105-225	Th; Cl = 1370-1400
	springs	14S.4W.4	94-110.8	—	—	—	Th; Cl = 1340-1380
	Cabello Springs	14S.5W.12.4	136	—	—	—	P
	Barney Iorio No. 1 fee	14S.5W.25	90	30	—	1550	K
	Sunray–Midcontinent No. 1	15S.2W.23	—	—	—	9774	BH 236°F
Socorro	Ojo Caliente	8S.7W.30	89	1350	—	—	SPSc
	Crater well	9S.1E.18.320	—	—	basalt	—	VW
Taos	Warm Sulphur Springs	—	68	—	—	—	P
	Glen–Woody Camp Springs	24N.11E.28	—	—	—	—	F
	Ponce de Leon Hot Spring	24N.13E.7	98	100	—	—	Sc
	Mamby's Hot Spring	26N.11E.1	100	—	—	—	HSc
	Warmsley Hot Spring	27N.12E.31	—	—	—	—	Jo
	Arsenic Springs	28N.12E.8.100	—	—	—	—	FWi
	springs	29N.12E.12	—	—	—	—	F
Valencia	warm spring	5N.1W.16	64-82	—	Rio Puerco fault	—	S
	spring	7N.2W.8	65	3	—	—	S
	spring	7N.2W.16	67	7	sandstone and shale intruded by porphyry	—	S
	Quelities Mineral Spring	8N.2W.17	80	3	—	—	S

B = open-file data of the N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res.
Ba = Bailey, 1961
BH = bottom-hole temperature
F = personal communications April 1965 from District Rangers, U.S. Forest Service
G = Gilbert, 1875
H = Herron, 1915, plate IV
J = Jemez Springs quadrangle, 1948
Jo = Jones, 1904
K = Kelley and Silver, 1956
L = Lee, 1907b
P = Peale, 1886
Pa = Paige, 1916
R = Reeder, 1957
Re = Reiche, 1940
S = Stearns, 1937
Sc = Personal communications May 1965 from the Work Unit Conservationists, U.S. Soil Conserva. Serv.
T = Personal communication April 1965 from Fred A. Thompson, N. Mex. Dept. Game and Fish
Th = Theis et al., 1941
U = Unpub. data in the files of the Ground-Water Branch, U.S. Geol. Surv.
V = Valverde quadrangle, 1958
W = Weber, 1963
Wi = Winograd, 1959

OREGON

Summary

A definitive study of water quality and predicted thermal reservoir temperatures for 32 thermal springs was completed by the U.S.G.S. in 1974 (Mariner, et.al.). Chemical composition of the spring waters suggests aquifer temperatures which range from 43°C to 181°C. Four springs have aquifer temperatures exceeding 150°C, as estimated by both silica and Na-K or Na-K-Ca geothermometers. Five other springs have estimated aquifer temperatures of 140°C-150°C. Chemical compositions of the springs are indicative of hot water-dominated geothermal systems.

Sodium is the principal cation in all of the spring waters. The pH's range from 6.53 to 9.68. Boron content ranges from 0.11 to 30 ppm. Only five springs have a boron content of 1.0 ppm or less, and three springs have 1.0-2.0 ppm boron conductances for the springs with estimated aquifer temperatures of at least 150°C range from 1,010 to 4,590.

The areas which have thermal springs are underlain principally by Cenozoic basalts, andesites and related tuffs, and sedimentary rocks. Almost all of the springs issue along faults and are generally located at or near the edge of an alluvium-filled valley.

Seven KGRA's have been designated in the state.

Generalized Geologic Setting

Areas of Oregon which have thermal springs are underlain principally by Cenozoic volcanic rocks (basalts or andesites), as well as related tuffs and sedimentary rocks. Late Cenozoic basalt and andesite flows crop out in the Cascade Range. Southeastern Oregon, part of the Basin and Range Province, consists chiefly of flows of basalt and andesite with some rhyolitic flows and domes interbedded with ash-flow tuffs and continental sedimentary rocks. The principal valleys all contain Quarternary alluvium and lake sediments, usually with some fluvial glacial deposits and pumice. Rocks exposed in the northeastern part of the state are largely Cenozoic basalts and andesites with some interbedded sedimentary rocks. A window of Mesozoic and Paleozoic rock crops out in Grant County. These pre-Cenozoic rocks include gabbro and granite in addition to sedimentary and volcanic rocks. Some of the sedimentary and volcanic rocks have been strongly metamorphosed. A similar window of pre-Cenozoic rocks is exposed in southwestern Oregon (Corcoran, 1969).

Rock types which crop out near the spring or may be present at depth are listed in Table 4. Recent papers on the geology around the various springs are listed for reference in Table 4. Almost all of the springs issue along faults. Generally, the springs are located at or near the edge of an alluvium-filled valley.

Tabular Data

Table 1 contains the name, location and topographic map coverage of the 32 thermal springs and wells reported on by the U.S. Geological Survey (Mariner et.al.).

Table 2 contains the results of water analysis reported for the major chemical constituents.

Table 3 contains a description of the rock type and estimated thermal aquifer temperatures of each hot spring. The underlined values represent the "best" estimates of thermal aquifer temperature.

Table 4 lists rock types and references to recent papers on the geology around each hot spring.

Water Quality

All of the hot springs and wells show sodium as the principal cation. Chloride is the principal anion of all four hot springs in the Cascade Range. Bicarbonate is the principal anion at Weberg, Blue Mountain, Ritter Crane, and the two unnamed hot springs in southern Malheur County. Sulfate is the principal anion at Olene Gap and Medical Hot Springs. The other springs are mixed anion waters with varying proportions of bicarbonate, sulfate and chloride. The thermal waters from the Cascade Range and southern Harney County are the most saline. Alvord Hot Spring in southern Harney County and Belknap Hot Spring in the Cascade Range are very saline, with total dissolved solids of 2,980 and 3,020 mg/l (milligrams per liter), respectively. The pH's range from 6.53 at Weberg Hot Spring to 9.68 at Ritter Hot Spring; both springs are in Grant County. Lithium, boron and, to a lesser extent, fluoride concentrations are high in thermal waters from southern Harney County. Kah-Ne-Tah Hot Spring in Wasco County is very high in fluoride, 20.5 mg/l.

Summary

Nine of the sampled thermal springs have chemical compositions which indicate aquifer temperatures of at least 140°C. Possible contamination with meteoric water of low specific conductance is not considered, and therefore the estimated thermal aquifer temperatures are minimum values. The chemical compositions of the springs are typical for springs associated with hot water-dominated systems. Specific conductances for the springs with estimated aquifer temperatures of at least 140°C are high to very high. Areas underlain by thermal aquifers of 140°C or more include: the Alvord area of southern Harney County, the Lakeview area of southern Lake County, and the Vale area of northern Malheur County. The Lakeview and Vale areas have been designated as KGRA's. Other KGRA's include: Breitenbush Hot Spring, Crump Geyser, Mt. Hood, Carey Hot Spring (Austin Hot Spring), and Klamath Falls.

Thermal springs are spread eastward from the west edge of the Cascade Mountains. Springs are concentrated along the linear belt that marks the boundary between the High Cascades of Pliocene to Holocene age and the western Cascades of early Tertiary age. Hot springs are scarce in the high Cascades, but there is some fumarolic activity near the summit of Mt. Hood. The southern and southeastern quadrants of the state lie within the Basin and Range Province where there are several thermal areas associated with many of the grabens. Greater than 40% of Oregon, mainly the southeastern lava plains and the Cascade Range, is underlain by Late Cenozoic volcano-tectonic and caldera collapse structures. Oregon has the youngest volcanism in the continental U.S.

Best known areas:

Klamath Falls
Temperature 185°F (85°C)

Lakeview
On the sourthern edge of the Goose Lake-Summer Lake graben complex

Warner Valley

Alvord Valley

Vale - a geological extension of the Bruneau-Oreana-Grandview geothermal trend
Average temperature of the major areas is 85°F (29°C)
Temperatures range up to 198°F (92°C)
Flows are up to 5,000 gpm

Blue Mountain Region - Walla Walla, WA, to Milton Freewater, Oregon
High temperature found in water wells
Thermal Spring
Wallowa-Olympic Lineament (major structural discontinuity)

Table 1.--Location and topographic map coverage of selected hot springs

Spring	Location	Topographic map coverage
	Baker County	
1 Radium Hot Springs(well)	NE 1/4 sec. 28, T. 7S., R. 39E.	Haines, Ore. (7-1/2'); Baker, Oregon-Idaho (2°)
	Clackamas County	
1 Austin Hot Springs	NW 1/4 sec. 30, T. 6S., R. 7E.	Fish Creek Mtn. Ore., (15'); Vancouver, Ore.-Wash. (2°)
	Grant County	
1 Weberg Hot Spring	sec. 18, T. 18S., R. 26E.	; Burns, Oregon (2°)
2 Blue Mountain Hot Springs	S 1/2 sec. 13, T. 14S., R. 34 E.	Prairie City, Ore. (15'); Canyon City, Oregon (2°)
3 Ritter Hot Springs	NW 1/4 sec. 8, T. 8S., R. 30E.	Ritter, Ore. (15'); Canyon City, Oregon (2°)
	Harney County	
1 Unnamed hot spring (Trout Creek)	sec. 16, T. 39S., R. 37E.	; Adel, Oregon (2°)
2 Hot Lake	sec. 15, T. 37S., R. 33E.	; Adel, Oregon (2°)
3 Unnamed hot spring (near Hot Lake)	sec. 15, T. 37S., R. 33E.	; Adel, Oregon (2°)
4 Alvord Spring (Indian Spring)	sec. 33, T. 34S., R. 34E.	; Adel, Oregon (2°)
5 Mickey Springs	sec. 13, T. 33S., R. 35E.	; Adel, Oregon (2°)
6 Unnamed hot spring (near Harney Lake)	sec. 36, T. 27S., R. 29-1/2E.	; Burns, Oregon (2°)
7 Crane Hot Springs	S 1/2 sec. 34, T. 24S., R. 33E.	Crane, Ore. (15'); Burns, Oregon (2°)
	Klamath County	
1 Olene Gap Hot Springs	SW 1/4 sec. 14, T. 39S., R. 10E.	Merrill, Ore.-Calif. (15'); Klamath Falls, Ore.-Calif. (2°)
	Lake County	
1 Fisher Hot Springs	NW 1/4 sec. 10, T. 38S., R. 25E.	Crump Lake, Ore. (7-1/2'); Adel, Oregon (2°)
2 Crump (Charles Crump's Spring)	sec. 27, T. 38S., R. 24E.	; Adel, Oregon (2°)
3 Barry Ranch Hot Springs	SE 1/4 sec. 27, T. 39S., R. 20E.	Lakeview NE, Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)
4 Hunters Hot Springs	NW 1/4 sec. 4, T. 39S., R. 20E.	Lakeview NE, Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)
5 Summer Lake Hot Spring	NE 1/4 sec. 12, T. 33S., R. 17E.	Slide Mtn. Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)

Tables extracted from: Mariner, et al., USGS (1974)

Table 1.--Location and topographic map coverage of selected hot springs--Continued

Spring	Location	Topographic map coverage
	Lane County	
1 Belknap Hot Springs	NE 1/4 sec. 11, T. 16S., R. 6E.	McKenzie Bridge, Ore. (15'); Salem, Oregon (2°)
2 Cougar Reservoir Hot Spring	sec. 7, T. 17S., R. 5E.	McKenzie Bridge, Ore. (15'); Salem, Oregon (2°)
	Malheur County	
1 Unnamed hot springs (near McDermitt)	sec. 25, T. 40S., R. 42E.	; Jordan Valley, Ore.-Idaho (2°)
2 Unnamed hot springs (at Three Forks)	sec. 3, T. 35S., R. 45E.	; Jordan Valley, Ore.-Idaho (2°)
3 Unnamed hot spring (near Riverside)	sec. 20, T. 24S., R. 37E.	; Burns, Oregon (2°)
4 Beulah Hot Springs	SE 1/4 sec. 2, T. 19S., R, 37E.	Beulah, Oregon (15'); Burns, Oregon (2°)
5 Neal Hot Springs	NW 1/4 sec. 9, T. 18S., R. 43E.	Jamieson, Oregon (15'); Baker, Idaho-Oregon (2°)
6 Unnamed hot springs (near Little Valley)	NW 1/4 sec. 30, T. 19S., R. 43E.	Harper, Oregon (15'); Boise, Idaho-Oregon (2°)
7 Mitchell Butte Hot Spring	NE 1/4 sec. 12, T. 21S., R. 45E.	Mitchell Butte, Ore. (7-1/2'); Boise, Idaho-Oregon (2°)
	Marion County	
1 Breitenbush Hot Springs	NE 1/4 sec. 20, T. 9S., R. 7E.	Breitenbush Hot Spring, Ore. (15'); Canyon City, Ore. (2°)
	Umatilla County	
1 Lehman Springs	NE 1/4 sec. 12, T. 5S., R. 33E.	Lehman Springs, Ore. (7-1/2'); Pendleton, Ore.-Wash. (2°)
	Union County	
1 Medical Hot Springs	NE 1/4 sec. 25, T. 6S., R. 41E.	Flagstaff Butte, Ore. (7-1/2'); Grangeville. Idaho-Ore.-Wash. (2°)
2 Hot Lake	SE 1/4 sec. 5, T. 4S., R. 39E.	Craig Mtn., Ore. (7-1/2'); Grangeville, Idaho-Ore.-Wash. (2°)
	Wasco County	
1 Kahneeta Hot Springs (Kah-Ne-Tah)	E 1/2 sec. 20, T. 8S., R. 13E.	Eagle Butte, Ore. (7-1/2'); Bend, Oregon (2°)

Table 2.--Chemical analyses of selected hot springs

Spring	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Baker County															
1 Radium Hot Springs (well)	58	9.56	290	78	1.5	0.1	58	1.1	0.01	86	27	34	17	1.3	0.42
Clackamas County															
1 Austin Hot Springs	86	7.63	1,720	81	35	.1	300	7.1	.4	56	<1	140	430	1.4	2.5
Grant County															
1 Weberg Hot Spring	46	6.53	2,570	82	38	7.8	610	36	.7	1,710	1	13	50	3.9	15
2 Blue Mountain Hot Springs	58	7.96	610	47	2.2	.2	140	3.3	.07	323	3	11	15	10.6	1.6
3 Ritter Hot Springs	41	9.68	319	70	1.4	<.05	72	.82	.01	86	28	9	29	4.0	2.6
Harney County															
1 Unnamed hot spring (Trout Creek)	52	6.77	1,168	105	18	.8	270	10.8	.68	439	1	204	24	12.8	.89
2 Hot Lake	36	7.28	2,410	190	16	.3	500	31	.65	420	1	350	300	9.0	16.6
3 Unnamed hot spring (near Hot Lake)	96	7.30	2,020	160	14	.3	450	28	.51	374	4	434	250	7.2	15
4 Alvord Spring (Indian Spring)	76	6.73	4,590	120	13	2.2	960	69	2.1	1,196	1	220	780	10.2	30
5 Mickey Springs	73	8.05	2,490	200	.9	.1	550	35	1.1	774	11	230	240	16	10.5
6 Unnamed hot spring (near Harney Lake)	68	7.26	2,970	92	12	1.8	630	13	.45	566	1	140	590	3.3	11.3
7 Crane Hot Springs	78	8.10	810	83	3.7	.1	170	3.9	.09	202	3	86	79	9.0	7.9
Klamath County															
1 Olene Gap Hot Springs	74	7.68	1,140	98	40	.2	190	7.2	.15	53	<1	400	59	1.2	1.0
Lake County															
1 Fisher Hot Springs	68	7.93	513	77	8.4	1.0	92	7.9	.04	105	1	59	56	3.5	2.2
2 Crump (Charles Crump's Spring)	78	7.26	1,490	180	16	.2	280	11	.4	153	1	200	240	4.9	13.6
3 Barry Ranch Hot Springs	88	7.76	1,370	130	8.8	.1	280	9.0	.15	232	2	240	170	5.4	11.2
4 Hunters Hot Springs	96	7.77	1,120	140	13	.1	210	8.5	.15	79	1	260	120	4.4	6.9
5 Summer Lake Hot Spring	43	8.43	1,790	94	2.1	.1	390	4.6	.15	406	10	120	280	2.2	6.9

Table 2.--Chemical analyses of selected hot springs--Continued

Spring	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Lane County															
1 Belknap Hot Springs	71	7.62	4,300	96	210	.2	690	15	.95	17	<1	170	1,300	1.2	6.4
2 Cougar Reservoir Hot Spring	44	7.76	2,890	50	225	.1	392	6.3	.52	19	<1	260	788	.8	5.1
Malheur County															
1 Unnamed hot springs (near McDermitt)	52	8.79	598	72	.6	<.1	130	1.0	.06	237	13	52	14	6.6	1.1
2 Unnamed hot springs (at Three Forks)	34	8.11	338	40	10.5	.7	61	1.2	.04	108	1	34	18	4.2	.11
3 Unnamed hot spring (near Riverside)	63	7.43	1,330	110	34	.5	240	9.7	.27	160	<1	290	140	4.8	6.6
4 Beulah Hot Springs	60	7.56	1,090	170	24	.2	200	6.0	.24	161	1	290	55	4.7	4.7
5 Neal Hot Springs	87	7.32	1,010	180	8.8	.2	190	16	.3	198	<1	120	120	9.4	4.1
6 Unnamed hot springs (near Little Valley)	70	8.71	740	115	3.2	<.05	160	3.2	.11	127	1	110	74	6.8	4.7
7 Mitchell Butte Hot Spring	62	8.69	559	94	4.6	<.1	110	1.6	.03	72	3	130	28	10.4	.49
Marion County															
1 Breitenbush Hot Springs	92	7.31	4,030	83	100	1.3	720	31	1.8	142	<1	140	1,300	3.4	4.1
Umatilla County															
1 Lehman Springs	61	9.18	252	44	.9	.1	53	.7	.03	101	13	23	5.4	2.1	.12
Union County															
1 Medical Hot Springs	60	8.23	1,173	80	72	.2	190	7.0	.05	26	<1	400	77	1.2	2.2
2 Hot Lake	80	9.21	688	48	4.9	<.1	130	2.7	.03	75	12	56	140	1.7	2.9
Wasco County															
1 Kahneeta Hot Springs (Kah-Ne-Tah)	52	8.32	1,370	104	3.2	<.05	325	3.4	.52	493	9	34	155	21	2.6

Table 3.--Geologic setting and estimated thermal aquifer temperatures of selected hot springs--Continued

Spring	Spring temperature (°C)	Flow (lpm)	Gas	Spring deposits		Rock type at the spring	Estimated thermal aquifer temperature				
				$CaCO_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3ca	Na-K-4/3ca
Lane County											
1 Belknap Hot Springs**	71	300	--	--	--	Olivine basalt	135	131	56	114	82
2 Cougar Reservoir Hot Spring**	44	200	--	--	--	Andesite, basalt, and basic tuff-breccia	89	92	38	95	49
Malheur County											
1 *Unnamed hot springs (near McDermitt)	52	750	T	--	--	Basalt	118	118	3	91	105
2 Unnamed hot springs (at Three Forks)**	34	4,000	--	--	--	Basalt	95	97	52	100	44
3 *Unnamed hot springs (near Riverside)	63	200	T	T	--	Andesite	142	137	98	138	97
4 Beulah Hot Springs	60	50	T	T	X	Vitric tuff	169	159	76	125	86
5 Neal Hot Springs	87	90	T	T	X	Basalt	173	162	164	181	151
6 *Unnamed hot springs (near Little Valley)***	70	550	T	T	T	Basalt and andesite	145	139	51	119	109
7 Mitchell Butte Hot Spring**	62	60	--	T	--	Volcanic arkose	133	130	33	100	72
Marion County											
1 Breitenbush Hot Springs	92	3,400	--	X	--	Andesite	127	124	103	149	128
Umatilla County											
1 Lehman Springs***	61	275	X	T	--	Andesite	98	98	28	97	73
Union County											
1 Medical Hot Springs**	60	200	X	T	--	Basalt	125	123	91	125	67
2 Hot Lake	80	1,500	T	T	--	Basalt and mylonite	102	103	53	115	90
Wasco County											
1 *Kahneeta Hot Springs (Kah-Ne-Tah)	52	200	T	T	--	Rhyolite, andesite, basalt, and tuffs	139	135	17	103	121

* Mixed waters

** Temperature estimates based on the solubility of cristobalite improve the agreement between the silica and cation geothermometers at Radium Hot Springs (72°C), Ritter Hot Springs (70°C), Olene Gap Hot Springs (84°C), Belknap Hot Springs (84°C), Cougar Reservoir Hot Springs (51°C), the unnamed hot springs near Three Forks (39°C), Mitchell Butte Hot Springs (83°C), and Medical Hot Springs (74°C). Solubility data from Fournier and Rowe (1962).

*** Temperature estimates based on the solubility of chalcedony improve the agreement between the silica and cation geothermometers at Austin Hot Springs (95°C), the unnamed hot springs near Little Valley (112°C), Summer Lake Hot Springs (107°C), and perhaps, Lehman Hot Springs (68°C). Solubility data from Fournier (1973).

Table 3.--Geologic setting and estimated thermal aquifer temperatures of selected hot springs

Spring	Spring temperature (°C)	Flow (lpm)	Gas	Spring deposits		Rock type of the spring	Estimated thermal aquifer temperature				
				CaCO$_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca	Na-K-4/3Ca
				Baker County							
1 Radium Hot Springs (well)**	58	1,100	X	--	--	Alluvium, quartzdiorite, and basalt	123	122	48	109	77
				Clackamas County							
1 Austin Hot Springs ***	86	950	T	T	--	Olivine basalt, basaltic andesite and pyroxene andesite	124	123	61	118	88
				Grant County							
1 Weberg Hot Spring	46	40	X	T	--	Arkosic sandstone	125	124	130	170	162
2 *Blue Mountain Hot Springs	58	250	--	T	--	Andesite	99	101	61	126	118
3 Ritter Hot Springs **	41	130	--	--	--	Basalt	118	117	20	92	71
				Harney County							
1 *Unnamed hot spring (Trout Creek)	52	200	T	--	--	Andesite, basalt, and rhyolite	140	135	97	144	118
2 Hot Lake	36	3,500	T	--	X	Alluvium, andesite, and basalt	176	165	134	176	181
3 Unnamed hot spring (near Hot Lake)	96	15	X	T	X	Alluvium, andesite, and basalt	165	156	134	176	178
4 *Alvord (Indian) Hot Spring	76	500	T	T	X	Rhyodacite, andesite, and basalt	148	142	148	199	254
5 *Mickey Springs	73	100	X	T	X	Andesitic tuff-breccia	179	168	136	207	330
6 *Unnamed hot spring (near Harney Lake)	68	550	T	T	--	Basaltic tuff, and olivine basalt	132	129	52	130	151
7 Crane Hot Springs	78	550	T	--	--	Augite andesite	127	125	59	124	114
				Klamath County							
1 Olene Gap Hot Springs **	74	200	T	--	--	Andesite, basalt, and andesitic tuff-breccia	136	132	93	130	80
				Lake County							
1 Fisher Hot Springs	68	70	T	T	--	Alluvium and olivine basalt	123	121	167	170	112
2 Crump (Charles Crump's Spring)	78	0-50	T	T	X	Alluvium and olivine basalt	173	162	96	144	123
3 *Barry Ranch Hot Springs	88	200	X	T	T	Andesite, andesitic tuff-breccia, and rhyolite	153	146	81	140	131
4 Hunters Hot Springs	96	2,300	T	T	T	Alluvium, andesite, and andesitic tuff-breccia	157	149	98	143	114
5 *Summer Lake Hot Spring ***	43	75	T	T	--	Alluvium, andesite, andesitic tuff-breccia	134	130	22	112	149

Table 4.--Age of bedrock and geologic coverage of each spring

Spring	Age of bedrock	Geologic reference
	Baker County	
1 Radium Hot Springs (well)	Quaternary alluvium, Late Cretaceous diorite, and Permian greenstone	Gilluly (1937)
	Clackamas County	
1 Austin Hot Springs	Pliocene to Holocene mafic flows and perhaps pyroclastic rocks	Peck, Griggs, Schlicker, Wells, and Dole (1964)
	Grant County	
1 Weberg Hot Spring	Lower and Middle Jurassic sandstone and volcanic rocks	Brown and Thayer (1966)
2 Blue Mountain Hot Springs	Miocene and Pliocene andesite flows	Brown and Thayer (1966)
3 Ritter Hot Springs	Miocene and Pliocene basalt flows	Brown and Thayer (1966)
	Harney County	
1 Unnamed hot spring (Trout Creek)	Quaternary alluvium, Miocene to Pliocene basalt, andesite, and rhyolite flows	Walker and Repenning (1965)
2 Hot Lake	Quaternary alluvium and playa deposits	Walker and Repenning (1965)
3 Unnamed hot spring (near Hot Lake)	Quaternary alluvium and playa deposits	Walker and Repenning (1965)
4 Alvord (Indian) Spring	Miocene rhyodacite, basalt, and andesite	Walker and Repenning (1965)
5 Mickey Springs	Miocene andesitic tuff-breccia, basalts, and andesites	Walker and Repenning (1965)
6 Unnamed hot spring (near Harney Lake)	Pliocene basalts, tuffs, and welded tuffs	Walker and Swanson (1967); Greene, Walker and Corcoran (1972)
7 Crane Hot Springs	Quaternary alluvium, Pliocene and Pleistocene pyroclastic rocks, and Pliocene basalt and andesite	Leonard (1970); Greene, Walker, and Corcoran (1972)
	Klamath County	
1 Olene Gap Hot Springs	Pliocene and Pleistocene basalts and associated pyroclastic rocks	Peterson and Groh (1967)
	Lake County	
1 Fisher Hot Springs	Quaternary alluvium and Miocene to Pliocene olivine basalt	Walker and Repenning (1965)
2 Crump (Charles Crump's Spring)	Quaternary alluvium and Miocene to Pliocene olivine basalt	Walker and Repenning (1965); Peterson (1959)
3 Barry Ranch Hot Springs	Oligocene(?) and Miocene basalt or andesite flows, tuff-breccia, tuff, and tuffaceous rocks	Walker (1963)

Table 4.--Age of bedrock and geologic coverage of each spring--Cont'd

Spring	Age of bedrock	Geologic reference
4 Hunter Hot Springs	Quaternary alluvium, Quaternary to late Tertiary basalts and andesites, middle Tertiary tuffs	Walker (1963)
5 Summer Lake Hot Spring	Tertiary and Quaternary sedimentary rocks overlying Tertiary andesite flows	Walker (1963)
	Lane County	
1 Belknap Hot Springs	Pliocene to Holocene basic volcanic flows and pyroclastic rocks	Peck, Griggs, Schlicker, Wells, and Dole (1964)
2 Cougar Reservoir Hot Spring	Miocene mafic to intermediate flows, tuffs, and tuff-breccias	Peck, Griggs, Schlicker, Wells, and Dole (1964)
	Malheur County	
1 Unnamed hot springs (near McDermitt)	Quaternary alluvium, Tertiary and Quaternary pediment gravels, and Miocene volcanic rocks	Walker and Repenning (1966)
2 Unnamed hot springs (at Three Forks)	Miocene and Pliocene volcanic flows and tuffs	Walker and Repenning (1966)
3 Unnamed hot springs (near Riversdie)	Miocene basalt	Walker and Repenning (1965)
4 Beulah Hot Springs	Miocene and Pliocene vitric tuff	Greene, Walker, and Corcoran (1972); Bowen (1956)
5 Neal Hot Springs	Miocene(?) volcanic flows	Walker (1973)
6 Unnamed hot springs (near Little Valley)	Pliocene basalt and sedimentary volcanic rocks	Corcoran, Doak, Porter, Pritchett, and Privrasky (1962)
7 Mitchell Butte Hot Spring	Pliocene conglomerate, sandstone, and siltstones	Corcoran, Doak, Porter, Pritchett, and Privrasky (1962)
	Marion County	
1 Breitenbush Hot Springs	Miocene basalt flows, tuff-breccias, and tuffs, near an area of propylitically altered rock	Peck, Griggs, Schlicker, Wells, and Dole (1964)

OREGON

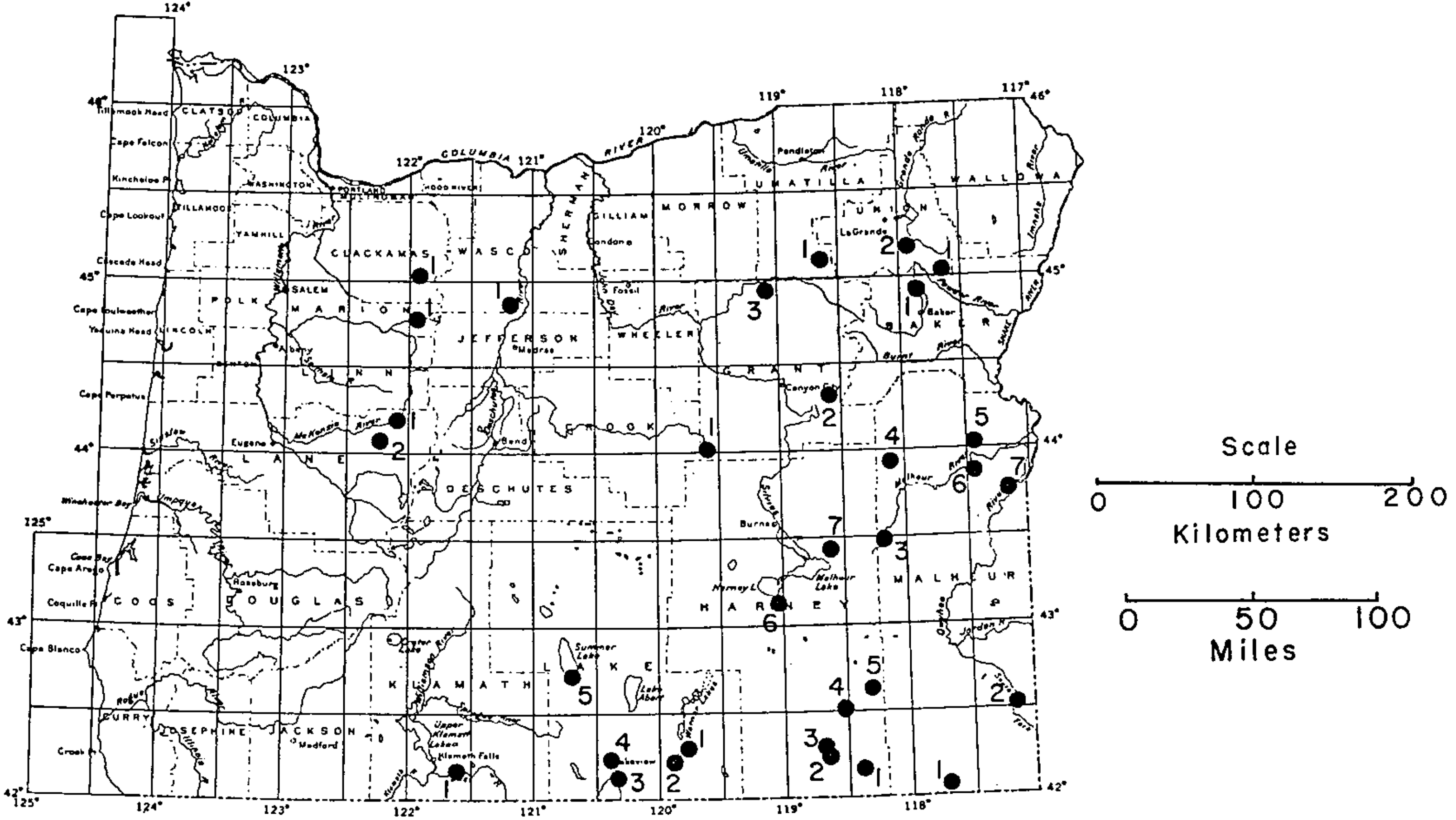

Figure 1. Map of the State of Oregon showing the location of sampled thermal springs and wells. The numbered dots correspond to sampled springs listed by county in tables 1, 2, 3, and 4 of the text.

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UTAH

SUMMARY

Mundorff (1970) conducted a reconnaissance study wherein data were obtained on the thermal, chemical and geologic characteristics of more than 50 thermal springs of Utah. Only three of the springs have temperatures near the boiling point of water; the maximum recorded temperatures of these springs range from 185° to 189° F.

Most thermal springs occur within a north-south zone 110 to 130 Km in width, bordered on the east by the Wasatch-Hurricane normal fault zone, and within the Basin and Range Province. Most of the springs are associated with Late Cenozoic faults. Only the three hottest are associated closely with Late Tertiary or Quaternary volcanic rocks. Most of the hotter springs occur along that portion of the Wasatch fault zone that extends from Provo northward to the Utah-Idaho border.

Temperatures of the thermal springs studied ranged from 68° to 189° F. Nearly all thermal springs in Utah are in or near fault zones.

Dissolved solids contents of the springs range from as low as 214 ppm for a spring having a temperature of 80° F to as high as about 45,000 ppm for a spring having a temperature of 132° F. Calculated dissolved solids average from 5000 to 8000 ppm. Most springs are sodium chloride in type, and all springs that contain more than 3000 ppm of dissolved solids are of the sodium chloride type. Silica concentrations exceed 100 ppm for two of the thermal springs. The pH of springs ranges from 6.2 to 8.8.

Water quality of thermal springs in Utah is, for the most part, unsuitable for industrial and agricultural uses.

UTAH, (cont'd)

Only two springs in the state, Roosevelt and Abraham Hot (Crater) Springs, have been designated as KGRA's by the U.S. Geological Survey.

Roosevelt (McKeans) Hot Springs
313-405 ppm SiO_2
131-185°F (55-85°C)
Dissolved solids 7800 ppm
pH 8.3
--water quality is poor

Abraham (Crater) Hot Springs
59 ppm SiO_2
180°F (82°C)
Dissolved solids 3630 ppm
pH 7.6
Discharge estimate 250 gpm
--water quality is poor

Thermo Hot Springs is the third hottest in the state.
100 ppm SiO_2
173°F (78°C)
Dissolved solids 1460 ppm
pH 8.1
--water quality is poor

Some thermal springs in Utah have large discharges (up to 900 gpm), low dissolved solids contents, and fairly low temperatures; these springs are valuable as water supplies for irrigation and stock use, but other non-electrical usages may be feasible.

The main undesirable effect of the thermal springs in Utah is that they add significant amounts of water having high dissolved solids contents to some streams and lakes. The inflow of LaVerkin Hot Springs to the Virgin River and of many thermal springs around Utah Lake results in a deterioration of the quality of the surface water supply.

Table 1. Chemical analyses of thermal springs in Utah.

Location	Name of spring	Date of collection	Estimated discharge (gpm)	Temperature (°F)	Silica (SiO$_2$)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Carbonate (CO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Total equivalents per million		Fluoride (F)	Nitrate (NO$_3$)
						ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	Major cations	Major anions		
(A-4-3) 31cab-S1	Como Warm Springs	5-18-66	9,000	77	19	109	31	35	8.5	250	-	243	28			2.0	0.1
						5.44	2.55	1.[illegible]	.21	4.10		5.[illegible]	.79	9.67	9.68		
(B-1-1) 16dcb-S1	Becks Hot Springs	1861	-	-	32	655	110	3,755	197		-	650	6,740			-	
		5-14-42 2/	-	-	32	251	135	[illegible]	465	239	-	675	[illegible],670			-	-
						12.58	11.0	125.[illegible]	11.[illegible]	3.91		14.[illegible]	216.[illegible]	150.2	[illegible]		
		8-29-47	-	-	35	688	136	4,100 1/		216	-	500	7,230			-	-
						34.33	11.19	-	-	3.55		10.40	203.39	-	-		
		11-1-51	-	-	36	720	125	4,[illegible]	262	227	-	579	7,[illegible]			2.1	-
						35.92	10.26	1[illegible].17	6.[illegible]	3.72		12.[illegible]	[illegible].80	2[illegible].1	[illegible]		
		11-9-66	550	130	32	[illegible]	135	4,170	195	[illegible]	-	[illegible]	7,310			1.2	.6
						[illegible].82	11.10	[illegible]	[illegible]	3.7[illegible]		[illegible]	206.[illegible]	[illegible]	229.3		
		7-26-67	60	132	32	746	131	4,290	150	[illegible]	-	955	7,470			1.1	-
						37.23	10.78	18[illegible].[illegible]5	3.8[illegible]	3.62		20.[illegible]	210.73	230.9	23[illegible]		
(B-1-1) 25db-S	Wasatch Hot Springs	3-10-35 2/	-	-	33	1,380	136	2,600	552	30[illegible]	-	1,330	5,800			-	-
						68.86	11.18	113.71	15.11	5.03		27.70	163.63	20[illegible].9	1[illegible].3		
		5-[illegible]-35 2/	-	-	62	270	98	1,950	163	2[illegible]	-	1,050	1,190			-	-
						13.50	8.06	[illegible]	[illegible]	[illegible].80		21.[illegible]	33.63	1[illegible]	1[illegible]		
		1-[illegible]-37 2/	-	-	41	51[illegible]	58	1,870	19[illegible]	293	-	1,4[illegible]	2,750			-	-
						25.[illegible]	4.77	81.34	4.96	4.80		29.[illegible]	77.57	111.7	111.6		
		3-16-40 2/	-	-	26	461	65	1,391	62	278	-	[illegible]	2,070			-	-
						23.00	5.35	60.50	1.58	4.55		26.55	58.39	90.5	89.[illegible]		
		5-19-42 2/	-	-	22	338	101	2,110	211	2[illegible]	-	417	3,650			-	-
						16.85	8.27	91.78	5.40	[illegible]		8.68	102.93	122.5	12[illegible]		
		11-3-66	-	108	15	565	109	2,410	111	270	-	1,060	4,170			1.9	.9
						28.12	8.90	10[illegible].86	2.84	4.43		22.07	117.6[illegible]	142.5	141.9		
		7-26-67		105	16	433	90	1,620	70	244	0	818	2,820			2.8	.3
						21.61	7.40	70.47	1.79	4.00		17.03	79.55	101.28	100.6		
(B-5-1) 27c-S	Hooper Hot Springs	11-3-51	-	140	28	523	118	2,390	283	255	-	30	5,380			.6	-
						26.09	9.71	103.96	7.24	4.01		[illegible]	151.87	147.0	148.6		
		9-15-52 3/	-	140	35	535	92	2,520	283	23[illegible]	-	[illegible]	4,370			.7	2.0
						26.70	7.57	109.62	7.28	3.83		[illegible]	123.27	153.[illegible]	127.[illegible]		
		10-7-53 3/	-	-	42	525	110	2,370	292	2[illegible]	-	1[illegible]	5,360			.4	6.5
						26.20	9.05	103.09	7.46	3.3[illegible]		[illegible]	151.12	145.8	151.2		
		6-20-57	-	130	34	510	85	2,420	169	297	-	40	4,940			.9	-
						25.[illegible]	6.99	105.27	4.30	4.87		.83	139.35	142.5	145.6		
		4-13-60	-	-	30	524	90	2,450	239	220	-	5[illegible]	5,000			-	17
						26.15	8.14	106.57	6.11	3.60		1.2[illegible]	141.58	147.0	146.4		
		11-7-66	-	118	30	506	91	2,350	256	22[illegible]	-	34	4,830			1.0	1.9
						25.25	7.49	102.22	6.55	3.67		.70	136.[illegible]	141.5	141.0		
(B-5-3) 28d-S	Southwest Hooper Warm Springs	9-15-53 3/	-	90	[illegible]	536	450	8,290	803	305	-	219	14,600			-	1.6
						26.75	37.06	360.62	20.53	5.00		4.56	4[illegible].2[illegible]	443.6	403.9		
(B-6-1) 23ccd-S1	Ogden Hot Springs	4-27-43	-	-	-	155	11	1,000 1/		208	-	102	5,060			3.0	
						7.71	.90	-	-	3.40		2.12	142.70	-	-		
		11-3-51		137	53	217	8	2,750	402	200	-	100	5,060			3.2	-
						10.82	.66	119.59	10.30	3.27		2.08	142.[illegible]	1[illegible].1	146.1		
		11-2-66	25	135	47	156	4.9	2,740	357	192	-	106	4,940			3.7	.4
						7.76	.40	11[illegible].[illegible]5	9.15	3.15		2.[illegible]	139.36	1[illegible].10	145.[illegible]		
		3-8-67	-	-	-	-	-	-	-	-	-	-	-			-	-
						-	-	-	-	-		-	-	-	-		
		5-18-67	-	134	45	320	49	2,690	347	192	-	121	5,000			3.8	.9
						15.97	4.03	117.02	8.87	3.15		2.52	140.72	145.9	146.4		
(B-7-2) 14dca-S1	Utah Hot Springs	11-18-31	-	-	-	1,175	28	8,5[illegible] 1/		158	-	203	15,029			-	-
						58.59	2.30	-	-	[illegible]		4.22	423.37	-	-		
		11-3-51	-	-	41	1,190	46	7,720	1,100	190	-	200	15,800			-	-
						59.38	3.78	335.57	28.13	3.26		4.16	4[illegible].50	4[illegible].1	4[illegible].9		
		3-2-54	-	-	13	659	39	5,550	752	190	-	161	10,600			2.6	6.5
						32.88	3.21	241.42	19.[illegible]	3.11		3.35	298.66	296.5	303.5		
		4-5-58	-	135	38	1,140	70	7,030	901	192	-	189	13,300			3.2	-
						56.89	5.76	305.50	23.04	3.15		3.93	375.19	391.5	382.3		
		11-3-66	-	137	15	1,050	39	6,590	935	1[illegible]	-	201	12,700			.3	.8
						52.40	3.21	286.[illegible]	23.91	2.95		4.18	358.27	366.2	365.4		
		3-8-67	-	-	-	-	-	-	-	-	-	-	-			-	-
						-	-	-	-	-		-	-	-	-		
		5-18-67	-	135	36	1,040	79	6,470	932	190	-	293	13,300			.1	[illegible]
						51.90	6.50	281.44	23.83	3.11		6.10	375.1[illegible]	381.1	384.4		
(B-10-3) 30bbd-S1	Stinking Hot Springs	11-18-31	-	-	-	678	129	10,500	-	393	-	26	18,500			-	-
						33.83	10.61	457.50	-	6.44		.54	521.86	527.[illegible]	528.7		
		10-27-51	-	118	53	998	355	11,200	658	518	-	58	20,600			0	-
						55.81	29.20	487.20	16.83	8.49		1.20	575.48	578.0	585.2		
		5-21-52	-	124	-	-	-	-	-	503	-	-	22,700			-	-
						-	-	-	-	8.24		-	640.[illegible]	-	-		
		6-29-52	-	124	-	-	-	-	-	497	-	-	21,600			-	-
						-	-	-	-	8.14		-	609.[illegible]	-	-		
		2-6-53	-	-	-	-	-	-	-	501	-	13[illegible]	22,200			-	-
						-	-	-	-	8.21		2.81	626.26	-	-		
		4-5-58	-	118	48	946	297	12,600	571	325	-	111	21,600			1.9	.0
						47.20	24.4	548.10	14.60	5.33		2.31	609.31	635.2	617.0		
		5-24-66	-	113	60	860	352	10,100	662	389	-	167	17,700			1.6	3.2
						42.92	28.93	439.35	16.93	[illegible]		3.48	499.32	528.2	505.6		
		7-17-67	-	111	41	652	431	9,780	492	420	-	152	17,200			1.8	2.1
						32.53	35.45	425.43	12.58	6.88		3.16	485.21	506.0	495.4		

1/ Calculated Na plus K, reported as Na.
2/ Analysis by Salt Lake City corporation.
3/ Analysis by U.S. Bureau of Reclamation.
e Estimate.

Table extracted from: Mundorff, J. C., Major Thermal Springs of Utah, U.S. Geological Survey Water Resources Bulletin #13, 60 pgs, (1970)

Table 1. (continued).

Boron (B)	Lithium (Li)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Dissolved solids		Specific conductance (micromhos at 25 C)	pH	Concentration, in micrograms per liter																
					Residue on evaporation at 180°C	Calculated			Aluminum Al	Beryllium Be	Bismuth Bi	Cadmium Cd	Chromium Cr	Cobalt Co	Copper Cu	Gallium Ga	Germanium Ge	Iron Fe	Lead Pb	Manganese Mn	Molybdenum Mo	Nickel Ni	Titanium Ti	Vanadium V	Zinc Zn
0.07	-	-	-	-	622	586	896	7.4	16	0.57	<0.29	1.4	<1.4	1.4	<1.4	5.7	2.9	4.6	<1.4	8.6	.29	0.8	0.6	0.29	18
-	-	-	-	-	12,585	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	13,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	13,100	19,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	13,500	20,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.0	2.1	-	-	0.62	-	13,600	21,600	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.2	-	-	-	-	-	13,900	20,800	7.4	31	<.6	<.3	1.4	<1.4	6.9	<1.4	<5.7	20	37	<1.4	486	<.3	4.3	<.6	.7	<5.7
-	-	-	-	-	-	12,800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	8,080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	7,310	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	5,590	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	7,770	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.2	.78	-	-	.26	8,680	8,590	13,700	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.9	-	-	-	-	-	6,000	9,540	7.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	8,600	14,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	9,310	14,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	9,980	16,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	8,350	14,300	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.0	-	-	-	.07	-	8,620	15,000	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.1	7.0	-	-	.14	-	8,230	14,300	7.6	34	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	46	137	1.4	<3,000	.29	5.1	<.57	<.29	<5.7
-	-	-	-	-	-	27,800	39,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	8,650	14,700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.6	6.0	-			-	8,820	-	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.6	5.4	-	-	.3	-	8,650	15,000	7.7	40	<.57	<.29	<1.4	<1.4	1.4	<1.4	<5.7	66	149	1.4	<3,000	<.29	3.7	<.57	1.7	<5.7
-	-	-	-	-	-	-	14,400	-	43	<.57	<.29	<1.4	19	<1.4	<1.4	<1.4	91	<90	<1.4	<800	<4.3	2.6	<.57	3.1	5.7
2.6	3.5	-	15	.39	-	8,680	14,400	7.7	69	<.6	<.3	<1.4	<1.4	1.4	1.4	5.7	54	154	1.4	914	<.3	5.4	<.6	<.3	<5.7
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	25,200	37,200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	18,900	28,300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.1	9.9	28	8.2	.2	-	22,900	34,300	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1	7.9	-	-	.24	-	21,600	34,800	7.5	51	<.57	<.29	<1.4	<1.4	26	1.4	<5.7	80	314	1.4	1,000	<.29	2.4	<.57	4.9	<5.7
-	-	-	-	-	-	-	34,600	-	66	<.57	<.29	<1.4	71	<1.4	1.4	5.7	80	214	1.4	860	8.3	5.4	<.57	2.9	5.7
3.3	2.5	-	34	.38	-	22,700	34,100	7.0	63	<.6	.3	<1.4	<1.4	<1.4	<1.4	5.7	53^{e}	460^{e}	<1.4	1,100^{e}	<.3	5.4^{e}	<.6	<.3	<5.7
-	-	-	-	-	-	30,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	33,900	48,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	53,000	6.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	51,000	6.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	52,200	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.6	5.9	31	15	1.3	-	36,600	53,900	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.6	3.86	-	-	-	-	29,900	46,100	7.3	27	<.57	<.29	-	-	<1.4	<1.4	5.7	<.3	-	1.4	286	<.29	-	<.57	<.29	<5.7
3.2	2.8	-	35	.76	-	29,000	42,500	7.1	43	<.6	<.3	<1.4	<1.4	<1.4	<1.4	<5.7	21	24	<1.4	217	.3	3.2	<.6	<.3	<5.7

Table 1. (continued).

Location	Name of spring	Date of collection	Estimated discharge (gpm)	Temperature (°F)	Silica (SiO2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Carbonate (CO3)	Sulfate (SO4)	Chloride (Cl)	Total equivalents per million: Major cations	Total equivalents per million: Major anions	Fluoride (F)	Nitrate (NO3)
						ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm				
(B-11-2)29da-S	Crystal (Madsen) Hot Springs	11-18-31	-	-		901	218	16,600	-	464	-	499	27,100			-	-
						44.96	17.93	722.10	-	7.55		10.39	764.39	785.0	782.3		
		10-27-51	-	132	33	803	219	14,700	763	465	-	466	25,000			0	-
						40.07	18.01	639.45	19.51	7.62		9.70	705.25	717.0	722.6		
		6-20-52	-	135	25	-	-	13,500	-	445	-	-	23,700			-	-
						-	-	587.20	-	7.29		-	668.36	-	-		
		2-6-53	-	-	-	-	-	-	-	468	-	480	25,300			-	-
						-	-	-	-	7.67		9.99	713.51	-	-		
		11-2-66	1,800	127	26	784	186	13,600	654	372	-	444	22,600			1.9	0.9
						39.10	15.28	591.60	16.72	6.10		9.24	637.55	662.7	653.0		
(B-12-19)11dda-S1	Unnamed hot spring	5-16-66	15	[illegible]	24	44	14	13[1/]		184	0	29	9.1	-	-	-	-
						2.20	1.12			3.02		.61	.26				
(B-1[illegible]-15)[illegible]ab-S1	Warm Spring	8-12-60	450	80	14	36	8.0	27	1.7	108	2	15	57			.2	.1
						1.8	.66	1.17	.04	1.77	.07	.31	1.61	3.67	3.76		
(B-13-3)23baa-S1	Udy Hot Springs	11-1-66	-	109	26	212	55	2,690	118	366	-	90	4,470			1.5	2.6
						10.59	4.52	117.02	3.02	6.00		1.87	126.10	135.1	134.0		
(B-13-5)29-S	Blue Warm Springs 4/	9-10-64	3,400	80	-	83	24	540	32	268	-	68	886			-	-
						4.1	2.0	23.5	.8	4.40		1.41	25.0	30.4	30.8		
(C-1-7)[illegible]9-S	Big Warm Springs	9-28-59	3,600	-	7.9	102	97	2,8[illegible]0[1/]		132	12	352	4,550			-	9.7
						5.08	7.97	-		2.16	-	7.33	128.35	-	-		
		9-29-59	-	-	10	136	79	2,730	92	214	0	327	4,360			.2	13
						6.79	6.49	118.75	2.36	3.50	-	6.81	122.99	134.5	133.3		
		1-5-60	2,750	-	9.5	138	81	2,810	106	223	-	345	4,550			-	10
						6.88	6.66	122.23	2.71	3.65		7.18	128.35	138.5	139.2		
		4-12-60	2,100	-	7.1	134	80	2,850	103	174	-	351	4,670			-	12
						6.68	6.58	123.97	2.63	2.85		7.31	131.70	139.9	141.9		
		7-8-60	3,200	-	7.0	144	73	2,790	99	200	-	332	4,500			-	14
						7.18	6.00	121.36	2.53	3.32		6.91	126.94	137.1	137.2		
		10-1-60	2,700	-	15	146	73	2,830	98	195	-	349	4,590			-	9.7
						7.28	6.00	123.10	2.50	3.17		7.26	129.48	138.9	139.9		
		10-11-60	1,000	-	9.0	139	77	2,800	93	205	-	345	4,510			-	10
						6.91	6.33	121.80	2.37	3.36		7.18	127.22	137.4	137.8		
		1-10-61	2,900	-	11	142	81	2,840	100	220	-	353	4,600			-	10
						7.08	6.66	123.54	2.55	3.60		7.35	129.76	139.8	140.7		
		4-4-61	-	-	5.5	144	88	2,890	103	218	-	352	4,720			-	13
						7.18	7.24	125.71	2.63	3.57		7.33	133.15	142.8	144.0		
		5-27-66	-	65	7.9	140	85	2,750	114	207	-	318	4,420			1.0	1.4
						6.99	6.99	119.62	2.91	3.39		6.62	124.69	136.5	134.8		
(C-2-6)16aad-S1	Grantsville Warm Springs	3-15-66	-	76	27	584	188	8,910	237	233	-	662	15,000			1.7	1.3
						29.14	15.46	387.58	6.06	3.82		13.78	423.15	438.2	440.7		
(C-4-1)11 & 12b-S	Crystal Hot Springs	1882	-	-	28	141	28	405	55	216	-	378	337			-	-
						7.03	2.30	17.61	1.40	3.54		-	-	-	-		
		5-22-34	-	137	60	106	25	304[1/]		285	-	97	598			-	-
						5.29	2.05	-	-	4.67		-	-	-	-		
		7-25-50	-	-	73	102	24	226[1/]		146	-	72	560			-	-
						5.08	1.97	-	-	2.39		-	-	-	-		
		9-10-52	-	-	66	80	32	411[1/]		336	2	85	616			.0	9.6
						3.99	2.63	-	-	5.50		-	-	-	-		
		5-27-58	-	-	50	142	31	330[1/]		340	-	72	595			-	4.7
						7.08	2.55	-	-	5.57		-	-	-	-		
(C-5-1)25-S	Crater Hot Springs	5-27-58	-	107	27	180	49	232[1/]		320	-	425	318			-	1.3
						8.98	4.03	-	-	5.25		8.85	8.97	-	-		
		6-4-58	-	110	28	191	52	235[1/]		320	-	441	338			-	2.5
						9.53	4.27	-	-	5.24		9.18	9.53	-	-		
(C-5-1)25cd-S	Saratoga Hot Springs	1931	-	-	-	148	34	273	-	281	-	388	361			-	-
						7.38	2.79	11.87		4.60		8.08	10.18	-	-		
		3-24-66	-	111	25	190	68	214[1/]		313	-	451	350			-	-
						9.48	5.59			5.13		9.39	9.87	-	-		
(C-5-5)9cba-S1	Mortons Warm Springs	9-22-64	1,000	75	20	58	24	110	11	174	-	90	179			1.0	0.4
						2.89	1.97	4.78	.28	2.85		1.87	5.05	9.92	9.77		
		5-27-66	-	77	18	56	24	109	13	172	-	89	182			1.2	.3
						2.79	1.97	4.74	.33	2.82		1.85	5.13	9.83	9.80		
		7-18-67	-	80	19	48	28	112	11	162	-	98	188			1.4	.0
						2.40	2.30	4.87	.28	2.66		2.04	5.30	9.84	9.99		
(C-7-5)17aaa-S1	Russells Warm Springs	4-29-66	450	71	17	51	21	73	11	170	-	55	124			1.6	.2
						2.54	1.73	3.18	.28	2.79		1.15	3.50	7.72	7.44		
		5-27-66	-	72	17	53	19	74	12	175	-	55	122			1.5	.1
						2.64	1.56	3.22	.31	2.87		1.15	3.44	7.72	7.46		
		7-18-67	-	-	19	55	17	71	10	170	-	65	122			1.5	.0
						2.74	1.40	3.09	.26	2.79		1.35	3.44	7.46	7.58		

1/ Calculated Na plus K, reported as Na.
4/ Analysis from Milligan and others (1966, table 1).

Table 1. (continued).

Boron (B)	Lithium (Li)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Dissolved solids		Specific conductance (micromhos at 25°C)	pH	Concentration, in micrograms per liter																
					Residue on evaporation at 160°C	Calculated			Aluminum Al	Beryllium Be	Bismuth Bi	Cadmium Cd	Chromium Cr	Cobalt Co	Copper Cu	Gallium Ga	Germanium Ge	Iron Fe	Lead Pb	Manganese Mn	Molybdenum Mo	Nickel Ni	Titanium Ti	Vanadium V	Zinc Zn
-	-	-	-	-	-	65,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	62,200	58,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	53,300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	56,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.1	4.8	-	-	.28	-	38,506	56,100	7.3	<1.4	<.57	.29	<1.4	<1.4	<1.4	<1.4	<5.7	11	111	<1.4	163	<.29	4.6	<.57	<.3	<5.7
					248	-	371																		
					-																				
.02	.02	-	.2	.00	-	214	406	8.5	2.7	<.57	.29	<1.4	<1.4	<1.4	<1.4	<.57	.29	18	<1.4	<1.4	<.29	<1.9	<.57	.7	<5.7
.69	.83	-	-	.1	-	7,850	13,600	7.9	19	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	<.29	54	<1.4	<1.4	<.29	3.1	<.57	<.3	<5.7
.2	.8	-	-	-	-	1,923	3,580	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	8,100	14,000	8.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.98	1.8	-	-	-	-	7,860	13,000	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.91	1.0	-	-	.05	-	8,160	13,700	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.95	-	-	-	.06	-	8,300	14,400	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.85	-	-	-	.04	-	8,060	13,200	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	[illegible]	-	8,210	13,800	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	.06	-	8,090	13,500	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	.06	-	8,250	13,800	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	.05	-	8,430	14,300	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.70	.67	-	-	-	-	7,940	13,300	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.5	-	-	-	-	-	25,800	40,400	7.5	37	<.57	<.29	<1.4	<1.4	<1.4	1.4	<5.7	<.29	6.6	<1.4	<1.4	3.4	7.4	<.57	2.9	197
-	-	-	-	-	-	1,680	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1,665	-	-	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,300	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,390	2,470	7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,390	2,140	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,440	2,230	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	1,503	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,450	2,220	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-		-	-	-	-	583	981	8.0	6.0																
.16	.04	-	-	-	-	578	1,030	7.7	16	.57	2.7	-	-	49	9.4	<5.7	<.29	-	<1.4	<1.4	3.1	-	<5.7	.6	<5.7
.18	.03	-	.3	.01	-	586	1,000	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.14	.03	-	.3	.01	-	438	779	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.09	.02	-	-	-	-	440	778	8.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.14	.02	-	.2	.02	-	445	744	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 1. (continued).

Location	Name of spring	Date of collection	Estimated discharge (gpm)	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Total equivalents per million		Fluoride (F)	Nitrate (NO_3)
						ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	Major cations	Major anions		
(C-10-14) 33-S	Wilson Hot Springs	7-12-67	100	141	33	741	224	7,090	18	178	-	1,560	11,900			4.0	.0
						36.97	18.43	308.42	.46	2.92	-	32.48	335.70	364.3	371.1		
(C-11-14) 23c-S	Fish Springs	7-12-67	75	82	20	136	26	470	36	312	-	340	630			2.0	0
						6.79	2.14	20.44	.92	5.11		7.08	17.77	30.3	29.96		
(C-11-14) 23db-S	do	3-26-56	-	77	-	-	-	-	-	321	-	-	-			-	-
						-	-	-	-	5.26		-	-	-	-		
(C-11-14) 23dc-S	do	3-26-56	-	65	-	-	-	-	-	296	-	-	-			-	-
						-	-	-	-	4.85	-	-	-	-	-		
(C-11-14) 23dd-S	do	3-26-56	-	72	-	-	-	-	-	316	-	-	-			-	-
						-	-	-	-	5.18	-	-	-	-	-		
(C-14-8) 10-S	Abraham (Crater) Hot Springs	11-12-27	-	-	-	550	-	[illegible]1/		156	-	560	1,410			-	-
						-	-	-	-	-		-	-	-	-		
		5-31-66	-	-	57	361	56	812	67	153	-	733	1,550			3.0	.2
						18.01	4.60	35.32	1.71	2.51	-	15.26	43.72	59.6	61.5		
		7-13-67	250	180	59	345	68	816	48	160	-	756	1,450			4.1	.0
						17.22	5.59	35.50	1.23	2.62		15.74	40.90	59.5	59.3		
(C-15-19) 31bc-S	Gandy Warm Springs	3-3-66	4,500	81	20	50	21	28	2.8	278	-	21	20			.7	3.6
						2.50	1.73	1.22	.07	4.56		.44	.56	5.52	5.56		
		7-12-67	9,000	80	21	50	18	29	3.7	250	-	29	26			.7	1.9
						2.50	1.48	1.26	.09	4.10		.60	.73	5.33	5.42		
(C-22-6) 2[illegible]ccc-S1	Meadow Hot Springs	5-12-66	-	106	44	419	97	1,040	157	314	-	1,020	1,750			5.3	.6
						20.91	7.98	45.25	4.01	5.15		21.24	49.37	78.1	75.7		
(C-22-6) 27ddd-S1	do	4-8-43		95	-	464	95	1,150 1/		452	-	1,040	1,830			3.9	2.0
						23.15	7.81	-	-	7.40		-	51.62	-	-		
		6-18-57	-	-	-	470	88	1,090 1/		440	-	993	1,780			-	2.2
						23.45	7.23		-	7.21		-	50.21	-	-		
		8-27-58	-	90	-	485	68	1,140 1/		436	-	1,050	1,820			-	2.8
						24.20	5.59		-	7.14		-	51.34	-	-		
		5-12-66	-	84	50	451	103	1,060	157	429	-	1,040	1,780			5.0	1.0
						22.50	8.47	46.11	4.01	7.03		21.65	50.21	81.1	78.9		
		5-22-67	-	106	47	433	114	1,020	138	408	-	1,130	1,800			5.5	1.6
						21.60	9.38	44.37	3.53	6.69		23.53	50.78	78.9	81.0		
(C-22-6) 35ddb-S1	Hatton Hot Springs	6-19-57	-	100	44	465	89	1,090 1/		427	-	985	1,780			-	2.4
						23.20	7.32	-	-	6.99		-	50.21	-	-		
		8-27-58	25	-	-	489	75	1,150 1/	-	484	-	1,050	1,810			-	2.8
						24.40	6.16	-	-	7.93		-	51.06	-	-		
(C-23-3) 2aaca-S1	Richfield Warm Springs	7-30-57	-	68	14	45	38	12	4.0	298	-	27	20			.2	.8
						2.25	3.13	.52	.10	4.88		.56	.56	6.00	6.00		
		6-6-66	700	72	11	51	35	15	3.2	280	4	29	20			.3	.1
						2.54	2.88	.65	.08	4.59	.13	.60	.56	6.13	5.88		
(C-25-3) 10dda-S1	Monroe (Cooper) Hot Springs	7-23-57	-	-	54	282	34	562	63	354	-	898	630			2.6	0
						14.07	2.79	24.44	1.61	5.80		18.70	17.77	42.9	42.3		
		9-10-57	-	169	54	288	33	555	67	416	-	833	660			3.0	0
						14.37	2.71	24.14	1.71	6.81		17.35	18.61	42.9	42.8		
		5-17-66	6	108	52	257	17	578	62	309	-	932	625			2.8	.7
						12.82	1.40	25.14	1.59	5.06		19.40	17.63	40.9	42.1		
(C-25-3) 11cac-S1	Red Hill Hot Spring	9-11-57	-	-	63	240	34	618	53	256	-	965	660			-	-
						11.97	2.80	26.88	1.35	4.19		20.10	18.61	43.0	42.9		
		5-2-66	40	170	51	200	34	597	66	158	-	928	665			2.8	.3
						9.98	2.80	25.97	1.69	2.59		19.33	18.75	40.4	40.7		
(C-25-3) 15a-S	Monroe (Cooper) Hot Springs	5-3-67	-	97	51	281	49	553	49	386	-	924	600			1.8	.2
						14.02	4.03	24.06	1.25	6.33		19.24	16.93	43.4	42.5		
(C-25-3) 27a-S	Johnson Warm Spring	6-19-67	10	77	32	30	15	44	1.5	175	-	163	14			1.8	.0
						1.49	1.23	1.91	.04	2.87		3.39	.39	6.66	6.65		
(C-25-4) 23-S	Joseph Hot Springs	7-23-57	-	130	85	282	36	1,440	68	426	-	1,270	1,750			2.7	-
						14.07	2.96	62.64	1.73	6.98		26.45	49.36	81.4	82.8		
		9-11-57	-	147	84	264	44	1,380	45	412	-	1,250	1,690			6.0	-
						13.17	3.61	60.03	1.15	6.75		26.03	47.67	78.0	80.4		
		5-3-66	-	145	77	261	49	1,470	60	410	-	1,260	1,700			3.0	1.1
						13.02	4.03	63.94	1.53	6.72		26.23	47.96	82.5	80.9		
		5-15-67	-	148	76	248	46	1,490	47	396	-	1,370	1,700			4.6	.0
						12.38	3.78	64.82	1.20	6.49		28.52	47.96	82.2	83.0		
(C-26-9) 34dcb-S1	Roosevelt (McKeans) Hot Springs	11-4-50	-	185	405	19	3.3	2,080	472	158	-	65	3,810			7.1	1.9
						.95	.27	90.48	12.07	2.57		1.35	107.48	103.8	111.4		
		9-11-57	-	133	313	22	0	2,500	488	156	-	73	4,240			7.5	11
						1.10	0	108.75	12.48	2.56		1.52	119.61	122.3	123.7		
(C-30-9) 7aca-S1	Radium (Dotsons) Warm Springs	8-21-63	-	91	31	110	24	172	18	220	3	480	65			9.8	.2
						5.48	1.97	7.48	.46	3.60		9.99	1.83	15.4	15.4		
		3-12-66	-	88	29	104	26	164	18	222	-	458	64			4.3	.1
						5.18	2.13	7.13	.46	3.64		9.54	1.81	14.9	15.0		
		7-11-67	100	89	32	88	35	169	17	228	-	435	63			4.5	.0
						4.39	2.87	7.35	.43	3.74		9.06	1.78	15.0	14.6		

1/ Calculated Na plus K, reported as Na.

Table 1. (continued).

Boron (B)	Lithium (Li)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Dissolved solids		Specific conductance (micromhos at 25°C)	pH	Concentration, in micrograms per liter																
					Residue on evaporation at 180°C	Calculated			Aluminum Al	Beryllium Be	Bismuth Bi	Cadmium Cd	Chromium Cr	Cobalt Co	Copper Cu	Gallium Ga	Germanium Ge	Iron Fe	Lead Pb	Manganese Mn	Molybdenum Mo	Nickel Ni	Titanium Ti	Vanadium V	Zinc Zn
2.6	2.1	-	23	.36		21,800	31,200	7.4	74	<.57	<.29	<1.4	1.4	<1.4	<1.4	<5.7	20	43	<1.4	160	8.0	4.0	<.57	<.29	<5.7
.79	.33	-	1.3	.02	-	1,820	3,050	7.7	25	.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	<.29	110	<1.4	1.4	9.4	2.5	<.57	1.0	110
-	-	-	-	-	-	-	3,160	7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	3,130	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	3,100	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	3,170	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.70	.78	-	-	-	3,710	-	5,910	7.8	31	<.57	<.29	-	-	<1.4	<1.4	<5.7	<.29	-	<1.4	100	<.29	-	<.57	<.29	<5.7
.83	.63	-	1.8	.09	-	3,630	5,570	7.3	4.3	<.57	<.29	1.4	<1.4	<1.4	<1.4	<5.7	.29	86	5.1	130	<.29	2.7	1.4	<.29	<5.7
.09	-	-	-	-	-	305	498	7.6	4.3	<.57	.29	1.4	<1.4	<1.4	<1.4	<5.7	4.6	3.4	<1.4	<1.4	1.5	1.6	<.57	1.6	197
.09	.02	-	.1	.00	-	303	485	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.2	2.5	-	1.3	.03	-	4,690	7,350	7.6	629	<.57	<.29	1.4	<1.4	<1.4	<1.4	<5.7	57	7.4	<1.4	<1.4	<.29	2.7	<.57	<.29	143
-	-	-	-	-	-	4,810	7,350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	4,690	7,360	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	4,850	7,270	7.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.3	1.5	-	1.3	.08	-	4,970	7,440	7.7	106	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	571	13	<1.4	<1.4	<.29	2.5	<.57	<.29	<109
[illegible]	1.2	-	4.0	.45	-	4,900	7,130	7.5	63	<.6	<.3	<1.4	<1.4	<20	<1.4	5.7	25	40	<1.4	<1.4	<.3	4.0	<.6	<.3	<5.7
-	-	-	-	-	-	4,670	7,270	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	4,850	7,380	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	.5	-	-	-	-	310	548	7.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.04	.04	-	.1	.01	-	307	551	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	4.8	-	-	-	-	2,700	4,100	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.9	1.1	-	-	-	-	2,860	4,020	6.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.6	.51	-	.4	.03	-	2,680	4,000	7.6	4.0	<.57	<.29	<1.4	<1.4	<1.4	<1.4	5.7	19	5.1	<1.4	<1.4	1.2	.9	<.57	<.29	<5.7
1.4	.9	-	-	-	-	-	4,020	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.7	.57	-	.3	.06	-	2,630	4,100	7.8	6.0	<.57	<.29	<1.4	<1.4	<1.4	1.4	<5.7	16	11	<1.4	<1.4	1.2	1.1	<.57	<.29	<5.7
2.3	.4	-	1.6	.04	-	2,700	3,900	7.9	571	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	16	29	<1.4	146	<.29	4.1	.57	<.29	<5.7
.08	.01	-	.1	.01	-	428	623	7.4	11	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	<.29	14	<1.4	<1.4	18	1.7	<.57	1.5	<5.7
-	-	-	-	-	-	5,150	7,790	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.8	1.5	-	-	-	-	4,970	7,520	6.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.0	1.5	-	.9	.10	-	5,090	7,480	7.6	714	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	129	16	37	177	19	5.4	<.57	<.29	<5.7
1.7	1.9	-	1.0	.12	-	5,180	7,530	7.8	19	<.6	<.3	<1.4	<1.4	<1.4	<1.4	<5.7	57	270	<1.4	343	25	4.6	<.6	<.3	<5.7
-	-	-	-	-	-	7,040	11,500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	.27	-	3.3	.1	-	7,800	12,700	7.9	.04	-	-	-	-	-	.00	-	-	-	.00	0	-	-	.0	-	0
.31	.4	1.2	.0	.01		1,020	1,420	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	.13	-	.0	.01	-	927	1,410	8.2	31	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	19	[illegible]	<1.4	1.4	2.1	1.4	<.57	<.29	91
.47	.11	-	.2	.09	-	956	1,390	7.4	29	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	27	110	<1.4	<1.4	<.29	2.3	<.57	<.29	<5.7

Table 1. (continued).

Location	Name of spring	Date of collection	Estimated discharge (gpm)	Temperature (°F)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Total equivalents per million		Fluoride (F)	Nitrate (NO_3)
						ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	ppm epm	Major cations	Major anions		
(C-30-12) 21-S	Thermo Hot Springs	10-23-39	-	-	-	-	-	-	-	370	-	460	217			-	-
						-	-	-	-	6.06		9.58	6.12				
		8-21-63	-	-	108	83	9.7	358	49	384	-	482	210			14	1.0
						4.14	.79	15.57	1.25	6.29		10.04	5.92	21.78	22.2		
(C-30-12) 28-S	do	8-21-63	-	-	103	71	9.2	367	45	314	16	469	215			4.7	1.1
						3.54	.75	15.96	1.15	5.15	.53	9.76	6.07	21.4	21.5		
		5-25-66	10	173	100	75	9.7	361	52	359	-	460	208			6.7	.1
						3.74	.80	15.70	1.33	5.88		9.58	5.87	21.6	21.3		
		7-11-67	-	170	100	76	12	364	47	374	-	460	212			14	.0
						3.79	.98	15.83	1.20	6.13		9.58	5.98	21.8	21.7		
(C-40-16) 7acb-S1	Veyo Hot Spring	3-30-66	90	90	30	59	29	32	4.4	220	-	100	30			.6	8.3
						2.94	2.39	1.39	.11	3.61		2.08	.85	6.82	6.52		
		4-20-67	-	90	32	53	28	32	3.6	230	-	90	30			.7	6.9
						2.64	2.30	1.39	.09	3.77		1.67	.85	6.42	6.47		
(C-41-13) 25-S	LaVerkin (Dixie) Hot Springs	6- 3-40	-	-	10	787	165	2,300	167	1,270	-	1,960	3,440			-	.2
						39.27	13.57	100.05	4.27	20.82		40.81	97.04	157.0	158.7		
		8-15-50	-	-	9.3	816	197	2,430[1]		1,290	-	1,940	3,580			-	-
						40.71	16.20	-	-	21.14		40.41	100.99	-	-		
		2- 5-51	-	-	30	825	169	2,340	175	1,300	-	1,970	3,600			3.1	3.2
						41.16	13.90	101.79	4.47	21.30		41.03	101.56	161.4	165.6		
		8-31-60	4,800	100	28	590	148	2,490	177	583	-	2,050	3,610			2.1	3.2
						29.44	12.17	108.31	4.52	9.55		42.70	101.83	154.4	154.1		
		3-25-66	4,500	108	28	643	128	2,530	220	721	-	1,990	3,620			2.6	.9
						32.09	10.53	110.06	5.63	11.82		41.43	102.12	158.3	155.4		
(D-3-4) 26bca-S1	Midway Hot Springs	7- 1-52	-	-	5.6	358	16	257[1]		754	-	698	121			.3	.1
						17.86	1.31	-	-	12.35		14.53	-	-	-		
(D-3-4) 26cca-S1	do	9-28-66	50	103	23	331	68	114	25	674	-	661	108			2.2	.1
						16.51	5.59	4.96	.64	11.05		13.76	3.05	27.7	27.9		
-3-4) 27bab-S1	do	9-13-67	-	113	27	345	83	148	16	644	0	742	132			2.5	.4
						17.22	6.83	6.44	.41	10.56		15.45	3.72	30.9	29.7		
(D-3-4) 27bac-S1	do	5-16-67	10	104	28	361	88	152	32	696	-	853	140			3.1	.0
						18.01	7.23	6.61	.82	11.41		17.76	3.94	32.7	33.1		
(D-3-4) 27bad-S1	do	9-28-66	150	103	28	389	73	151	31	728	-	820	138			2.5	.1
						19.41	6.00	6.57	.79	11.93		17.07	3.89	32.8	32.9		
(D-3-4) 27cbd-S1	do	9-28-66	0	84	21	353	72	125	28	716	-	702	115			2.1	.1
						17.61	5.92	5.44	.72	11.74		14.62	3.24	29.7	29.6		
		5-15-67	0	84	22	228	95	130	28	476	-	719	115			2.3	.1
						11.37	7.81	5.66	.72	7.80		14.97	3.24	25.5	26.0		
(D-3-4) 27cbd-S2	do	9-28-66	0	85	19	329	70	111	25	686	-	643	103			2.2	.1
						16.41	5.75	4.83	.64	11.24		13.39	2.90	27.6	27.5		
		5-15-67	0	90	17	279	74	114	26	572	-	611	105			2.4	.0
						13.92	6.08	4.96	.66	9.38		12.72	2.96	25.6	25.1		
(D-3-4) 27cbd-S3	do	5-16-67	0	83	21	329	88	163	33	584	-	805	150			2.7	.0
						16.41	7.23	7.09	.84	9.57		15.66	4.23	31.6	29.5		
(D-4-24) 16cdd-S1	Split Mountain Warm Spring	9-19-48	5,400	86	18	97	32	193[1]	193	198	-	212	291			-	1.2
						4.84	2.63	-	-	3.24		4.41	8.20	-	-		
(D-7-1) 5cch-S1	Warm spring west shore of Utah Lake	9-11-58	-	77	15	144	58	342[1]		348	-	325	510			-	.8
						7.18	4.77	-	-	5.70		6.76	14.38	-	-		
(D-7-1) 8bbc-S1	do	9-11-58	-	75	16	88	59	342[1]		196	-	314	510			-	.8
						4.39	4.85		-	3.21		6.54	14.38	-	-		
(D-8-1) 3dda-S1	Lincoln Point Warm Springs	5-27-64	-	87	.22	457	114	1,820[1]		756	-	953	2,800			-	-
						22.80	9.37		-	12.39		19.84	78.99	-	-		
		6-16-66	-	89	21	451	136	1,510	159	751	-	940	2,530			2.8	2.4
						22.50	11.19	65.68	4.07	12.31		19.57	71.37	103.4	103.2		
(D-8-5) 14d-S	Diamond Fork Warm Springs	10-20-67	450	68	17	104	32	117	8.3	264	0	390	36			1.6	.5
						5.20	2.64	5.09	.21	4.33		8.12	1.02	13.1	13.5		
(D-9-4) 18ba-S	Castilla Hot Springs	10-20-67	20	104	30	469	80	1,680	10	542	0	1,400	2,320			3.6	4.8
						23.40	6.60	73.08	2.56	8.88		29.15	65.45	105.6	103.6		
(D-10-1) 8c-S	Goshen Warm Springs	5-27-64	-	70	18	84	41	356[1]		316	-	102	558			-	2.2
						4.19	3.40	-	-	5.18		2.12	15.74	-	-		
		6-15-66	-	70	17	87	40	343	19	314	-	115	540			1.2	2.1
						4.34	3.29	14.92	.49	5.15		2.39	15.23	23.0	22.8		
(D-18-2) 13cad-S1	Livingston(Crystal) Warm Spring	2- 6-41	-	-	5.6	26	15	129[1]		421	-	86	55			.7	3.0
						1.29	1.23			6.90		-	-	-	-		
(D-19-2) 4dca-S1	Sterling Warm Spring	8-27-57		67	13	38	19	94	3.8	310	-	71	34			1.1	.1
						1.89	1.56	4.08	.09	5.08		1.47	.95	7.62	7.50		

[1] Calculated Na plus K, reported as Na.

Table 1. (continued).

Boron (B)	Lithium (Li)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Dissolved solids: Residue on evaporation at 180°C	Dissolved solids: Calculated	Specific conductance (micromhos at 25°C)	pH	Aluminum Al	Beryllium Be	Bismuth Bi	Cadmium Cd	Chromium Cr	Cobalt Co	Copper Cu	Gallium Ga	Germanium Ge	Iron Fe	Lead Pb	Manganese Mn	Molybdenum Mo	Nickel Ni	Titanium Ti	Vanadium V	Zinc Zn
									Concentration, in micrograms per liter																
-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.64	1.3	.7	.0	.03	-	1,500	2,120	8.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.60	-	.8	.0	.03	-	1,460	2,100	8.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.50	.98	-	.2	.03	-	1,450	2,130	7.7	>230	<.57	<.29	<1.4	<1.4	<1.4	6.3	<5.7	<.57	8.3	17	24	.29	1.6	<.57	<.3	<5.7
.85	.85	-	.4	.04	-	1,470	2,100	7.4	<1.4	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	<.29	49	<1.4	60	<.29	3.7	<.57	<.3	<5.7
.14	.05	-	.2	.00	-	402	640	7.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.14	.02	-	.1	.01	-	389	600	7.6	<1.4	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	.29	9.4	<1.4	<1.4	<.29	<.29	<.57	5.7	<5.7
-	-	-	-	-	-	9,460	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	9,610	13,900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.3	-	-	-	-	-	9,760	13,800	6.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.0	-	-	-	-	-	9,390	13,500	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.8	2.0	-	1.5	.02	-	9,530	14,200	7.2	100	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	60	9.7	<1.4	<1.4	<.29	1.9	<.57	<.3	14
-	-	-	-	-	-	1,890	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.67	.28	-	.9	.01	-	1,670	2,200	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.64	-	-	-		-	1,810	2,410	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	.3	-	.5	.02	-	2,000	2,490	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.79	.36	-	.7	.01	-	1,990	2,560	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.70	.31	-	.6	.01	-	1,770	2,330	7.4	11	<.57	<.29	<1.4	<1.4	<1.4	<1.4	<5.7	12	25	<1.4	51	<.29	4.6	<.57	<.3	<5.7
.71	.3	-	.5	.01	-	1,570	2,280	7.8	12	<.6	<.3	<1.4	<1.4	<1.4	1.4	<5.7	<14	36	<1.4	<1.4	.3	43	<.6	<.3	<5.7
.64	.27	-	.5	.00	-	1,640	2,180	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.64	.2	-	.5	.01	-	1,510	2,120	7.9	12	<.6	<.3	<1.4	<1.4	<1.4	<1.4	<5.7	18	13	<1.4	<1.4	<.3	3.7	<.6	<.3	<5.7
.80	.3	-	.9	.02	-	1,880	2,610	7.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	942	1,570	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,570	2,570	6.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	1,430	2,430	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	6,550	9,490	7.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.7	1.7	-	-	-	-	6,140	9,340	7.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.2	.10	-	.05	.03	-	837	1,180	7.6	27	<.6	<.3	<1.4	<1.4	<1.4	<1.4	<5.7	13	49	<1.4	≤3.9	.3	3.4	<.6	<.3	<5.7
1.4	1.3	-	1.5	.08	-	6,360	9,480	7.9	20	<.6	<.3	<1.4	<1.4	<1.4	<1.4	<5.7	37	14	<1.4	103	≤.3	≤.3	<.6	<.3	<5.7
-	-	-	-	-	-	1,320	2,310	7.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
.21	4.33	-	-	-	-	1,320	2,320	7.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	635	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	.4	-	-	-	-	429	711	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. Ratios, by weight, of selected constituents in thermal springs in Utah.

Location	Name of spring	Date	Dissolved solids (ppm)	Calcium / Magnesium Ca/Mg Magnesium / Calcium Mg/Ca	Sodium / Calcium Na/Ca Calcium / Sodium Ca/Na	Sodium / Potassium Na/K Potassium / Sodium K/Na	Sodium / Lithium Na/Li Lithium / Sodium Li/Na	Chloride / Sulfate Cl/SO_4 Sulfate / Chloride SO_4/Cl	Chloride / Fluoride Cl/F Fluoride / Chloride F/Cl	Chloride / Bicarbonate Cl/HCO_3 Bicarbonate / chloride HCO_3/Cl	Chloride / Bromine Cl/Br Bromine / Chloride Br/Cl	Bromine / Iodine Br/I Iodine / Bromine I/Br
(A-4-3)31cab-S1	Como	5-18-66	586	3.5	0.31	4.0	-	0.12	-	-	-	-
				.29	3.2	.25		8.3				
(B-1-1)14dcb-S1	Becks	1881	12,580	6.3	5.4	19.0	-	8.0	-	-	-	-
				.16	.19	.05		.12				
		5-19-42	13,900	4.9	6.2	9.1	-	8.8	-	32.1	-	-
				.20	.16	.11		.11		.03		
		8-29-47	13,100	5.1	6.0	-	-	9.0	-	30.7	-	-
				.20	.17			.11		.03		
		11- 3-51	13,500	5.8	5.6	15.5	-	8.3	3,160	32.0	-	-
				.17	.18	.06		.12	.0003	.03		
		11- 9-66	13,600	5.5	5.6	20.8	1,790	7.9	2,250	31.9	-	-
				.18	.18	.05	.0006	.13	.0004	.03		
		7-26-67	13,900	5.7	5.7	26.6	-	7.6	2,260	33.8	-	-
				.18	.18	.04		.13	.0004	.03		
(B-1-1)25db-S	Wasatch	3-16-34	12,800	10.1	1.9	4.8	-	4.4	-	18.9	-	-
				.10	.53	.21		.22		.05		
		May 1935	8,080	4.8	4.1	11.9	-	3.3	-	11.6	-	-
				.21	.24	.08		.30		.08		
		Jan. 1937	7,310	7.1	4.5	9.6	-	1.9	-	9.5	-	-
				.14	.22	.10		.53		.11		
		3-16-40	5,590	7.1	3.0	22.1	-	2.1	-	7.4	-	-
				.14	.33	.04		.48		.14		
		5-19-42	7,770	5.2	3.9	10.0	-	4.0	-	14.2	-	-
				.19	.26	.10		.25		.07		
		11- 3-66	8,590	5.2	4.3	21.7	3,090	3.8	2,290	19.0	-	-
				.19	.23	.05	.0003	.26	.0004	.05		
		7-26-67	6,000	4.8	3.7	23.2	-	3.4	1,010	11.6	-	-
				.21	.27	.04		.29	.001	.08		
(B-5-3)27c-S	Hooper	11- 3-51	8,600	4.4	4.6	8.4	-	142	8,500	20.8	-	-
				.23	.22	.12		.007	.0001	.05		
		9-15-53	9,310	5.8	4.7	8.8	-	121	6,240	18.7	-	-
				.17	.21	.11		.008	.0002	.05		
		10- 7-53	9,980	4.8	4.5	6.1	-	140	12,950	19.5	-	-
				.21	.22	.12		.007	.0001	.05		
		6-20-57	8,350	6.1	4.7	14.4	-	124	-	5.5	-	-
				.16	.21	.07		.008		.18		
		4-13-60	8,620	5.3	4.7	10.3	-	86.3	-	23.1	-	-
				.19	.21	.10		.01		.04		
		11- 7-66	8,230	5.6	4.6	9.2	1,175	127	4,840	21.6	-	-
				.18	.21	.11	.0009	.008	.0002	.05		
(B-5-3)28d-S	Southwest Hooper	9-15-53	27,800	1.2	15.5	10.3	-	65.8	-	47.4	-	-
				.83	.06	.10		.02		.02		
(B-6-1)23ccd-S1	Ogden	4-27-43	8,650	32.3	8.5	-	-	49.8	1,690	24.4	-	-
				.03	.12			.02	.0006	.04		
		11- 3-51	8,820	42.1	8.1	6.7	456	50.6	1,490	25.3	-	-
				.02	.12	.15	.002	.02	.0007	.04		
		11- 2-66	8,650	7.1	7.7	7.6	66.5	46.6	1,340	25.7	-	-
				.14	.13	.13	.02	.02	.0008	.04		
		5-18-67	8,680	6.5	8.4	7.7	99	41.2	1,310	26.0	333	38
				.15	.12	.13	.01	.02	.0008	.04	.003	
(B-7-2)14dca-S1	Utah	11-18-11	-	41.9	-	-	-	74.3	-	80.2	-	-
				.02				.02		.01		
		11- 3-51	25,200	25.9	6.5	7.0	-	74.0	-	74.4	-	-
				.04	.15	.14		.02		.02		
		3- 2-54	18,900	22.0	6.5	7.5	-	59.7	4,150	56.8	-	-
				.05	.15	.13		.02	.0002	.02		
		4- 5-58	22,900	16.3	6.7	7.8	710	70.4	4,160	69.2	1,620	41
				.06	.16	.13	.001	.02	.0002	.02	.0006	
		11- 3-66	21,600	26.2	6.5	7.0	833	61.2	2,950	69.8	-	-
				.04	.15	.14	.001	.02	.0003	.02		
		5-18-67	22,700	13.1	6.6	7.4	916	45.3	3,240	70.0	3,910	89
				.08	.15	.14	.001	.02	.0003	.02	.0003	
(B-10-3)30bbd-S1	Stinking	11-18-11	30,400	2.3	11.8	-	-	925	-	47.1	-	-
				.43	.08			.001		.02		
		10-27-51	33,900	2.5	12.5	17.0	-	352	-	39.4	-	-
				.40	.08	.06		.003		.03		
		2- 6-53	-	-	-	-	-	164	-	44.3	-	-
								.006		.02		
		4- 5-58	36,600	3.2	13.3	22.1	1,830	194	11,370	66.7	1,440	9.4
				.31	.08	.05	.0005	.005	.00009	.01	.0002	
		5-24-66	29,900	2.5	12.0	15.3	2,620	106	11,100	105	-	-
				.40	.08	.07	.0004	.009	.00009	.01		
		5-17-67	29,000	1.5	15.9	19.9	3,330	111	-	113	491	46
				.67	.07	.05	.0003	.009		.009	.002	
(B-11-2)29da-S	Crystal	11-18-11	45,500	4.1	18.4	-	-	54.3	-	59.7	-	-
				.24	.05			.02		.02		
		10-27-51	42,200	3.7	18.3	-	-	53.6	-	54.0	-	-
				.27	.05			.02		.02		
		2- 6-53	-	-	-	-	-	52.7	-	54.0	-	-
								.02		.02		
		11- 2-66	38,500	4.2	17.3	20.7	2,830	50.9	11,900	60.9	-	-
				.24	.06	.05	.0004	.02	.00009	.02		
(B-11-19)11dda-S1	Unnamed hot spring	5-16-66	248	3.1	-	-	-	.31	-	.05	-	-
				.32				3.2		20.2		
(B-12-15)19aab-S1	Warm	8-12-66	214	4.5	.75	15.9	1,350	3.8	285	.53	285	-
				.22	1.33	.06	.0007	.26	.004	1.9	.003	
(B-13-3)23baa-S1	Uddy	11- 1-66	7,850	3.9	12.7	22.8	3,240	49.7	[illegible]	12.2	-	-
				.26	.08	.04	.0003	.02	.0003	.08		

Table 2. (continued).

Location	Name of spring	Date	Dis-solved solids (ppm)	Calcium/Magnesium Ca/Mg Magnesium/Calcium Mg/Ca	Sodium/Calcium Na/Ca Calcium/Sodium Ca/Na	Sodium/Potassium Na/K Potassium/Sodium K/Na	Sodium/Lithium Na/Li Lithium/Sodium Li/Na	Chloride/Sulfate Cl/SO4 Sulfate/Chloride SO4Cl	Chloride/Fluoride Cl/F Fluoride/Chloride F/Cl	Chloride/Bicarbonate Cl/HCO3 Bicarbonate/Chloride HCO3/Cl	Chloride/Bromine Cl/Br Bromine/Chloride Br/Cl	Bromine/Iodine Br/I Iodine/Bromine I/Br
(C-1-7)8b9-S	Big	9-26-59	8,100	1.05 .95	27.5 .04	-	-	12.9 .08	-	34.5 .03	-	-
		9-29-59	7,860	1.70 .59	20.1 .05	28.1 .04	1,520 .0007	13.3 .08	21,800 .00005	20.0 .05	-	-
		1- 5-60	8,160	1.70 .59	20.4 .05	26.5 .04	2,810 .0004	13.2 .08	-	20.4 .05	-	-
		4-12-60	8,300	1.70 .59	21.3 .05	27.2 .04	-	13.3 .08	-	26.8 .04	-	-
		7- 8-60	8,060	1.95 .51	19.4 .05	27.2 .04	-	13.6 .07	-	21.8 .05	-	-
		10- 1-60	8,210	2.00 .50	19.4 .05	28.9 .04	-	11.2 .08	-	23.7 .04	-	-
		10-11-60	8,090	1.80 .56	20.1 .05	30.1 .03	-	13.1 .08	-	22.0 .05	-	-
		1-10-61	8,250	1.75 .57	20.0 .05	28.4 .04	-	13.0 .08	-	20.9 .05	-	-
		4- 4-61	8,430	1.65 .61	20.1 .05	28.1 .04	-	13.4 .08	-	21.7 .05	-	-
		5-27-66	7,940	1.6 .62	19.6 .05	24.1 .04	4,100 .0002	13.9 .07	4,425 .0002	21.4 .05	-	-
(C-2-6)16aad-S1	Grantsville	3-15-66	25,800	3.1 .32	15.3 .07	37.6 .03	-	22.7 .04	8,920 .0001	64.4 .02	-	-
(C-4-1)12b-S	Crystal	1882	1,680	5.0 .20	2.9 .35	7.4 .14	-	.89 1.1	-	1.6 .62	-	-
		5-22-34	1,665	4.2 .24	2.9 .35	-	-	6.2 .16	-	2.1 .47	-	-
		7-25-50	1,300	4.2 .24	2.2 .45	-	-	7.8 .13	-	3.8 .26	-	-
		9-10-52	1,550	2.5 .40	-	-	-	7.3 .14	-	1.9 .53	-	-
		5-27-58	1,390	4.6 .22	-	-	-	8.3 .12	-	1.8 .56	-	-
(C-5-1)25-S	Crater	5-27-58	1,390	3.7 .27	-	-	-	.75 1.3	-	1.0 1.0	-	-
		6- 4-58	1,440	3.7 .27	-	-	-	.77 1.3	-	1.1 .91	-	-
(C-5-1)25cd-S	Saratoga	1933	1,500	4.4 .23	1.8 .56	-	-	.93 1.1	-	1.3 .77	-	-
		3-24-66	1,450	2.8 .36	-	-	-	.78 1.3	-	1.1 .91	-	-
(C-5-5)9cba-S1	Morgans	9-22-64	583	2.4 .42	1.9 .53	10.0 .10	-	2.0 .50	179 .005	1.0 1.0	-	-
		5-27-66	578	2.3 .43	1.9 .53	8.4 .12	2,720 .0004	2.0 .50	151 .007	1.1 .91	-	-
		7-18-67	586	1.7 .59	2.3 .43	10.2 .09	3,730 .0003	1.9 .53	134 .007	1.2 .83	627 .0015	30
(C-5-5)17aaa-S1	Russells	4-29-66	438	2.4 .42	1.4 .71	6.6 .15	-	2.3 .43	-	.72 1.4	-	-
		5-27-66	440	2.8 .36	1.4 .71	6.2 .16	3,750 .0003	2.2 .45	81 .012	.70 1.4	-	-
		7-18-67	445	3.2 .31	1.3 .77	7.1 .14	3,550 .0001	1.9 .53	81 .012	.72 1.4	610 .0016	10
(C-10-14)33-S	Wilson	7-12-67	21,800	3.3 .30	9.6 .10	39.4 .02	3,360 .0003	7.6 .13	2,980 .0003	66.9 .01	517 .0019	63.9
(C-11-14)23c-S	Fish	7-12-67	1,820	5.2 .19	3.5 .28	13.1 .08	1,420 .0007	1.9 .53	315 .003	2.0 .50	485 .0020	65
(C-14-8)10c-S	Abraham	11-12-27	3,170	-	-	-	-	2.5 .40	-	9.0 .11	-	-
		5-31-66	3,710	6.4 .15	2.2 .45	12.1 .08	1,040 .0009	2.1 .48	517 .019	10.1 .10	-	-
		7-13-67	3,630	5.1 .20	2.4 .42	17.0 .06	1,300 .0008	1.9 .53	354 .028	9.1 .11	806 .0012	20
(C-15-19)31bc-S	Candy	3- 3-66	305	2.4 .42	.56 1.8	10 .10	-	.95 1.0	-	.07 1.4	-	-
		7-12-67	303	2.8 .36	.58 1.7	7.8 .13	1,450 .0006	.9 1.1	37 .027	.10 1.0	260 .036	-
(C-22-6)26ccc-S1	Meadow	5-12-66	4,690	4.3 .23	2.5 .40	6.6 .15	416 .002	1.7 .59	310 .003	5.6 .18	1,350 .0007	43
(C-22-6)27ddd-S1	do	4- 8-43	4,810	4.9 .20	-	-	-	1.8 .56	-	4.0 .25	-	-
		6-18-57	4,690	5.3 .19	-	-	-	1.8 .56	-	4.0 .25	-	-
		8-27-58	4,850	7.1 .14	-	-	-	1.7 .59	-	4.2 .24	-	-
		5-12-66	4,870	4.4 .23	2.4 .42	6.8 .15	707 .001	1.7 .59	356 .003	4.1 .24	1,370 .0007	16.2
		5-22-67	4,900	3.8 .26	2.4 .42	73.9 .01	319 .003	1.6 .62	327 .003	4.4 .23	450 .022	8.9
(C-22-6)35ddb-S1	Hatton	6-19-57	4,670	5.2 .19	-	-	-	1.8 .56	-	4.2 .24	-	-
		8-27-58	4,850	6.5 .15	-	-	-	1.7 .59	-	3.7 .27	-	-
(C-23-3)26aca-S1	Richfield	7-30-57	310	1.2 .83	.26 3.8	3.0 .33	24 .042	.74 1.3	100 .010	.07 14.3	-	-
		6- 6-66	307	1.5 .67	.29 3.4	4.7 .21	375 .003	.69 1.4	67 .015	.14 7.1	200 .050	10

Table 2. (continued).

Location	Name of spring	Date	Dissolved solids (ppm)	Calcium/Magnesium Ca/Mg Magnesium/Calcium Mg/Ca	Sodium/Calcium Na/Ca Calcium/Sodium Ca/Na	Sodium/Potassium Na/K Potassium/Sodium K/Na	Sodium/Lithium Na/Li Lithium/Sodium Li/Na	Chloride/Sulfate Cl/SO$_4$ Sulfate/Chloride SO$_4$/Cl	Chloride/Fluoride Cl/F Fluoride/Chloride F/Cl	Chloride/Bicarbonate Cl/HCO$_3$ Bicarbonate/Chloride HCO$_3$/Cl	Chloride/Bromine Cl/Br Bromine/Chloride Br/Cl	Bromine/Iodine Br/I Iodine/Bromine I/Br
(C-25-3)10dda-S1	Monroe	7-23-57	2,700	8.3 .12	2.0 .50	8.9 .11	117 .008	0.70 1.4	242 .004	1.8 .55	-	-
		9-10-57	2,860	8.9 .11	2.1 .48	12.5 .08	1,060 .0009	.68 1.5	-	1.4 .71	-	-
		5-17-66	2,680	15.1 .07	2.2 .45	9.3 .11	1,130 .0008	.67 1.5	222 .004	2.0 .50	1,560 .0006	13.3
(C-25-3)11cac-S1	Red Hill	5- 2-66	2,630	5.9 .17	3.0 .33	9.0 .11	1,050 .0009	.72 1.4	239 .004	4.2 .24	2,220 .000	5.0
(C-25-3)15a-S	Monroe	5- 3-67	2,700	5.7 .18	2.0 .50	11.1 .09	1,380 .0007	.65 1.5	333 .003	1.6 .62	375 .026	40.0
(C-25-3)27a-S	Johnson	4-19-67	428	4.7 .21	.63 1.6	29.3 .03	4,400 .0002	.89 1.1	7.8 .13	.83 1.2	140 .007	10.0
(C-25-4)23-S	Joseph	7-23-57	5,150	7.8 .13	5.1 .20	21.1 .05	180 .005	1.4 .71	648 .002	4.1 .24	-	-
		10-11-57	4,970	6.0 .17	5.2 .19	30.1 .03	-	1.4 .71	262 .004	4.1 .24	-	-
		5- 3-66	5,090	5.3 .19	5.6 .18	16.1 .05	98.0 .01	1.3 .77	567 .002	4.1 .24	1,890 .0005	9.0
		5-15-67	5,180	5.4 .18	6.0 .17	31.7 .03	786 .012	1.2 .83	330 .003	4.3 .23	570 .002	25
(C-26-9)34dcb-S1	Roosevelt	11- 4-50	7,040	5.6 .18	109 .009	4.4 .23	-	58.6 .02	-	24.1 .04	-	-
		9-11-57	7,800	-	114 .008	5.1 .20	-	58.1 .02	-	27.2 .04	-	-
(C-30-9)7aca-S1	Radium	8-21-63	1,020	4.6 .22	1.6 .62	9.6 .10	860 .011	.14 7.1	6.6 .15	.68 1.5	-	-
		3-12-66	977	4.0 .25	1.6 .62	9.1 .11	1,260 .0008	.14 7.1	14.9 .07	.40 2.5	-	-
		7-11-67	956	2.5 .40	1.9 .53	10.0 1.0	1,540 .0006	.14 7.1	14.0 .07	.28 3.6	315 .003	-
(C-30-12)21-S*	Thermo	10-23-39	-	-	-	-	-	.47 2.1	-	.59 1.7	-	-
		8-21-63	1,500	8.6 .12	4.3 .23	7.3 .14	275 .004	.44 2.3	15.0 .07	.55 1.8	-	-
(C-30-12)28-S	do	8-21-63	1,460	7.7 .13	5.2 .19	8.2 .12	-	.46 2.2	46.0 .02	.68 1.5	-	-
		5-25-66	1,450	7.7 .13	4.8 .21	6.9 .14	368 .003	.45 2.2	31.0 .03	.58 1.7	1,040 .0010	.67
		7-11-67	1,470	6.3 .16	4.8 .21	7.7 .13	428 .002	.46 2.2	15.1 .07	.53 1.9	530 .002	10
(C-40-16)6cdb-S1	Veyo	3-30-66	402	2.0 .50	.54 1.8	7.3 .14	640 .002	.30 3.3	50.0 .02	.14 7.1	150 .007	0.2
		4-20-67	389	1.9 .53	.60 1.7	8.9 .11	1,600 .0006	.33 3.0	42.9 .02	.13 7.7	300 .003	10
(C-41-13)25-S	LaVerkin	6-3-40	9,460	4.8 .21	2.9 .34	13.8 .07	-	1.8 .55	-	2.7 .37	-	-
		2- 5-51	9,760	4.8 .21	2.8 .36	13.4 .07	-	1.9 .52	-	2.8 .36	-	-
		3-25-66	9,530	5.0 .20	3.9 .27	11.5 .09	1,260 .0008	1.8 .55	1,390 .0007	5.0 .20	2,410	4.7
(D-3-4)26bca-S1	Midway	7- 1-52	1,890	22.4 .04	-	-	-	.17 5.9	-	.16 6.2	-	-
(D-3-4)26cca-S1	do	9-28-66	1,670	4.9 .20	.34 2.9	4.6 .22	407 .002	.16 6.2	49.1 .02	.16 6.2	120 .008	90
(D-3-4)27bac-S1	do	5-16-67	2,000	4.1 .24	.42 2.4	4.8 .21	507 .002	.16 6.2	45.1 .02	.20 5.0	280 .003	25
(D-3-4)27bad-S1	do	9-28-66	1,990	5.3 .19	.39 2.6	4.9 .20	419 .002	.17 5.9	55.2 .02	.19 5.3	197 .005	70
(D-3-4)27cbd-S1	do	9-28-66	1,770	4.9 .20	.28 3.6	4.5 .22	403 .002	.16 6.2	54.8 .02	.16 6.2	192 .005	60
		5-15-67	1,570	2.4 .42	.57 1.7	4.6 .22	433 .002	.16 6.2	50.0 .02	.24 4.2	230 .004	50
(D-3-4)27cbd-S2	do	9-28-66	1,640	4.7 .21	.33 3.0	4.4 .23	411 .002	.16 6.2	46.8 .02	.15 6.7	206 .005	-
		5-15-67	1,510	3.8 .26	.41 2.4	4.4 .23	570 .002	.17 5.9	43.8 .02	.18 5.5	210 .005	50
(D-3-4)27cbd-S3	do	5-16-67	1,880	3.7 .27	.50 2.0	4.9 .20	543 .002	.19 5.3	55.5 .02	.26 3.8	167 .006	45
(D-4-24)16cdd-S1	Split Mountain	9-19-48	942	3.0 .33	-	-	-	1.4 .71	242 .04	1.5 .67	-	-
(D-7-1)5ccb-S1	Warm spring, west shore of Utah Lake	9-11-58	1,570	2.5 .40	-	-	-	1.6 .62	-	1.5 .67	-	-
(D-7-1)8bbc-S1	do	9-11-58	1,430	1.5 .67	-	-	-	1.6 .62	-	2.6 .38	-	-
(D-8-1)3dda-S1	Lincoln Point	5-27-64	6,550	4.0 .25	-	-	-	2.9 .35	-	3.7 .27	-	-
		6-16-66	6,140	3.3 .30	3.3 .30	9.4 .11	-	8.2 .12	-	3.4 .29	-	-
(D-8-5)14d-S	Diamond Fork	10-20-67	837	3.2 .31	1.1 .91	14.1 .07	1,170 .0008	.09 .11	22.5 .04	.14 7.1	-	-
(D-9-4)1bba-S	Castilla	10-20-67	6,360	5.9 .17	3.6 .27	16.8 .06	1,290 .0007	1.7	644 .002	4.3 .23	-	-
(D-10-1)8c-S	Goshen	5-27-64	1,320	2.0 .50	-	-	-	5.5 .18	-	1.8 .55	-	-
		6-15-66	1,320	2.2 .45	3.9 .26	18.1 .05	-	4.7 .21	-	1.7 .59	-	-
(D-18-2)13cad-S1	Livingston	2- 6-41	635	1.7 .59	5.0 .20	-	-	.64 1.6	-	.13 7.7	-	-
(D-19-2)4dca-S1	Sterling	8-27-57	429	2.0 .50	-	-	-	.48 2.1	-	.11 9.1	-	-

WASHINGTON

Because of the basaltic and andesitic nature of the extensive Tertiary and Quaternary volcanism in Washington; hot spring activity is relatively minor. There are approximately 20 hot springs with temperatures ranging up to 190°F (88°C) which tend to be directly associated with the volcanism.

Average temperature 95-100°F (35-38°C)
Flows are up to 7,700 gpm
North slope of Mt. St. Helens - temperature 142-190°F (61-88°C)
Some fumerolic activity

Hottest springs:

Sol Duc Hot Springs
50°C temperature
Flow - 50 gpm at 56°C
SiO_2 - 120 ppm

Kennedy (Byrne) Hot Springs
Temperature - 34°C
Flow - 30 gpm at 43°C
SiO_2 - 380 ppm

Gamma Hot Springs
Temperature - 60°C
Flow - 3-4 gpm
SiO_2 - 150 ppm

Blue Mountain Region - Walla Walla, Washington to Milton Freewater, Oregon
High temperature found in water wells
Thermal spring
Wallowa-Olympic Lineament (major structural discontinuity)

Table on page 178 and map on page 179 extracted from: Thorsen, G. W., Prospects for Geothermal Energy in Washington, First Northwest Conference on Geothermal Power, Washington State Department of Natural Resources, 18 pages. (1971).

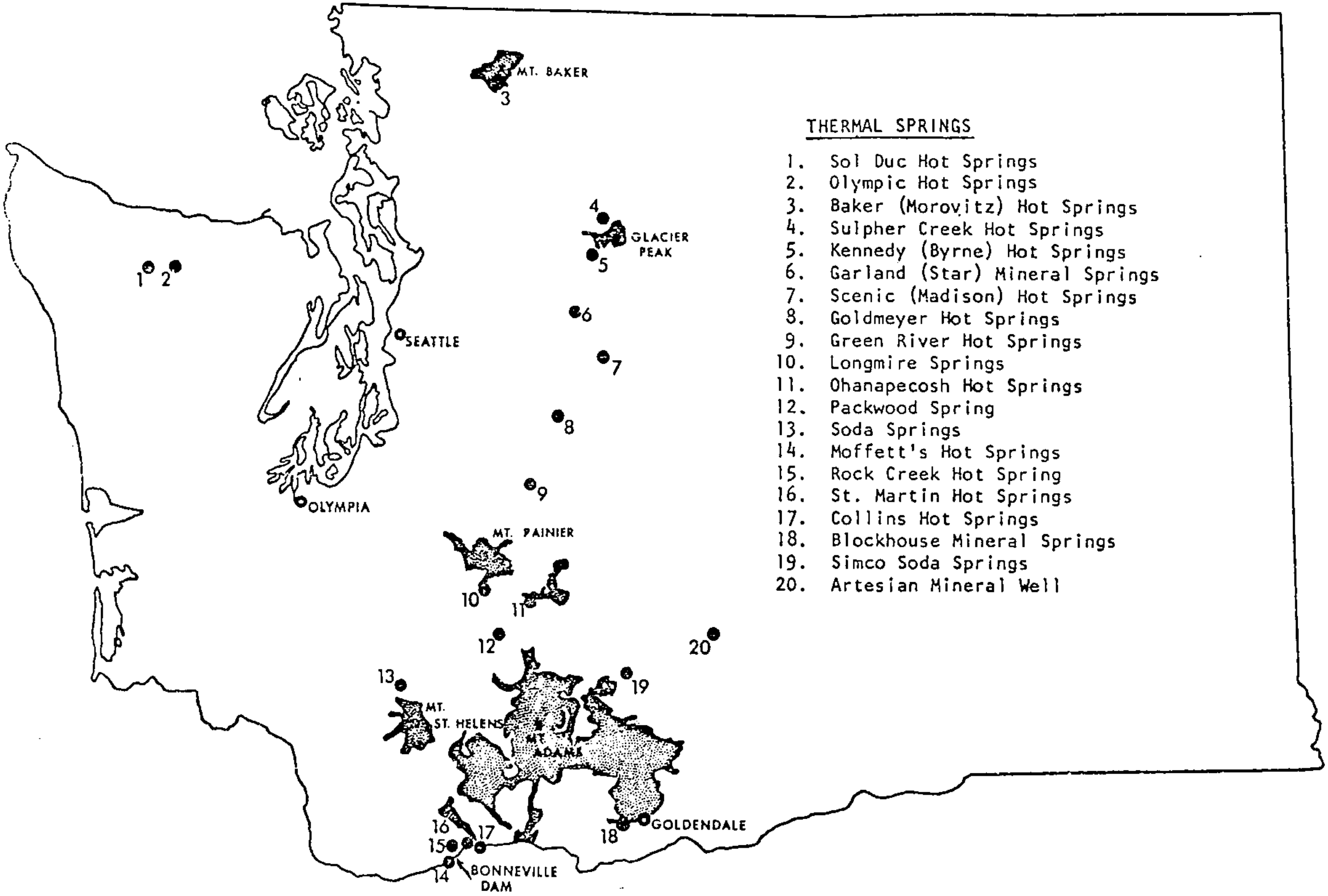
SOME[x] THERMAL[xx] SPRINGS OF WASHINGTON

NAME	LOCATION	TEMPERATURE Cent.	TEMPERATURE Fah.	FLOW (gpm)	pH	SiO2[xxx]	Mg	Li	Na	K	Ca	Cl	GEOLOGY and REMARKS
Olympic (1)	Clallam County SW ¼ 27(29-8W) 7 more springs max.	26 30 48	79 86 118	135 at 52°C. (2)	6-7 7 7.5	<20 30 80	<0.005 <0.005 <0.005	<0.1 <0.1 <0.1	39 51 78	0.7 0.9 1.3	3.6 2.7 1.4	<0.25 0.43 0.74	Mesozoic - Tertiary volcanics, springs along a fault zone, faint H2S, minor ppt.
Sol Duc (1)	Clallam County NW ¼ 32(29-9W) 3 springs	50	122	50 at 56°C (2)	7.5	120	<0.005	<0.1	84	1.6	1.6	1.7	Mesozoic - Tertiary volcanics, very faint H2S
Garland (Star) (1)	Snohomish County 25(28-11E) 2 springs	21	70	25 at 38°C (2)	6	120	74.8	7.5	1592	130	336	26.71	Tertiary granitics
Baker (Morovitz) (1)	Whatcom County NE ¼ 30(38-9E)	42	108	7	8	140	<0.005	0.4	165	10.0	7.9	108	Granite overlain by Tertiary lava associated with Mt. Baker flows very faint H2S, minor ppt
Longmire (1)	Pierce County SE cor. 29 (15-8E)	21	70		6	170	151.2	1.8	402	37.2	298	615	Tertiary volcanics within Mt. Rainier flows.
Bonneville (Moffetts) (1)	Skamania County 16(2-7E)	32	90	20 at 35°C (2)	9.5	<20	<0.005	<0.1	126	1.5	42	151	Tertiary andesite flows, 30 mi. from Mt. St. Helens
St. Martin's (1)	Skamania County SE cor. 21(3-8E)	49	120		7	<20	<0.005	0.2	291	6.2	104	636	Tertiary volcanics, Recent volcanics
Kennedy (Byrne) (1)	Snohomish County 1(30-12E)	34	93	30 at 43°C (2)	7	380	604	3.7	808	67.8	228	612	Granitics overlain by Recent volcanics associated with Glacier Peak flows strong H2S, extensive ppt.
Sulphur Creek (1)	Snohomish County NE ¼ 30(32-12E)	37	99	4 at 37°C (2)	8	120	<0.005	0.1	108	2.4	<0.2	52	Tertiary granitics, 10 miles from Glacier Peak. Strong H2S, minor ppt.
Ohanapecosh (1)	Lewis County	40	104	60 at 49°C (2)	7	80	7.5	3.3	981	50.9	85	869	Tertiary volcanics and sandstone 10 miles from Mt. Rainier, extensive ppt.
Malotte (3)	Yakima County SE ¼ 32(16-17E)	17	62		7.7	53	6.6		17	4.3	12	1.8	Tertiary volcanics (Yakima Basalt) in Wenas Syncline.
Gamma (4)	Snohomish County	60	140	3-4	7.9	150	2.6	2.6	491	77	47		5000' elevation on NE flank of Glacier Peak
Spring (3)	Franklin County NW ¼ 24(12-28E)	16	60		7.9	32	43		68	11	110	86	Tertiary volcanics (Yakima Basalt) in Ahtanum-Moxee Syncline.
Warm Spring (5)	Walla Walla County NW ¼ 14(4-37E)	22	72	50								11	Tertiary volcanics (Yakima Basalt) concealed fault?

1) Campbell and others, 1970
2) Stearns, Stearns, and Waring, 1937
3) Van Denburgh and Santos, 1965
4) Tabor and Growder, 1969
(5) Newcomb, 1965

x Other springs listed only as "hot" or "warm" in Valentine (1960) not included.
xx Based on the criterion of a temperature greater than 5°C above mean annual.
xxx Quantities listed in parts per million.

NOTE: all data is from reference given in "Name" column unless otherwise indicated.



Map showing areas covered by young volcanic rocks, which are considered to be favorable places to prospect for geothermal steam. The circles show locations of thermal springs.

TABLE 1.—Thermal springs in Washington

[Modified from Tables 1 and 2, Campbell and others, 1970]

Name	Location	Geology	Temp. °C	pH	Analyses[1/]												Remarks (presence of H_2S vapor and (or) ppt. at site)
					Li	Na	K	Mg	Ca	Sr	Mn	Si	Cl	CO_2	SO_4	Fe ppt)	
Olympic	Clallam County Sec. 27, T. 29 N., R. 8 W.	Springs located along fault zone in early Tertiary volcanic rocks.	46	7.5	<0.1	74	1.3	<0.1	1.4	<0.1	<0.1	120	0.49	X	X		Very faint H_2S, minor ppt.
Garland	Snohomish County Sec. 25, T. 28 N., R. 11 E.	Tertiary granitics; 13 mi. S. of Glacier Peak.	21	6	1.4	358	27.9	21.6	90	0.3	0.25	<0.1	461	X	X	X	Extensive ppt.
Ohanapecosh	Lewis County Sec. 4, T. 14 N., R. 10 E.	Tertiary volcanic breccia, sandstone and pyroclastic; 10 mi. E. of Mt. Rainier.	40	7	3.3	981	50.9	7.5	85	0.3	<0.1	80	869	X	X	X	Extensive ppt.
Mt. Baker	Whatcom County Sec. 20, T. 38 N., R. 9 E.	Granite overlain by Tertiary volcanics, assoc. with Mt. Baker flows.	42	8	0.4	165	10.0	<0.1	7.9	<0.1	<0.1	140	108		X		Very faint H_2S, minor ppt.
Sol Duc	Clallam County Sec. 32, T. 29 N., R. 9 E.	Early Tertiary basalt, pillow basalt, and flow breccia.	50	7.5	<0.1	84	1.6	<0.1	1.6	<0.1	<0.1	120	1.7	X	X		Very faint H_2S.
Longmire	Pierce County Sec. 29, T. 15 N., R. 8 E.	Tertiary volcanic breccia and pyroclastic, within Mt. Rainier flows.	21	6	1.8	402	37.2	151.2	298	2.1	0.07	170	615	X	X	X	Faint H_2S, some ppt.
Bonneville	Skamania County Sec. 16, T. 2 N., R. 7 E.	Tertiary andesite flows, congl., and tuff; 30 mi. S. of Mt. St. Helens.	32	9.5	<0.1	126	1.5	<0.1	42	<0.1	<0.1	<0.1	151		X		
Kennedy	Snohomish County Sec. 1, T. 30 N., R. 12 E.	Granitics overlain by Glacier Peak flows.	34	7	3.7	808	67.8	60.4	228	0.5	0.27	380	612	X		X	Strong H_2S, extensive ppt.
Sulfur Creek	Snohomish County Sec. 30, T. 32 N., R. 12 E.	Tertiary granitics; 10 mi. N. of Glacier Peak on Downey Mt.	37	8	<0.1	108	2.4	<0.1	<0.1	<0.1	<0.1	120	52		X		Strong H_2S, minor ppt.
Gamma	Snohomish County NE. flank of Glacier Peak on Gamma Creek	Tertiary volcanic rocks, assoc. with Glacier Peak flows.	60	7.9	2.6	491	77	2.6	47	ND	ND	150	728		X	X	Strong H_2S, some ppt.
St. Martin	Skamania County Sec. 21, T. 3 N., R. 8 E.	Tertiary volcanic rocks, within Recent flows.	49	7	0.2	291	6.2	<0.1	104	<0.1	<0.1	<0.1	636		X		

[1/] Concentrations in ppm. X = present, ND = not determined.

TABLE 2.— Mineral springs in Washington

Modified from Tables 1 and 2, Campbell and others, 1970]

Name	Location	Geology	Temp. °C	pH	Analyses[1/]												Remarks (presence of H_2S vapor and (or) ppt. at site)
					Li	Na	K	Mg	Ca	Sr	Mn	Si	Cl	CO_2	SO_4	Fe (ppt.)	
Diamond	King County Sec. 21, T. 21 N., R. 6 E.	Tertiary volcanic rocks; 26 mi. NW. of Mt. Rainier.	11	8	<0.1	1280	5.5	55.3	118	1.4	<0.1	<0.1	1574			X	Minor ppt.
Summit Creek	Lewis County Sec. 28, T. 14 N., R. 11 E.	Tertiary volcanic breccia and carb. shale; 14 mi. E. of Mt. Rainier.	13	6	5.9	1790	86.7	87.5	278	1.9	0.35	170	1552	X		X	Extensive ppt.
Iron Mike	Skamania County Sec. 31, T. 5 N., R. 7 E.	Tertiary volcanic rocks, within Recent flows.	10	7	0.4	211	6.2	50.1	192	0.5	0.83	40	318	X	X	X	Ppt. present.
Bubbling Mike	Skamania County Sec. 31, T. 5 N., R. 7 E.	Tertiary volcanic rocks, within Recent flows.	8.5	6.5	0.3	176	5.1	42.8	154	0.4	0.88	50	276	X	X	X	Ppt. present.
Little iron Mike	Skamania County Sec. 31, T. 5 N., R. 7 E.	Tertiary volcanic rocks, within Recent flows.	10	6.5	0.8	404	9.6	82.4	309	0.6	2.11	<0.1	561	X	X	X	Ppt. present.

[1/] Concentrations in ppm. X = present.

WYOMING

Yellowstone National Park is the only KGRA in Wyoming. The available data on thermal areas in Wyoming implies that reservoir temperatures are not high enough for development. Within the borders of Wyoming, the occurrence of geothermal phenomena can be divided into two distinct geological provinces: 1) Yellowstone National Park, a high volcanic plateau with nearly 100 separate localities of various types of intense, high-temperature hot spring and geyser activity; and 2) the rest of the state, which is mostly non-volcanic Laramide Rocky Mountain ranges and basins has only about 20 scattered low-temperature springs. The few thermal springs known elsewhere in Wyoming have temperatures less than 60°C. Heat flow in the region is about average for the rest of western U.S., 1.5 HFU.

Table 1. Thermal Springs and Wells in Wyoming, excluding Yellowstone Park

No. on Fig. 2	Name or Location	Temp. °C	Flow gal/min	Geology	Comments and References
1	DeMaris Hot Springs. 4 miles southwest of Cody, Wyo.	24-38	50-100	Dinwoody and Park City Fm. (Permian).	Several Springs. Resort and Sanitarium. Deposits of sulfur and Travertine. Refs. 1, 14, 15, 16, 17, 18, 36, 42, 43, 54, 58.
2	T. 55 N., R. 94W. In Sheep Canyon of the Big Horn River, near mouth of Five Springs Creek.	Warm	?	Cretaceous sediments.	Several Springs. Water used locally. Refs. 16, 54.
3	T. 53 N., R. 94W. Near Upper end of Black Canyon (Wyoming) of the Big Horn River.	Warm	Small	Paleozoic sediments.	Refs. 16, 54.
4	Flagg Ranch Hot Springs (Later called Huckleberry Hot Springs). Sec. 8, T. 48N., R. 115 W.	Many boiling	100-800	Pleistocene rhyolite.	Refs. 1, 36, 42, 48, 54.
5	Astoria Springs. T. 39 N., R. 116 W.	34-40 (Main pool)	100	Permian sediments.	Hot Baths. Refs. 36, 54.
6	Granite Hot Springs. Sec. 6, T. 39 N., R. 113 W.	41-43	360 or Large	Flathead sandstone (Cambrian), near granite.	Several Springs. Refs. 36, 54.

Table 1 (cont'd)

No. on Fig. 2	Name or Location	Temp. °C	Flow gal/min	Geology	Comments and References
7	Auburn Hot Springs. 2.5 miles north of Auburn, Wyo.	20-62	38	Faulted Phosphoria Fm. (Permian)	Many springs. H_2S smell, salty taste. Bubbling at some springs. Sulfur and salt deposits nearby, and in neighboring subsurface section. Travertine deposits. Refs. 39, 42, 46.
8	Kendall Warm Springs, Sec. 2, T. 38 N., R. 110 W. on Green River near Wells, Wyo.	Warm	> 850	Phosphoria Fm. (Permian)	Six Springs. Ref. 36, 54.
9	Steele Hot Springs. T. 32 N., R. 107 W. Near Fremont Butte.	Hot	Small	Precambrian granite	Water used for bathing. Refs. 27, 33, 54.
10	Near Warm Spring Creek, 4 miles northwest of Dubois, Wyo.	29 (Max)	?	Phosphoria Fm. (Permian)	Several springs. Deposits of Travertine. Refs. 19, 28, 42, 45, 52, 54.
11	Near mouth of Little Warm Spring Creek, 3 miles southwest of Dubois.	20	?	Phosphoria Fm. (Permian)	Several springs. Deposits of Travertine. Refs. 19, 42, 52, 54.
12	Fort Washakie Hot Springs. Sec. 2, T. 1S. R. 1 W. 24 miles west of Riverton	43+	2,000	Chugwater Fm., Red Peak member (Triassic)	Several Springs, rising in deep pools. Refs. 1, 7, 14, 15, 18, 29, 30, 42, 49, 54.

Table 1 (cont'd)

No. on Fig. 2	Name or Location	Temp. ^{o}C	Flow gal/min	Geology	Comments and References
13	T. 30 N., R. 97 W. 4 miles southwest of Hailey,	38-49	100	Undivided Triassic sediments, near Phosphoria Fm. (Permian)	Several springs, water smells of H_2S. Refs. 1, 15, 22, 42, 54.
14	T. 29 N., R. 96 W. Near Sweetwater River, 12 miles southwest of Myersville,	Warm	?	Sandstone (Oligocene)	Several springs, water used locally. Refs. 22, 54.
15	Big Horn (Thermopolis) Hot Springs on the Big Horn River at Thermopolis.	57+	12,600	Red Beds (Triassic), overlying Embar limestone.	One large spring, several small. Large deposits of Travertine. Refs. 1, 7, 8, 10, 11, 12, 14, 16, 17, 18, 24, 29, 42, 44, 51, 54, 59.
16	3.5 miles northwest of Thermopolis, near sulfur deposits.	Hot	Small	Red Beds (Triassic)	Deposits of Travertine and sulfur. Flow formerly much greater. Refs. 54, 59.
17	Sec. 35, T. 32 N., R. 36 W. on Horse Creek near Independence	Warm	Large	Oligocene strata near Chugwater Fm. (Triassic and Permian)	Several springs, water used locally. Refs. 30, 42, 54.
18	Alcova Hot Springs. T. 30 N., R. 83 W., in Fremont Canyon of the North Platte River.	59+	75	Faulted Tensleep and Amsden Fm. (Pennsylvanian)	Several springs, resort. Refs. 1, 6, 22, 42, 50, 54. Alcova Dam covers springs.

Table 1 (cont'd)

No. on Fig. 2	Name or Location	Temp. °C	Flow gal/min	Geology	Comments and References
19	Sec. 8, T. 31 N., R. 71 W, Near the North Platte River, 9 miles south of Douglas.	Warm	?	Triassic and Permian sediments, undivided (Includes Chugwater Fm.)	Water used for bathing and irrigation. Refs. 1, 54.
20	Saratoga Hot Springs. T. 17 N., R. 84 W.	48-53	10-120	North Park Formation (Late Miocene)	Resort. Several Springs. Refs. 1, 38, 41, 42.
21	Guernsey Hot Springs(?)	23+	?	Tertiary sediments (?)	Possibly mislocated by Waring (1965) (?). Refs. 4, 54.
22	Jackson Lake Hot Springs	50 (Max)	?	Madison limestone (Mississippian)	13 orifices visible above lake level at low water. Ref 36.
23	Kelley Warm Spring	30 (Max)	> 3400	Pliocene tuff and lake sediments	Ref. 36.
24	Abercrombie Warm Spring	?	?	Fault between Ordovician and Pliocene	Ref. 36.
25	Teton Valley Warm Spring. T. 42 N., R. 115 W.	23- (Max)	> 6900	Madison limestone (Mississippian)	Ref. 36.
26	School Section Spring. T. 41 N., R. 117 W.	31+	?	Thrust fault between Cambrian on upper Cretaceous	Flows 6" pipe of water. Ref. 36.
27	Bradco-Gilcrease Well. T. 39 N., R. 116 W.	48-		Triassic sediments	6" pipe flows 48-°C water from depth of 3065 ft. Ref. 36.

Table 1 (cont'd)

No. on Fig. 2	Name of Location	Temp. °C	Flow gal/min	Geology	Comments and References
28	Dallas Well T. 33 N., R. 99 W.	38–43		Madison limestone (Mississippian)	Flows 8" pipe of 38–43°C water. Ref. 36.
29	Carter Cole Well (Carter Oil Co.) T. 33 N., R. 68 W.	135		Lower Cretaceous sediments (50% shale, 50% sandstone)	Bottom-hole temperature at 11,000 ft. Ref. 36.
30	Fremont Petroleum Co. Well. T. 52 N., R. 101 W.	69-		Tensleep Sandstone (Pennsylvanian)	Bottom-hole temperature at 1476 ft (flowing water). Ref. 36.
31	SW $\frac{1}{4}$, Sec. 20, T. 28 N., R. 118 W.	Warm(?)	8000(?)	Mesozoic and Paleozoic strata.	Several cold springs, one warm. Several travertine deposits. Ref. 23.

Table 2. Chemical analyses of thermal springs in Wyoming, exclusive of Yellowstone Park

References: (a) Love (personal communication, 1972); (b) open file, Wyoming Geological Survey; (c) White et al. (1963); (d) White (written communication, 1972).

Locality:	DeMaris Hot Springs		Saratoga Hot Springs	Thermopolis Hot Springs		Auburn Hot Springs		Flagg Ranch Hot Springs
	#WRL-429(a)	#WRL-430(a)	Hobo Pool (b)	#1(b)	#2(c)	#1(d)	#2(d)	(d)
Flow (gal/min)	50	50	120	12,600(?)	12,600(?)	?	3±	?
T, °C	~28	~28	48	57.2(?)	57.2(?)	62	15.5	71
pH	6.9	7.1	7.3	-	6.2	8.2	8.2	7.1
	ppm		ppm	ppm		ppm		ppm
SiO_2	18	18	62	82	36	110	110	124
Fe	.06	.2	-	.08	.04	-	-	.03
Ca	354	369	125	385	374	134	252	12
Mg	72	63	9	76	74	74	70	1.1
Na	33	33	453	262	271	1410	1500	201
K	16	16	29	49	44	156	180	7.8
HCO_3	952	993	77	766	756	94	70	372
SO_4	422	418	568	769	726	1100	1430	12
Cl	21	20	511	328	320	1890	2000	102
F	2	2	6.5	3.7	3.5	3.5	3.5	10
NO_3	.1	.1	6.5	.1	-	< 10	6.6	.1
B	-	-	.1	-	7.8	1.8	3.0	-

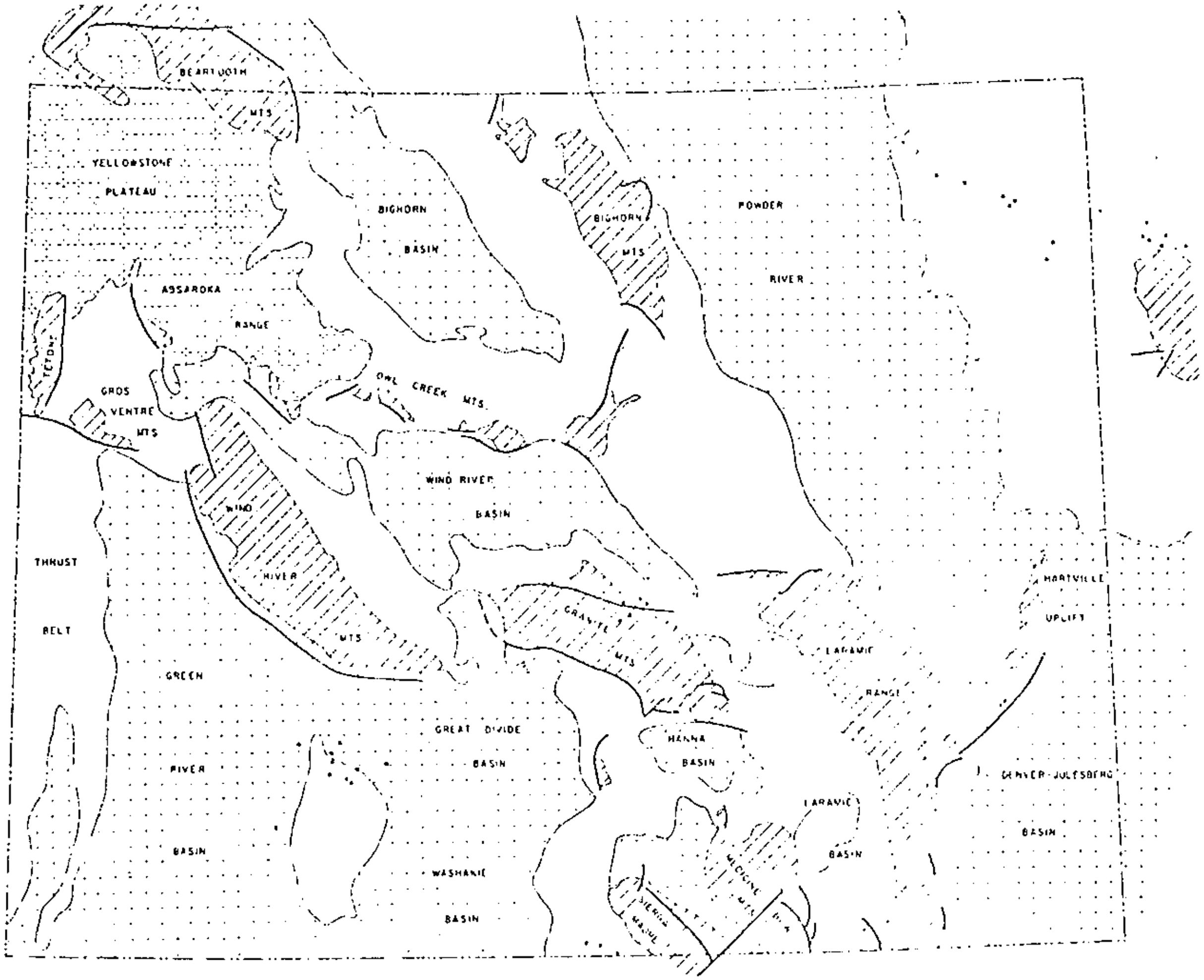


Figure 1. Generalized geology of Wyoming (after Houston (1969)). Diagonal lines = Precambrian; no pattern = Paleozoic-Mesozoic; dots = Tertiary; cross-hatch = Tertiary volcanic sedimentary rocks, flows and tuffs; solid dots = Tertiary intrusive centers.

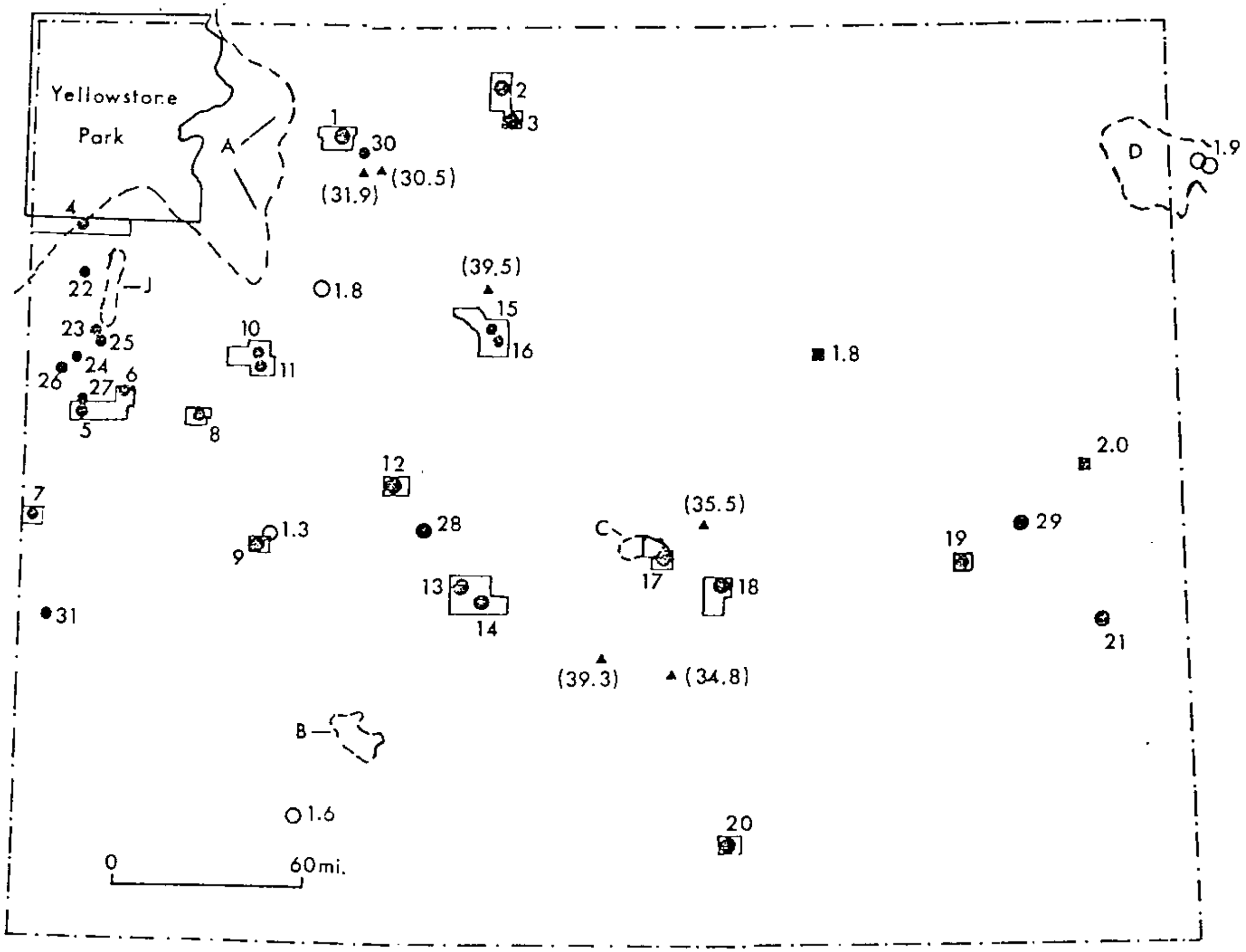


Figure 2. Thermal springs and wells, and other geothermal data in Wyoming. Solid circles represent locations of thermal springs or wells. Open circles represent locations of published heat flows (Blackwell, 1969; Sass et al., 1971); solid squares represent locations of estimated heat flows (Blackwell, 1969). Solid triangles represent locations of gradients, in brackets, determined by Blackwell (1969). Heat flows in microcal/cm^{2}sec, gradients in °C/km. Tertiary volcanic fields (after Houston (1963)): A = Yellowstone-Absaroka; B = Leucite Hills; C = Rattlesnake Hills; D = Black Hills; J = Jackson Source Area. See Table 1 for locations of springs and wells.

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ALASKA

Seward Peninsula

Surface temperatures average about 65°C. Silica Predicted temperatures average 100°C. Water Quality is marginal for most agricultural purposes (Total dissolved solids for warmer springs range from 2,000 to 5,000ppm.

Interior

Surface temperatures average 55°C. Silica predicted temperatures average 70°C. Water quality is marginal for vegatable crops - about 200-1,000ppm

Aleutian Islands

Surface temperatures are hot, - boiling point.

Silica Predicted temperatures - 100-200°C.

Water quality marginal for agricultural purposes - generally 1,000-2,000ppm total dissolved solids.

Southeastern Alaska

Surface temperatures average 58°C.

Silica predicted temperatures range up to 150°C, but average 100°C.

Water quality is variable, ranging from 200 to 5,000ppm total dissolved solids. The quality of the hottest spring is excellent, 422ppm.

The U.S., east of Montana, Wyoming, Colorado and New Mexico, has very few significant geothermal areas. With the exceptions of Arkansas, Georgia, West Virginia and Virginia, the central and eastern portions of the U.S. are virtually devoid of thermal waters.

Arkansas

There are approximately 60 thermal springs in Arkansas, with 46 of these located in Hot Springs National Park. Water temperature ranges up to 147°F and flow rates up to 185 gpm.

Florida

Florida has one major hot spring with a temperature of 86°F and a flow rate of 4,900 gpm. The water is used for bathing.

Massachusetts

There is one major hot spring in Massachusetts with a maximum temperature of 76°F and a flow rate of 400 gpm. Water is bottled for table use and in manufacture of soft drinks.

New York

New York has one significant hot spring with a temperature of 76°F and a flow rate of 500 gpm. Water is bottled and marketed.

North Carolina

North Carolina has one hot spring area with water temperature up to 117°F and flow rate up to 30 gpm.

Pennsylvania

Pennsylvania has one hot spring with water temperature of 72°F and a flow rate of 90 gpm. This hot spring was used as a resort at one time.

South Dakota

Four springs with temperatures up to 90°F and flow rates up to 7,000 gpm. Water is used mainly for irrigation.

Texas

Texas has three main hot springs with temperatures up to 118°F and flow rates up to 45 gpm. Water is used for bathing.

Virginia

Virginia has approximately 20 hot spring areas with temperatures up to 106°F, averaging 70°F, with flow rates up to 2,000 gpm. Some water is bottled, but most is used locally. Springs occur in folded or faulted Paleozoic strata.

West Virginia

There are 30 major thermal areas in West Virginia with temperatures ranging up to 73°F and averaging 65°F. Flow rates are up to 1,630 gpm, and water is used for bathing and drinking.

Classification of Public Lands Valuable for Geothermal Steam and Associated Geothermal Resources

By L. H. Godwin, L. B. Haigler, R. L. Rioux, D. E. White, L. J. P. Muffler, and R. G. Wayland

ABSTRACT

The Organic Act of 1879 (43 U.S.C. 31) that established the U.S. Geological Survey provided, among other things, for the classification of the public lands and for the examination of the geological structure, mineral resources, and products of the national domain. In order to provide uniform executive action in classifying public lands, standards for determining which lands are valuable for mineral resources, for example, leasable mineral lands, or for other products are prepared by the U.S. Geological Survey. This report presents the classification standards for determining which Federal lands are classifiable as geothermal steam and associated geothermal resources lands under the Geothermal Steam Act of 1970 (84 Stat. 1566).

The concept of a geothermal resources province is established for classification of lands for the purpose of retention in Federal ownership of rights to geothermal resources upon disposal of Federal lands. A geothermal resources province is defined as an area in which higher than normal temperatures are likely to occur with depth and in which there is a reasonable possibility of finding reservoir rocks that will yield steam or heated fluids to wells.

The determination of a "known geothermal resources area" is made after careful evaluation of the available geologic, geochemical, and geophysical data and any evidence derived from nearby discoveries, competitive interests, and other indicia. The initial classification required by the Geothermal Steam Act of 1970 is presented.

INTRODUCTION

The Organic Act of 1879 (43 U.S.C. 31) that established the U.S. Geological Survey provided, among other things, for the classification of the public lands and for the examination of the geological structure, mineral resources, and other products of the national domain. With the enactment of the Geothermal Steam Act of 1970, that authority and responsibility now includes, without limitation, to the same extent as in classifying lands under the mineral leasing laws, the authority and responsibility to classify lands as valuable for geothermal steam and associated geothermal resources. Land is so classified in order to reserve or retain those substances in Federal ownership and to determine for the Department of the Interior which lands are included within "known geothermal resources areas" and thus subject to the competitive leasing provisions of the Geothermal Steam Act of 1970 (84 Stat. 1566).

The Geothermal Steam Act of 1970 (see "Appendix"), effective December 24, 1970, includes the following provisions:

> SEC. 2(e). "known geothermal resources area" means an area in which the geology, nearby discoveries, competitive interests, or other indicia would, in the opinion of the Secretary, engender a belief in men who are experienced in the subject matter that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose.
>
> SEC. 4. If lands to be leased under this Act are within any known geothermal resources area, they shall be leased to the highest responsible qualified bidder by competitive bidding under regulations formulated by the Secretary. If the lands to be leased are not within any known geothermal resources area, the qualified person first making application for the lease shall be entitled to a lease of such lands without competitive bidding. * * *
>
> SEC. 21(a). Within one hundred and twenty days after the effective date of this Act, the Secretary shall cause to be published in the Federal Register a determination of all lands which were included within any known geothermal resources area on the effective date of the Act. He shall likewise publish in the Federal Register from time to time his determination of other known geothermal resources areas specifying in each case the date the lands were included in such area;

SEC. 25. As to any land subject to geothermal leasing under section 3 of this Act, all laws which either (a) provide for the disposal of land by patent or other form of conveyance or by grant or by operation of law subject to a reservation of any mineral or (b) prevent or restrict the disposal of such land because of the mineral character of the land, shall hereafter be deemed to embrace geothermal steam and associated geothermal resources as a substance which either *must be reserved* or *must prevent* or *restrict the disposal of such land*, as the case may be. [Italics added.] This section shall not be construed to affect grants, patents, or other forms of conveyances made prior to the date of enactment of this Act.

In order to assure uniform executive action in the classification of leasable mineral lands in the public domain, standards for determining which lands are mineral lands have been prepared from time to time by the U.S. Geological Survey. It is the duty of the Geological Survey to use geologic expertise to identify those Federal lands that are underlain by or have a reasonable expectation of containing mineral deposits or other products that meet or exceed the minimum limits set by the classification standards. Field examination and a study of subsurface, geophysical, and geochemical data may precede classification. Similarly, all known pertinent geologic facts are considered in determining which legal subdivisions of lands are classified as geothermal steam and associated resources lands.

The purpose of this report is to present the classification standards that have been established to implement the Geothermal Steam Act of 1970. Figures 1 and 2 show those areas which include, in part, Federal lands classified as known geothermal resources areas that may be leased only competitively to the highest qualified bidder and those lands classified as valuable prospectively for the purpose of retention of geothermal rights in Federal ownership upon disposal of the lands. Table 1 lists the known geothermal resources areas effective December 24, 1970.

TABLE 1.—*Known geothermal resources areas*

[Number corresponds to location shown in fig. 1 or 2. Detailed land descriptions of these areas have been published in the "Federal Register," v. 36, p. 5626, March 25, 1971; v. 36, p. 6118, April 2, 1971; v. 36, p. 6441, April 3, 1971; v. 36, p. 7319, April 17, 1971; and v. 36, p. 7759, April 24, 1971]

Locality	Name
	Alaska
1	Pilgrim Springs
2	Geyser Spring Basin and Okmok Caldera
	California
1	The Geysers
2	Salton Sea
3	Mono-Long Valley
4	Calistoga
5	Lake City
6	Wendel-Amedee
7	Coso Hot Springs
8	Lassen
9	Glass Mountain
10	Sespe Hot Springs
11	Heber
12	Brawley
13	Dunes
14	Glamis
	Idaho
1	Yellowstone
2	Frazier
	Montana
1	Yellowstone
	Nevada
1	Beowawe
2	Fly Ranch
3	Leach Hot Springs
	Nevada—Continued
4	Steamboat Springs
5	Brady Hot Springs
6	Stillwater-Soda Lake
7	Darrough Hot Springs
8	Gerlach
9	Moana Springs
10	Double Hot Springs
11	Wabuska
12	Monte Neva
13	Elko Hot Springs
	New Mexico
1	Baca Location No. 1
	Oregon
1	Breitenbush Hot Springs
2	Crump Geyser
3	Vale Hot Springs
4	Mount Hood
5	Lakeview
6	Carey Hot Springs
7	Klamath Falls
	Utah
1	Crater Springs
2	Roosevelt
	Washington
1	Mount St. Helens

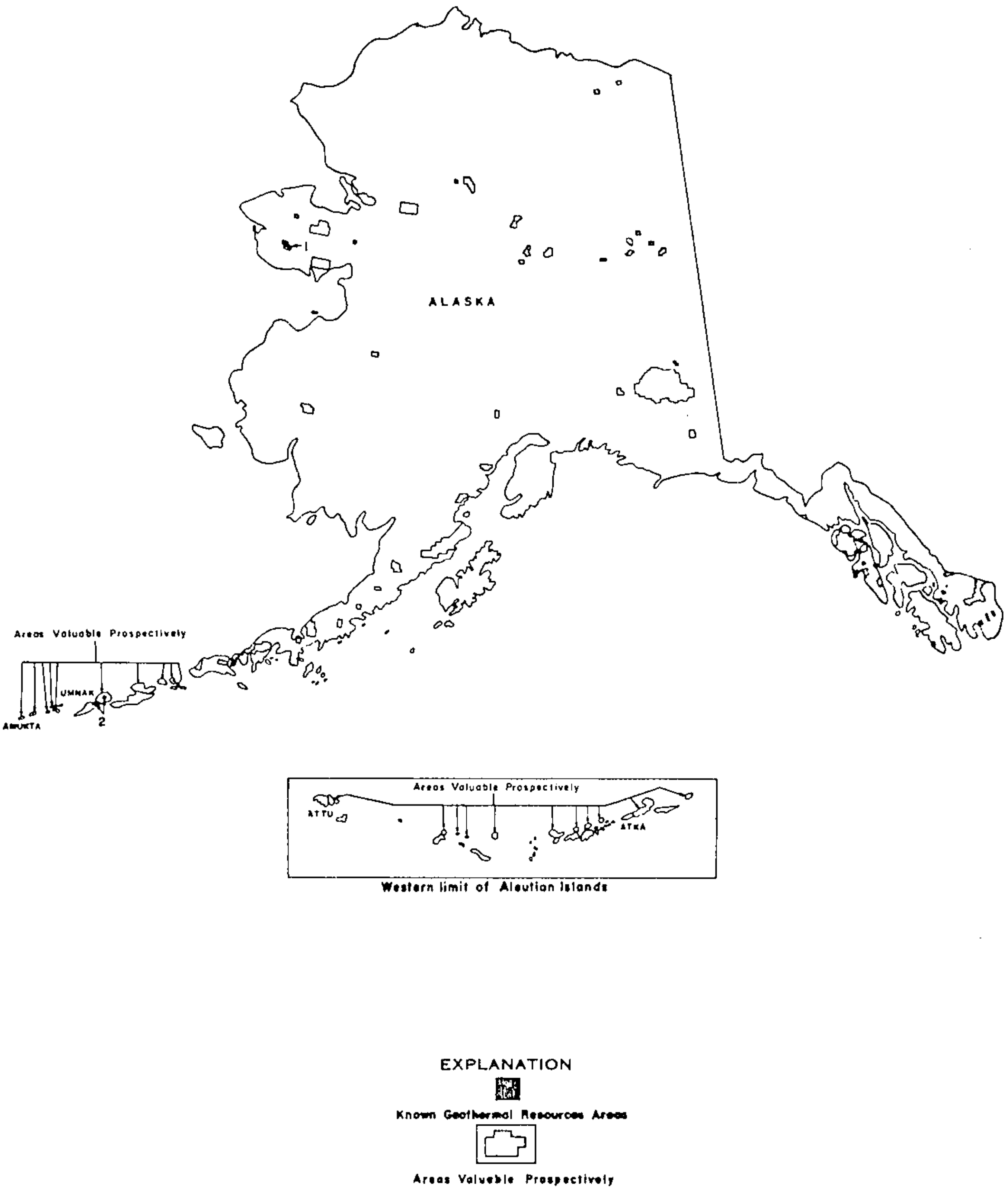


FIGURE 1.—Map of Alaska showing lands classified for geothermal resources effective December 24, 1970. Numbers correspond to areas listed in table 1.

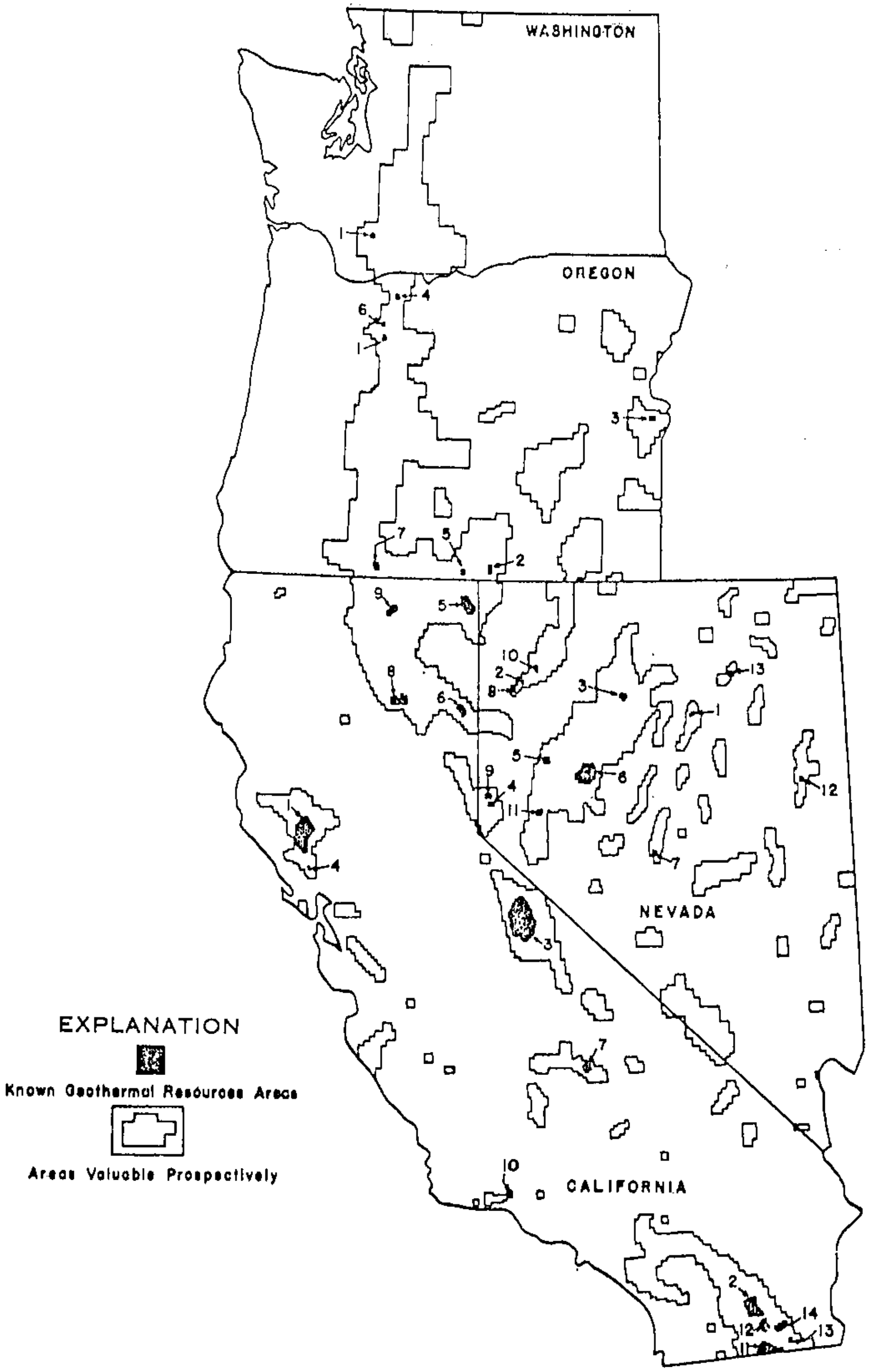
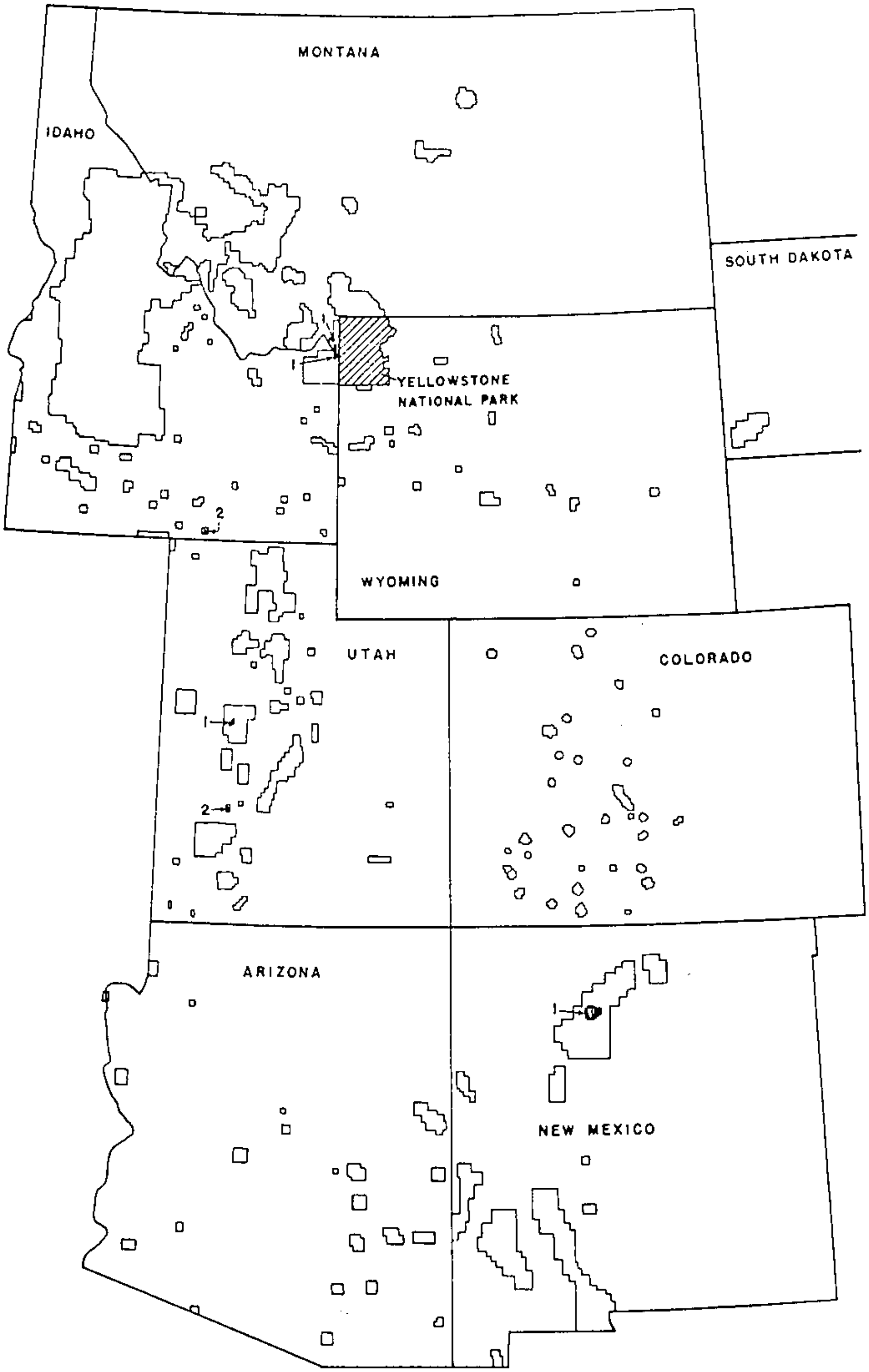


FIGURE 2.—Map of the Western United States showing lands classified for geothermal



resources effective December 24, 1970. Numbers correspond to areas listed in table 1.

Several Geological Survey personnel contributed helpful suggestions in critical reviews during the preparation of this report, and their assistance is gratefully acknowledged. The review and suggestions made by John F. Hughes, Office of the Solicitor, concerning the classification standards were especially useful.

NATURE OF GEOTHERMAL RESOURCES

The earth is an immense reservoir of energy, but most of this energy is contained in the earth's core and mantle at depths unlikely ever to be tapped by any foreseeable drilling technology. Within the earth at depths potentially accessible to drilling (about 6 miles) are stored approximately 10^{24} British thermal units of heat (White, 1965, p. 2), but most of this heat is far too diffuse to be considered as a potential resource. However, economically significant concentrations of geothermal energy do occur in local "hot spots" where high temperatures (150° to 650°F) are found in porous rocks containing liquid water and (or) steam; such concentrations of extractable heat are known as "geothermal reservoirs." The reservoirs are found in regions of recent volcanism and mountain-building and in the deep parts of many sedimentary basins.

The energy in a geothermal reservoir consists of heat, largely stored in rocks and to a lesser extent in liquid water and (or) steam-filling pores and fractures. The water and steam provide the means by which heat from deep sources is transferred by convection to depths shallow enough to be tapped by drilling. Water and steam also serve as the agents by which geothermal heat escapes at the surface in hot springs and fumaroles and through which geothermal heat can be tapped commercially by wells.

The fluid in most geothermal reservoirs is liquid water (White and others, 1971) that is held at temperatures above surface boiling by the confining pressure. Decrease in pressure upon withdrawal of the liquid water causes steam to form by boiling, and a mixture of steam and water is produced at the surface. A few reservoirs contain primarily steam, and the wells produce dry or superheated steam with no water. These dry steam reservoirs are positively known only in the Larderello-Mt. Amiata region of Italy and at The Geysers, Calif.

For a geothermal reservoir to have appreciable potential for exploitation, it must meet the following requirements: (1) relatively high temperature (greater than 150° to 400°F, depending on processing technology), (2) a depth shallow enough to permit drilling (currently 10,000 ft or less), (3) sufficient rock permeability to allow the heat transfer agent (water and (or) steam) to flow continuously at a high rate, and (4) sufficient water recharge to maintain production over many years.

Limited exploitation of geothermal resources has occurred since the turn of the century, primarily to generate electric power. Geothermal resources also have been used for space heating, product processing, and agricultural heating, and in addition some geothermal fluids contain chemicals and metals that are potentially valuable byproducts. Furthermore, geothermal energy appears to have an important potential use in desalination, either of the geothermal fluid itself or of other saline waters that may occur near a source of geothermal energy.

PRESENT STATE OF GEOTHERMAL KNOWLEDGE

Geothermal areas exist throughout the world, primarily along the belts of young volcanism that ring the Pacific Ocean and that follow the midoceanic ridges. Geothermal areas of the United States are found primarily in the Western States, along the circum-Pacific belt of young volcanism and mountain-building and where the Pacific ridge system (a locus of high heat flow) intersects the North American continent along the Gulf of California and the Imperial-Coachella Valley of California. In the Eastern United States, potentially economic reservoirs of geothermal heat have been identified in the deep parts of the Gulf of Mexico sedimentary basin.

The distribution, extent, and magnitude of the geothermal resources of the United States are, at present, poorly known. The general extent of the resource in the Western States can be inferred from the distribution of hot springs and in a more general way from the distribution of young volcanic rocks. In the past, geothermal exploration was primarily on sites identified by hot springs (an exploration method analogous to the primitive oil exploration methods of the turn of the century when oil fields could be located only by finding surface oil seeps). Available geologic and geochemical techniques have not been used adequately in discovering and evaluating new fields, and geophysical principles and techniques are only now beginning to be adapted to geothermal exploration.

Knowledge of the characteristics and parameters of individual geothermal systems in the United States has come from exploratory drilling in about 40 hot-spring areas (J. B. Koenig, "Geothermal Exploration in the Western United States": Paper II/19, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September 1970), from developmental drilling (mainly at The Geysers of northern California and the Salton Sea in southern California), and from scientific studies of a few major thermal-spring areas, supplemented by shallow research drilling. Extrapolation of knowledge from other countries, mainly New Zealand, Italy, and Iceland, has proven useful, but techniques for estimating the size and power potential of geothermal sites prior to drilling are only beginning to be developed. Techniques for efficiently utilizing all the energy produced from geothermal wells (that is, by desalination or by two-phase generation) are only beginning to be investigated and developed.

CLASSIFICATION FACTORS FOR RETENTION

The petroleum province is an established concept in classification of oil and gas lands for purposes of retention of Federal mineral rights upon disposal of public lands. A geothermal resources province (GRP) similar in concept to a petroleum province is necessary to define those areas valuable prospectively for geothermal steam and associated geothermal resources.

A geothermal resources province is an area in which higher than normal temperatures are likely to occur with depth and there is a reasonable possibility of finding reservoir rocks that will yield steam or heated fluids to wells. In most prospective areas, data on geothermal gradients and conductive heat flow are scarce. Adequate temperature-depth data exist only in sedimentary basins that have been extensively explored for oil and gas. Most of these basins are characterized by nearly "normal" geothermal gradients rather than the abnormally high rates needed for development of geothermal energy.

The present-day use of geothermal energy includes generation of electricity, manufacturing, agriculture, and space heating. The minimum present-day use for geothermal resources is the exploitation of stored heat energy for space heating. Geothermal fluids used for space heating are generally delivered at above 100°F and are available at the surface or at shallow depths below the surface. S. S. Einarsson ("Utilization of Low Enthalpy Water for Space Heating, Industrial, Agricultural and Other Uses": Rapporteur rept., Sec. X, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September 1970) reported use of 118°F water in space heating in Olafsfjordhur, Iceland, and 104°F water in Japan. S. H. Ross ("Geothermal Potential of Idaho": Paper II/1, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September 1970) reported use of 104°F water for agricultural purposes in Idaho. Because a heat exchanger can extract the heat from the geothermal fluid, the chemical composition or the corrosiveness of the fluid is not necessarily a controlling factor in classification.

The classification of geothermal resources provinces is based on geologic inference similar to that used by the Geological Survey in classifying lands for retention of oil and gas mineral rights and should provide adequate protection against alienation of leasable geothermal resources. One or more of the following indicia are necessary for the retention classification of lands in geothermal resources provinces:

1. Volcanism of late Tertiary or Quaternary age—especially caldera structures, cones, and volcanic vents.
2. Geysers, fumaroles, mud volcanoes, or thermal springs at least 40°F higher than

average ambient temperature.

3. Subsurface geothermal gradients generally in excess of two times normal, as reflected in deep water wells, oil well tests, and other test holes.

CLASSIFICATION FACTORS FOR A KNOWN GEOTHERMAL RESOURCES AREA

Lands shall be classified as a "known geothermal resources area" (KGRA) when "the prospects for extraction of geothermal steam or associated geothermal resources from an area are good enough to warrant expenditures of money for that purpose." The accumulation of geothermal resources is in some ways similar to the accumulation of oil and gas resources, and only a test hole can establish with certainty the existence of adequate temperatures, pressures, and production capacity of an area. However, the definition of a "known geothermal resources area" departs from the concept of a "known geologic structure of a producing oil or gas field" (Finley, 1959) in that it does *not* require a producible well. Thus, any relevant data and information pertaining to the criteria enumerated in sec. 2(e) of the Geothermal Steam Act can be considered in determining whether lands are included within any KGRA.

The extent of a KGRA is influenced by such geologic factors as the pattern of temperature gradient, structure, stratigraphy, porosity, conductivity, permeability, heat source, and rate of recharge of fluids. The determination of a KGRA is made after evaluating the net effect of all geologic, geochemical, and geophysical data and any evidence derived from nearby discoveries, competitive interests, and other indicia.

GEOLOGY (INCLUDING GEOPHYSICAL AND GEOCHEMICAL DATA)

The following kinds of data, considered together, indicate that the prospects for extraction of geothermal steam or associated geothermal resources are good enough to warrant expenditures of money for that purpose:

1. Siliceous sinter and natural geysers both imply high subsurface temperatures, generally 350°F or greater (D. E. White, "Geochemistry Applied to the Discovery, Evaluation and Exploitation of Geothermal Energy Resources": Rapporteur rept., Sec. V, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September 1970) in hot-water systems, because of relationships generally existing between temperature and SiO_2 content of liquid water.
2. The temperatures of fumaroles, thermal springs, and mud volcanoes provide minimum subsurface temperatures.
3. The SiO_2 content of spring water is a very useful chemical geothermometer for indicating the reservoir temperatures of many hot-water systems (R. O. Fournier and A. H. Truesdell, "Chemical Indicators of Subsurface Temperature Applied to Hot Spring Waters of Yellowstone National Park, Wyoming, U.S.A.": Paper V/2, United Nations Symposium on the Development and Utilization of Geothermal Resources, Pisa, Italy, September 1970; D. E. White, see above).
4. The Na/K ratio in spring waters of many hot-water systems is also a useful chemical geothermometer when there is adequate knowledge of competing influences (D. E. White, see above).
5. Most known potential geothermal systems occur in or near volcanoes and calderas of late Tertiary or Quaternary age.
6. Abnormally high conductive heat flow and the geothermal gradient are the best indicators of deep, concealed geothermal reservoirs. Although specific limits have not yet been established, two to 10 times the world-wide average (heat flow of 1.5 microcalories per cm^2 per second; temperature gradient of 1°F per 100 ft) extended consistently over hundreds of feet of depth appears favorable.
7. The porosity and the permeability of a potential reservoir are important parameters but can be established only by drilling and testing. Where stratigraphic control of the reservoir fluid or steam by a caprock is expected, near-surface characteristics of the rocks may provide preliminary evaluations.
8. Electrical resistivity surveys are probably

the best geophysical means to geothermal evaluation available at this time, especially for the hot-water systems.

9. Magnetic, gravity, and airborne infrared geophysical surveys may provide useful suplemental data.
10. Other geophysical methods such as microseismic, seismic ground noise, electromagnetic, and telluric surveys may have significant future use in evaluation.

NEARBY DISCOVERIES

In classifying land as a KGRA, the discovery of a deposit of geothermal steam or associated geothermal resources in the vicinity of such lands is evaluated together with the available data concerning the other criteria enumerated in sec. 2(e) of the Act which are to be considered in classification action.

COMPETITIVE INTERESTS

Competitive interest is considered together with the available data concerning the other criteria enumerated in sec. 2(e) of the Act in classifying lands as being within a KGRA.

Available information which could be considered in determining the existence of competitive interest in connection with an application for a geothermal lease would include information concerning the existence of bona fide, allowable applications for geothermal leases which have been filed for all or any part of the lands sought under the application being considered, or for lands in the vicinity of the lands being sought. The circumstance that two or more companies are exploring, applying for, or actually leasing available State or fee lands for geothermal resources in the same general area might constitute competitive interest that would affect Federal lands considered valuable prospectively for geothermal resources and could warrant its classification as a KGRA. The absence of indicated competitive interest, however, is, in and of itself, no bar to classification of lands for inclusion in a KGRA and would not be sufficient to warrant revocation of a KGRA.

OTHER INDICIA

Any pertinent engineering and (or) economic data may be considered together with other available data relating to the criteria enumerated in sec. 2(e) of the Geothermal Steam Act in classifying land for inclusion in a KGRA.

In defining the lands valuable for geothermal resource development under the proposed withdrawal published in the "Federal Register," v. 32, p. 4506, March 24, 1967, the Director of the Geological Survey used primarily a combination of the then known geologic and geophysical data as well as temperature and chemical data, in part supplied by industry, from areas that had been drilled in exploration for geothermal steam. Future developments will provide substantially more geologic and geophysical information as well as engineering and economic data. These factors will be considered in future determinations of KGRA's.

REFERENCES CITED

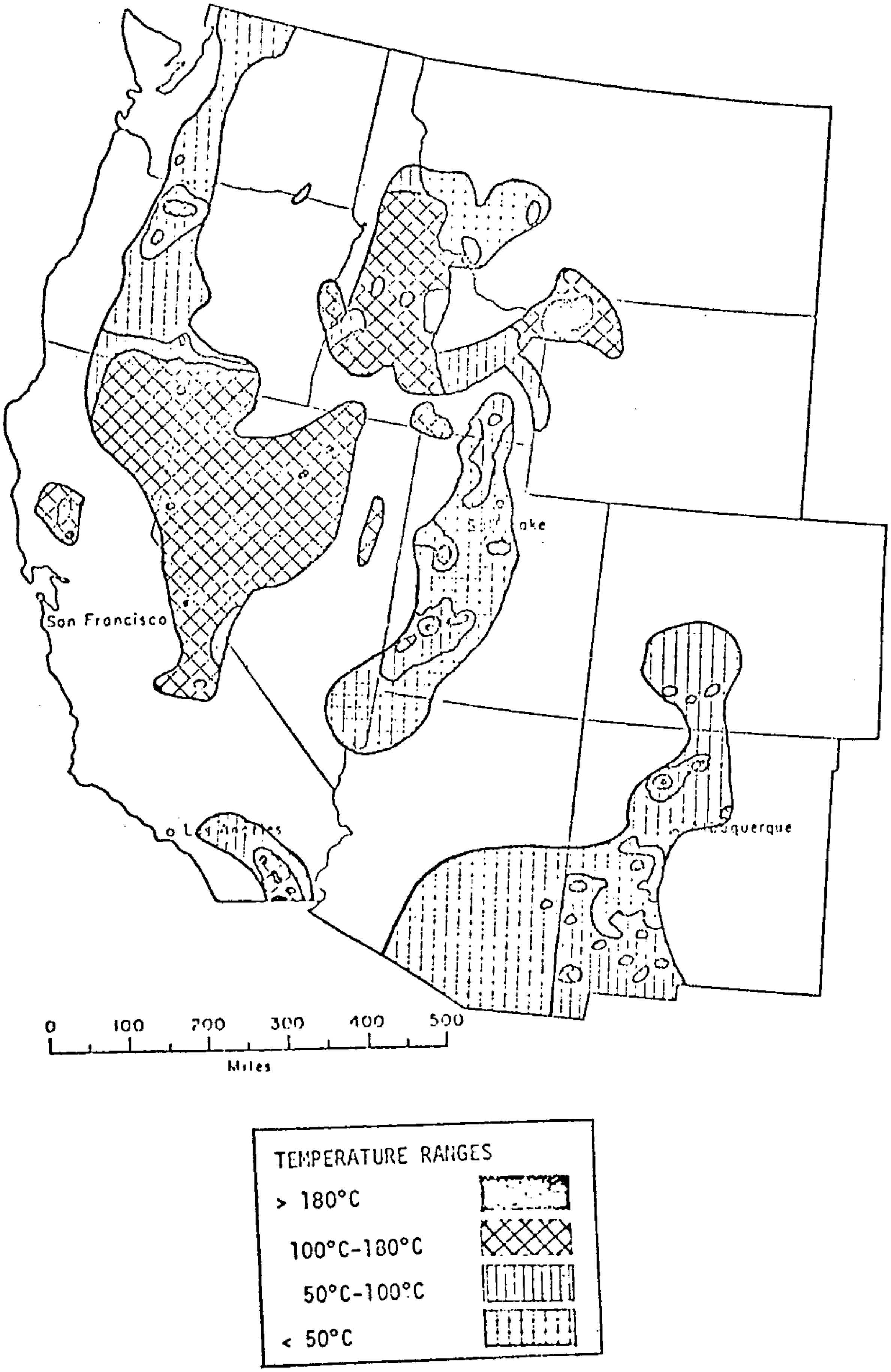
Finley, E. A., 1959, The definition of known geologic structures of producing oil and gas fields: U.S. Geol. Survey Circ. 419, 6 p.

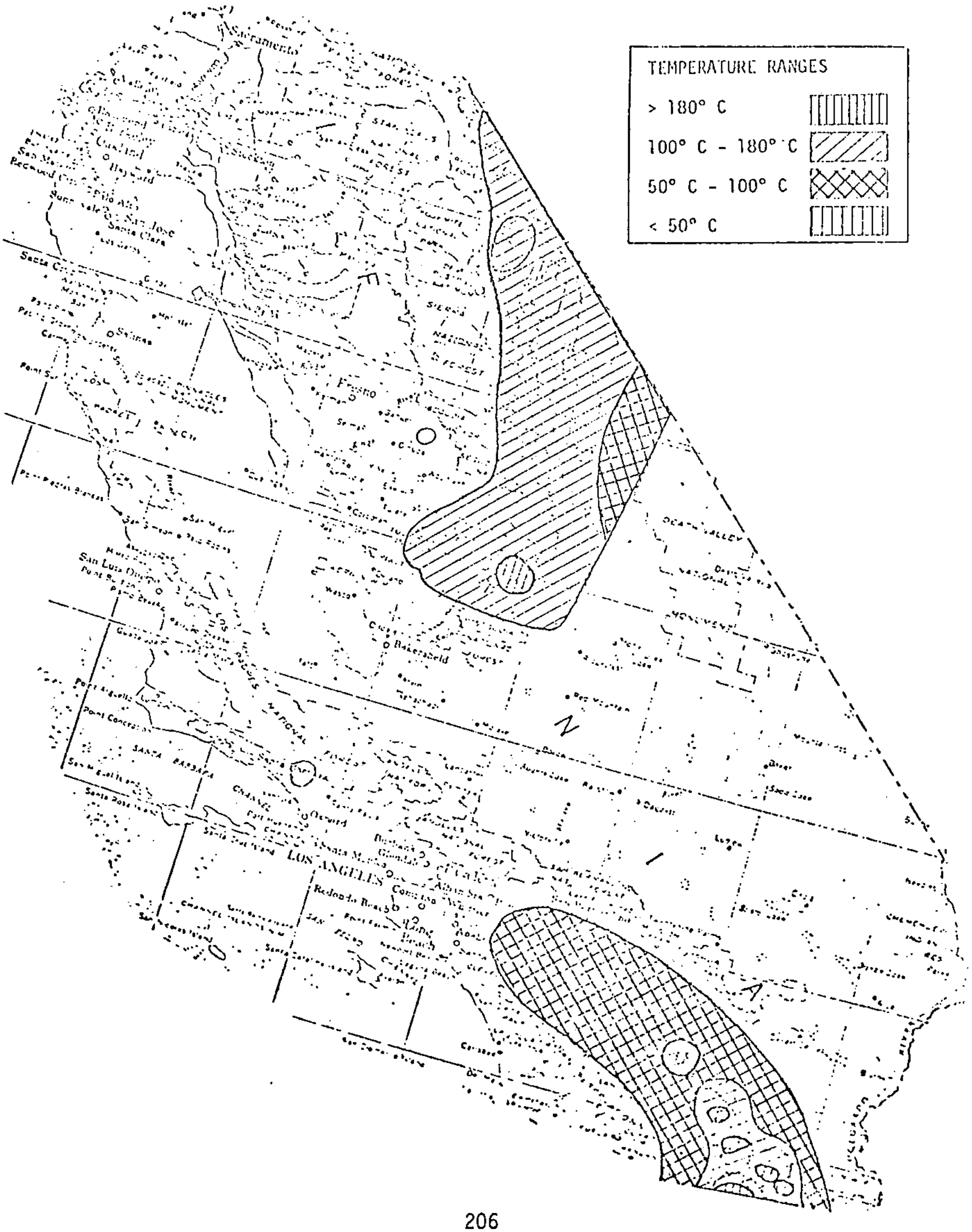
White, D. E., 1965, Geothermal energy: U.S. Geol. Survey Circ. 519, 17 p.

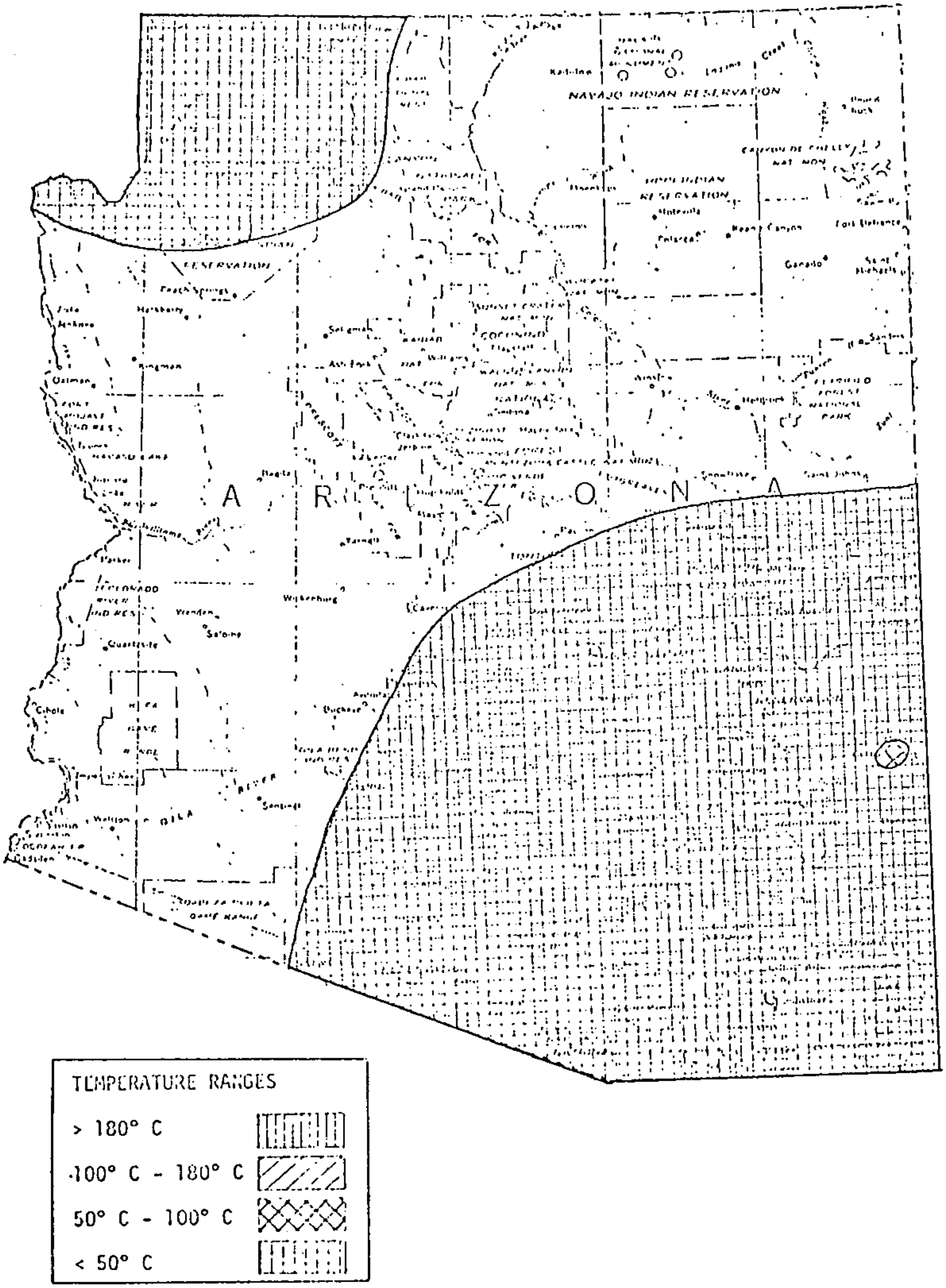
White, D. E., Muffler, L. J. P., and Truesdell, A. H., 1971, Vapor-dominated hydrothermal systems, compared with hot-water systems: Econ. Geology, v. 66, no. 1, p. 75-97.

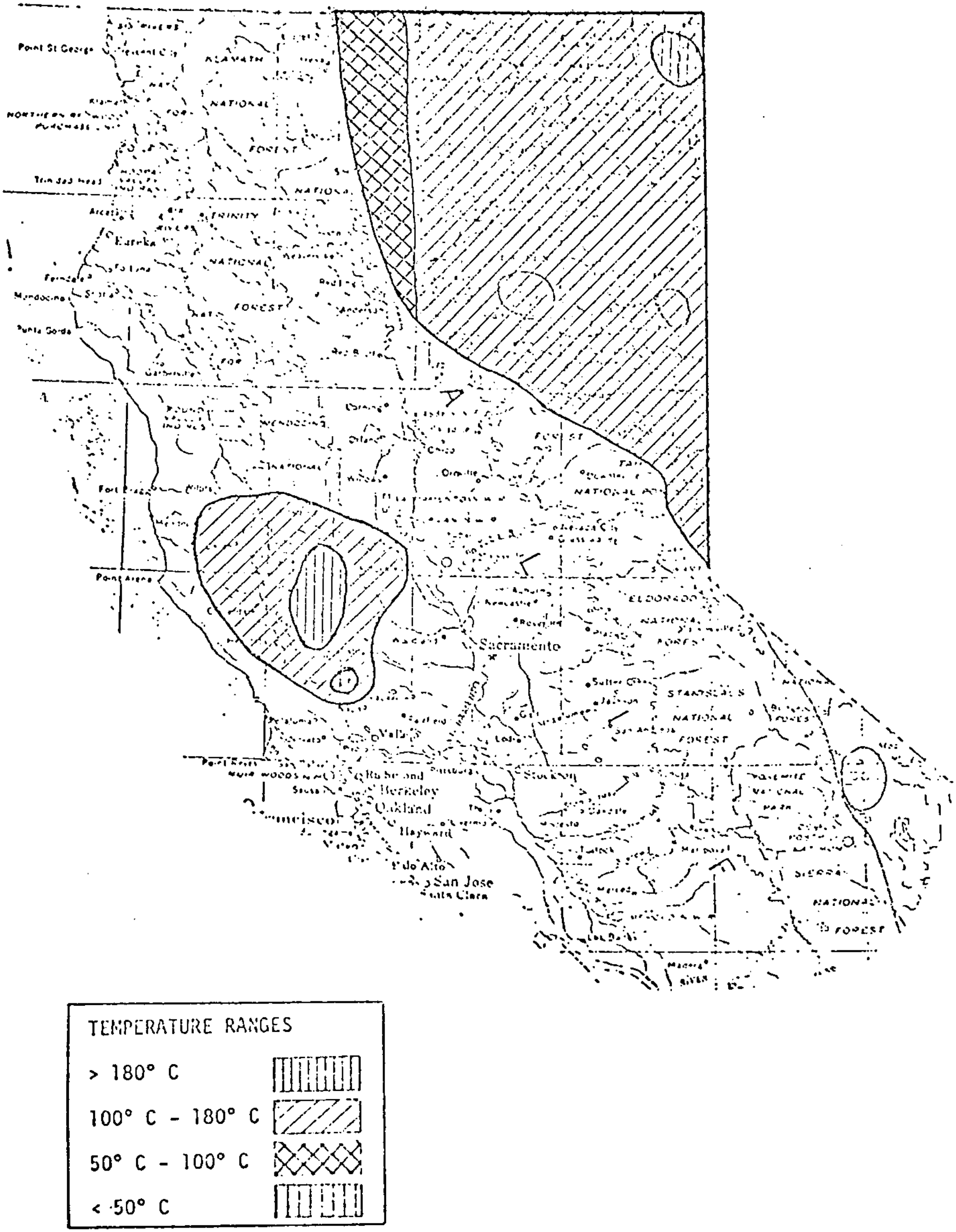
Appendix II.

MAP CLASSIFICATION OF AREAS BY TEMPERATURE RANGE, WATER QUALITY AND BORON CONTENT


San Francisco
Los Angeles
Salt Lake
Albuquerque
0
100
200
300
400
500
Miles
TEMPERATURE RANGES
> 180°C
100°C-180°C
50°C-100°C
< 50°C


TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C
Sacramento
Stockton
Hayward
San Jose
Santa Clara
Salinas
Fresno
Bakersfield
San Luis Obispo
Santa Barbara
Oxnard
Santa Monica
LOS ANGELES
Redondo Beach
Long Beach
Death Valley


NAVAJO INDIAN RESERVATION
HOPI INDIAN RESERVATION
CANYON DE CHELLY NAT. MON.
Fort Defiance
Ganado
Holbrook
COCONINO
Seligman
Ash Fork
Peach Springs
RESERVATION
Kingman
Oatman
Parker
COLORADO RIVER IND. RES.
Quartzsite
Wenden
Salome
Wickenburg
Cibola
Wellton
GILA
Sentinel
Gadsden
A R I Z O N A
TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C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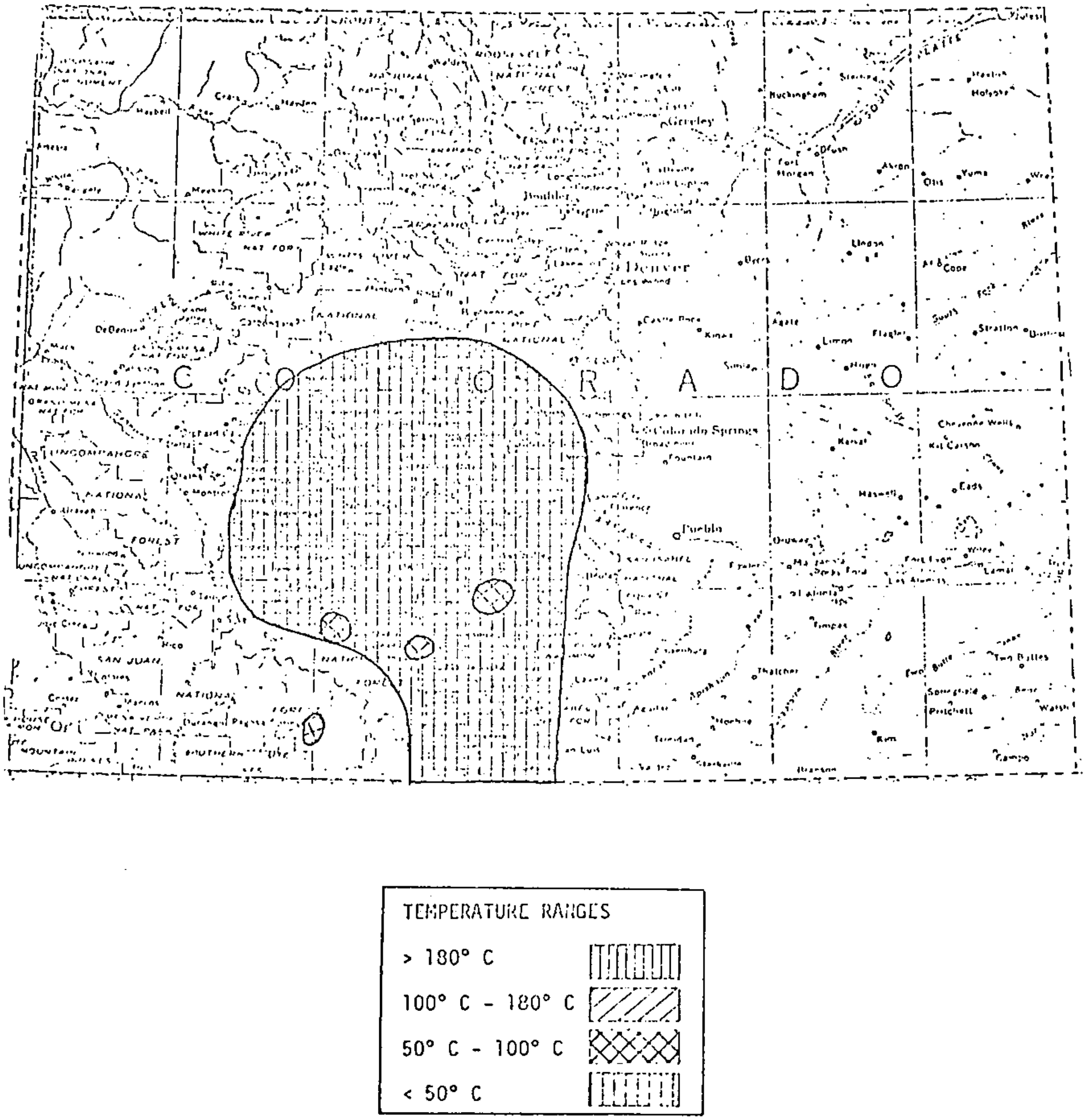
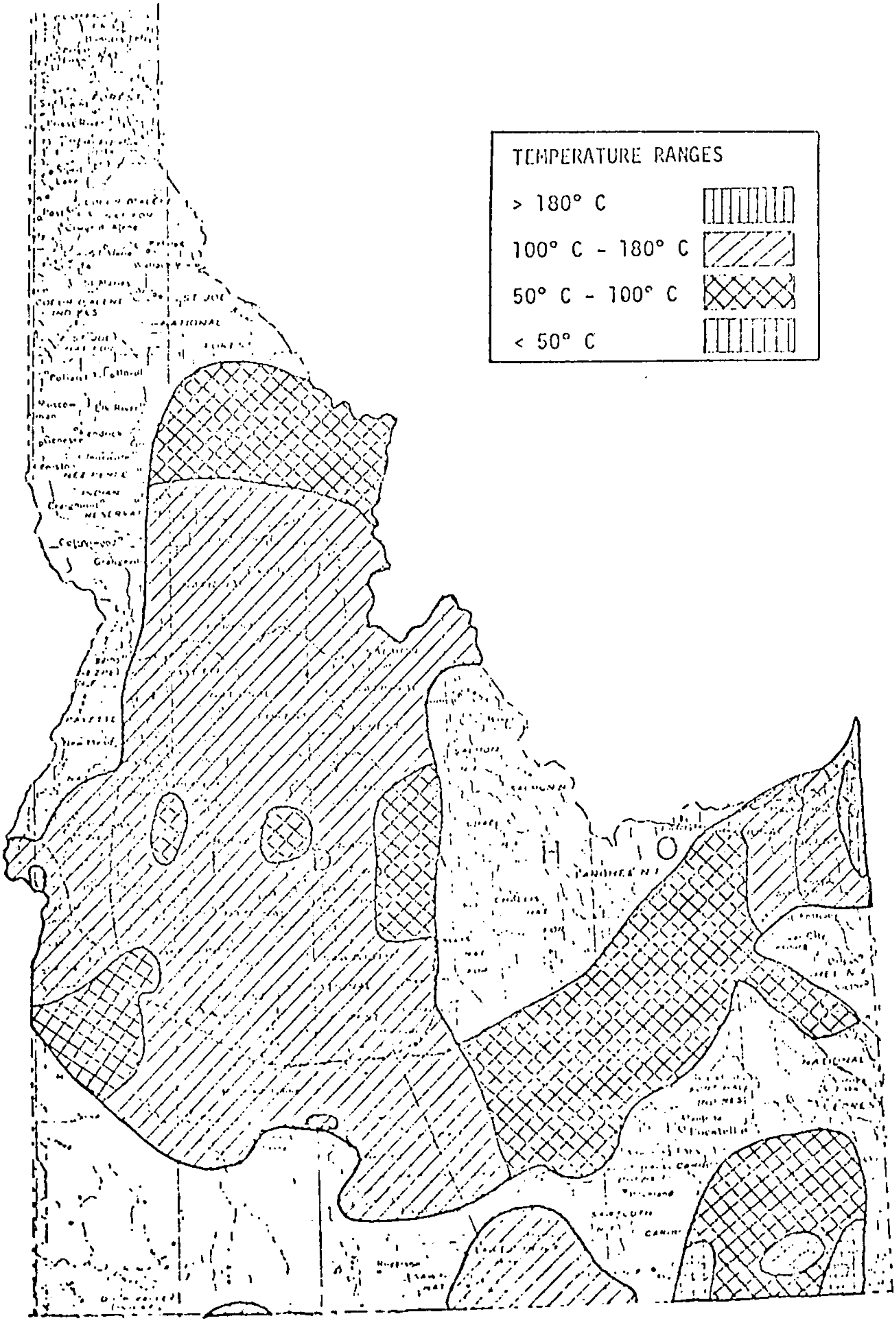
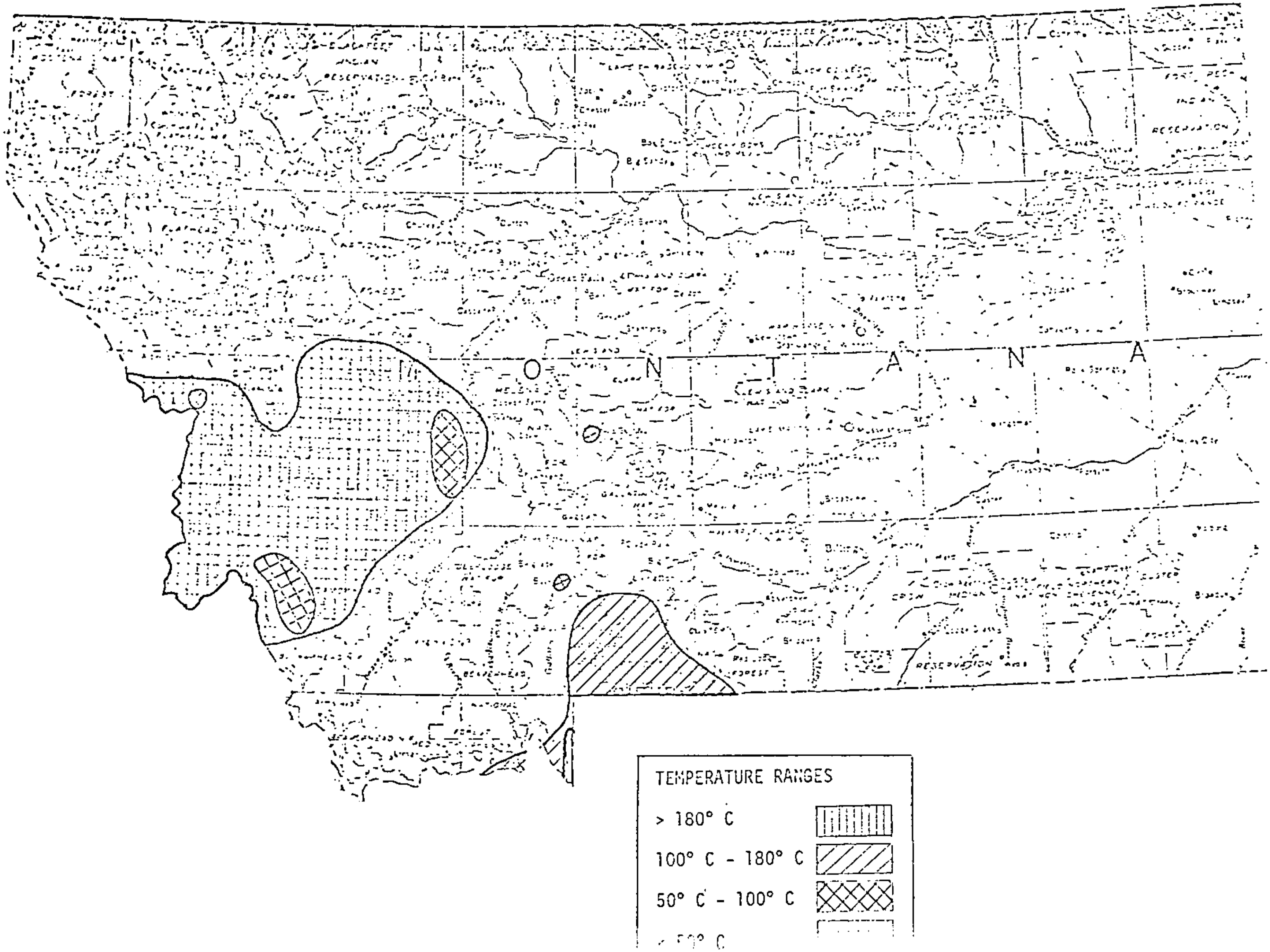
Eureka
Mendocino
Punta Gorda
Point Arena
Fort Bragg
Trinidad Head
KLAMATH
NATIONAL
FOREST
TRINITY
A
ELDORADO
NATIONAL
FOREST
STANISLAUS
NATIONAL
FOREST
YOSEMITE
NATIONAL
PARK
SIERRA
NATIONAL
FOREST
Sacramento
Stockton
Vallejo
Berkeley
Oakland
Hayward
Palo Alto
San Jose
Santa Clara
TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C


C O L O R A D O
Denver
Greeley
Boulder
Colorado Springs
Pueblo
Fountain
Fort Morgan
Akron
Limon
Kit Carson
Eads
Lamar
Walsh
Campo
Trinidad
UNCOMPAHGRE
NATIONAL
FOREST
SAN JUAN
NATIONAL
ROOSEVELT
NATIONAL
FOREST
WHITE RIVER
NAT FOR
Rico
Durango
TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C


TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C
ST JOE
NATIONAL
FOREST
NEZ PERCE
INDIAN
RESERVATION
H
O
NATIONAL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TEMPERATURE RANGES
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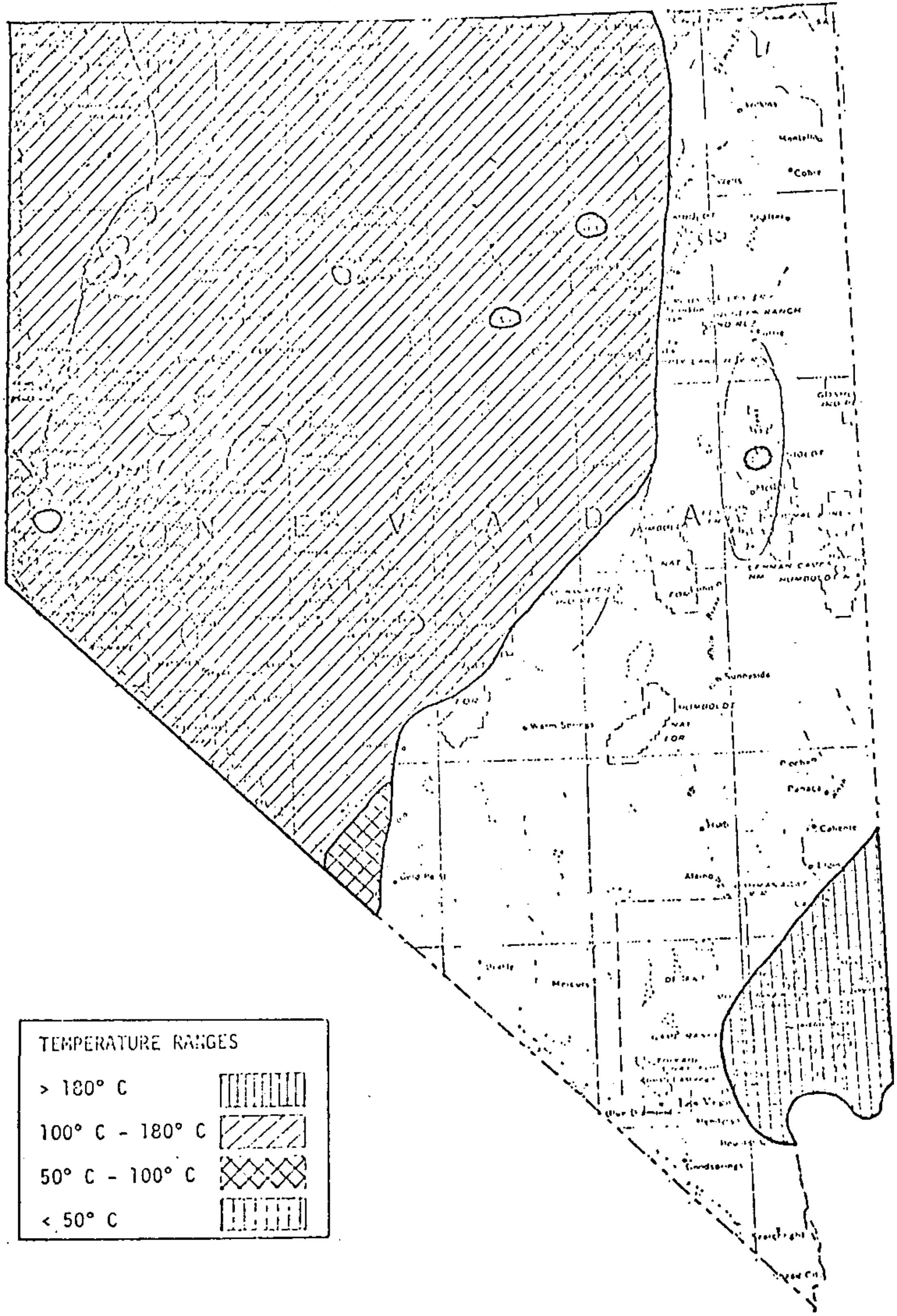
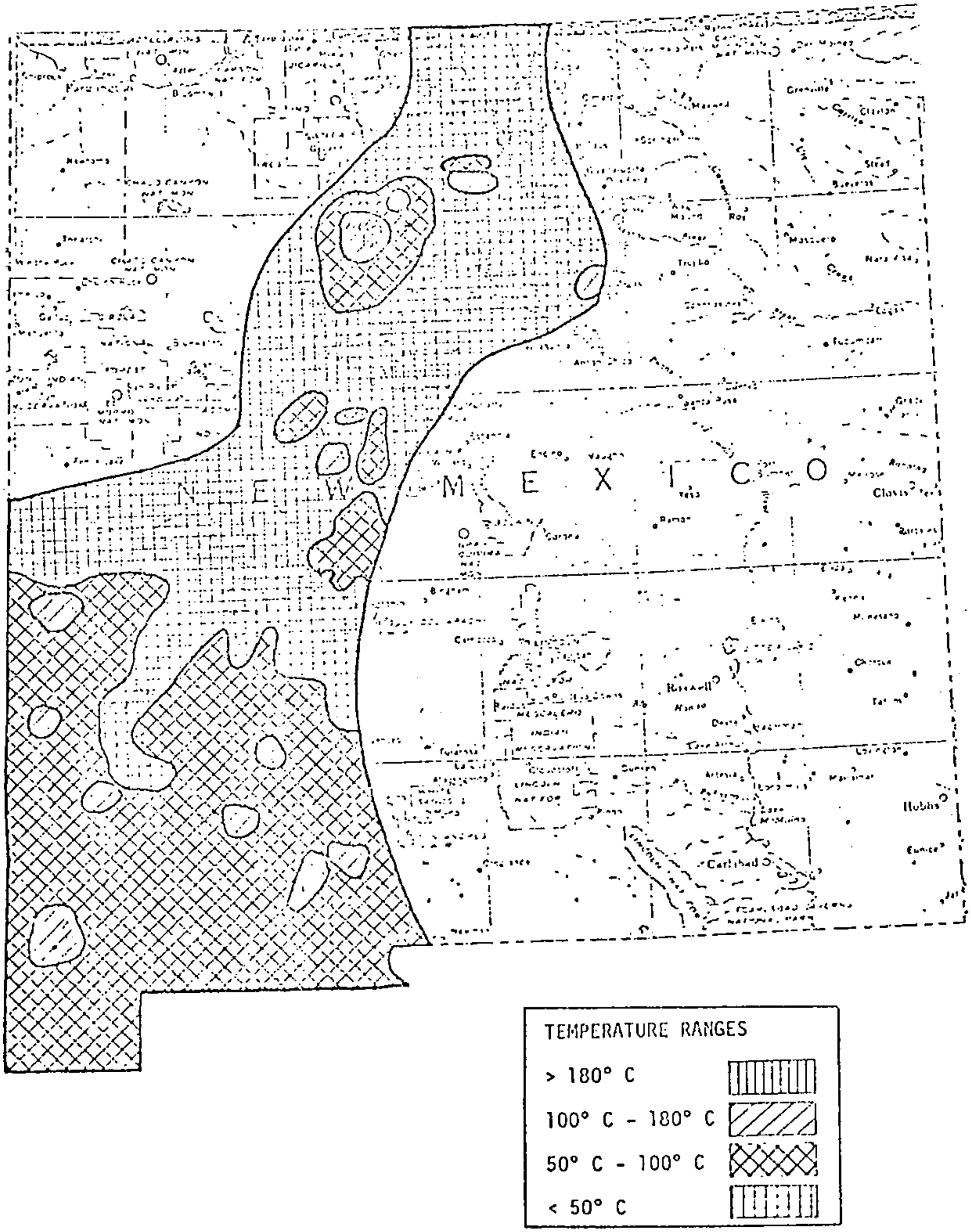
100° C - 180° C
50° C - 100° C
< 50° C

TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C
N E V A D A
Montello
Cobre
Wells
LEHMAN CAVES NM
HUMBOLDT
HUMBOLDT NAT FOR
Sunnyside
Warm Springs
Pioche
Panaca
Caliente
Alamo
Mercury
Las Vegas
Henderson
Goodsprings
Searchlight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Hobbs
Carlsbad
Roswell
Clovis
Eunice
TEMPERATURE RANGES
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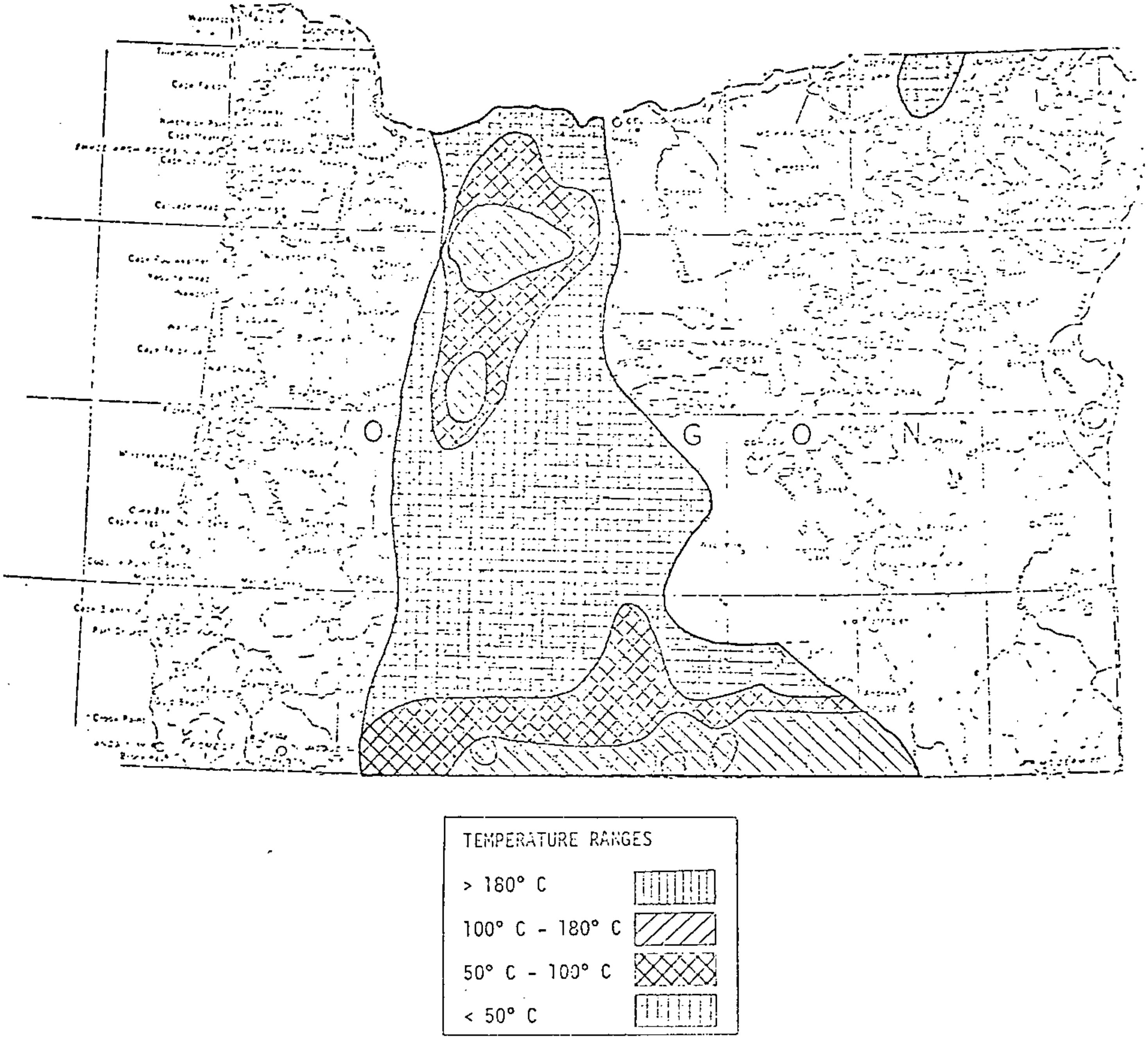
100° C - 180° C
50° C - 100° C
< 50° C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N
TEMPERATURE RANGES
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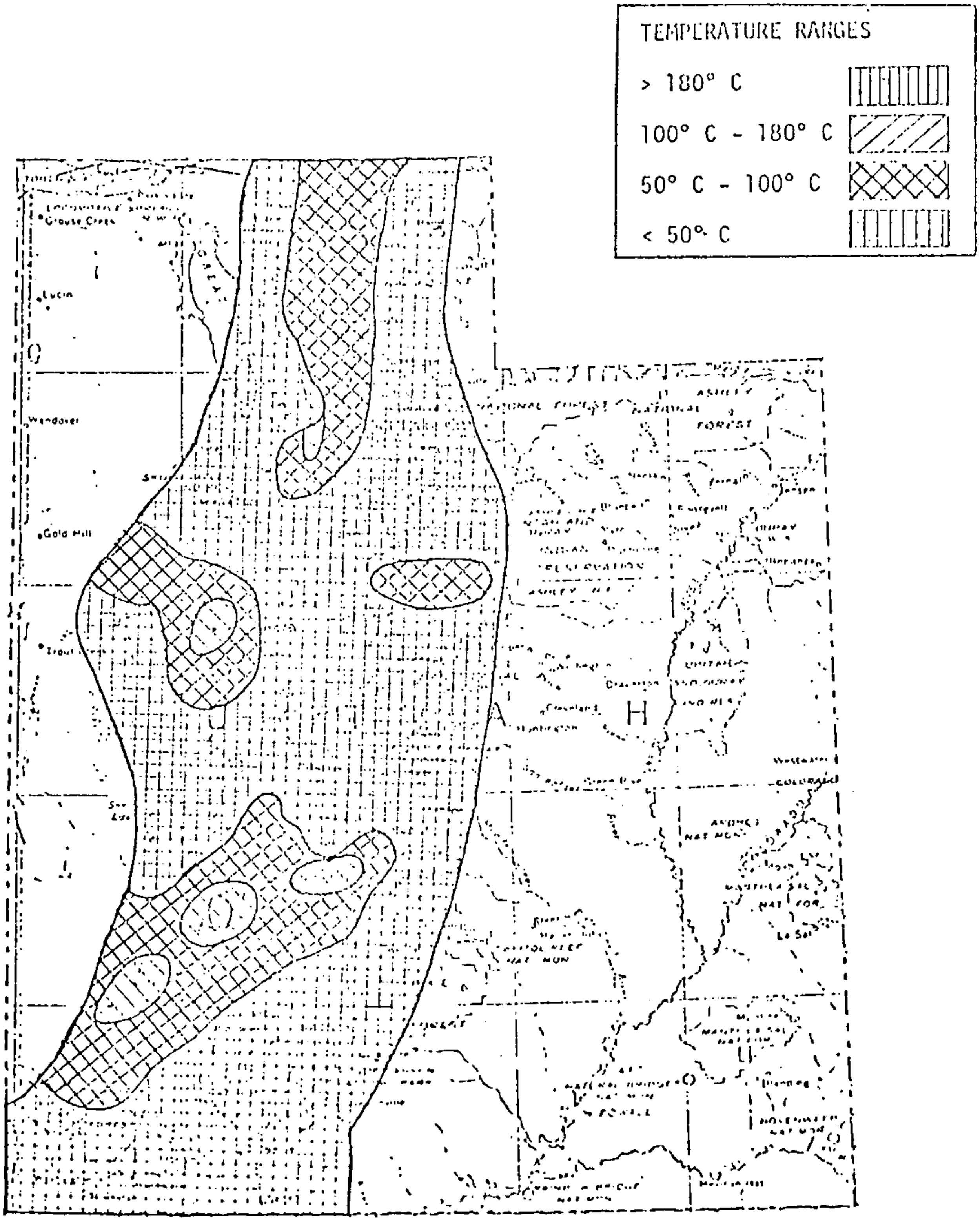
100° C - 180° C
50° C - 100° C
< 50° C


TEMPERATURE RANGES
> 180° C
100° C - 180° C
50° C - 100° C
< 50° C
Grouse Creek
Lucin
Wendover
Gold Hill
Trout
ASHLEY NATIONAL FOREST
Cleveland
Huntington
Westwater
COLORADO
ARCHES NAT MON
CAPITOL REEF NAT MON
MANTI-LA SAL NAT FOR
La Sal
NATURAL BRIDGES NAT MON
HOVENWEEP NAT MON
RAINBOW BRIDGE NAT MON
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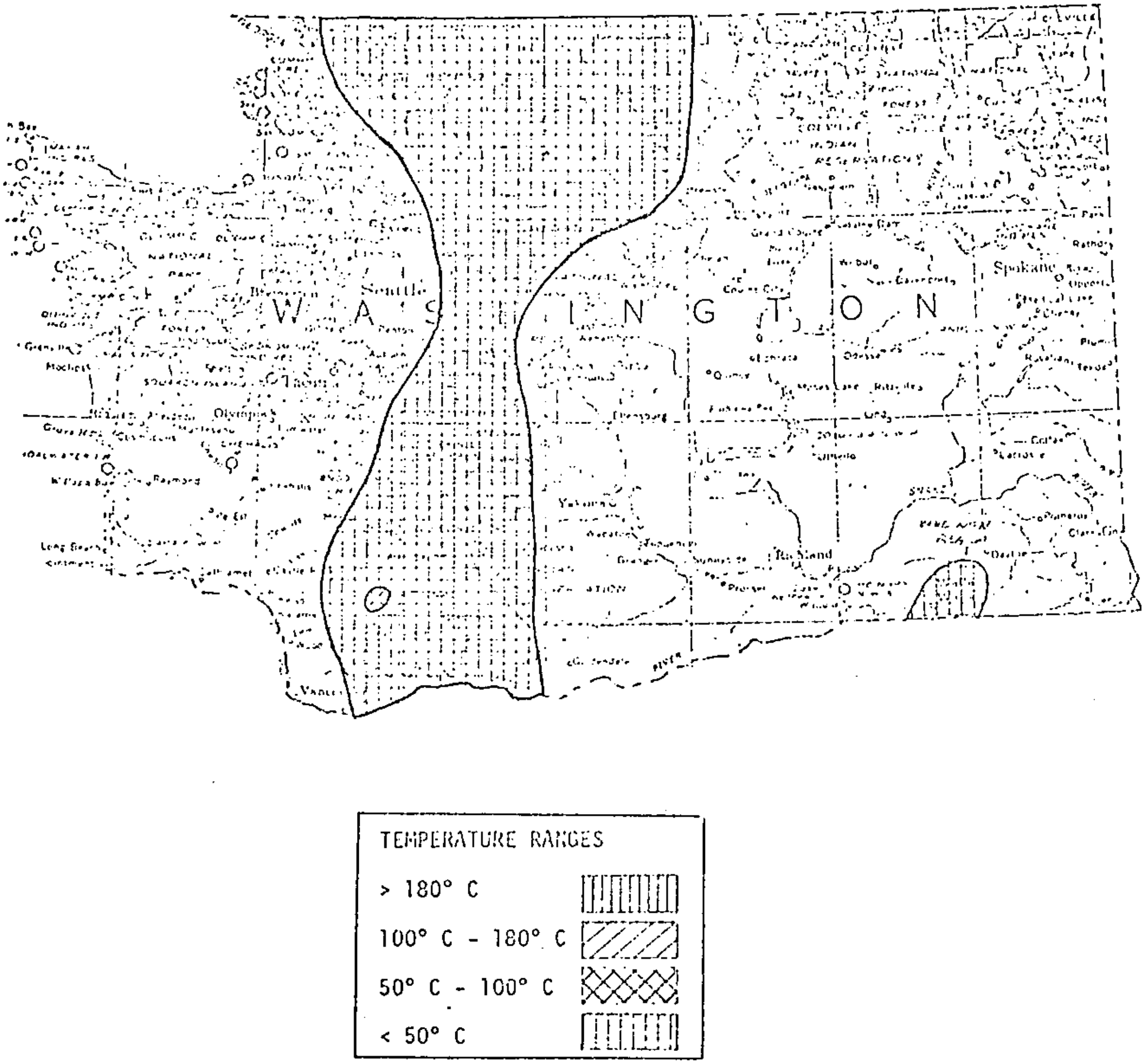
H


W A S H I N G T O N
Seattle
Tacoma
Olympia
Spokane
Yakima
Richland
TEMPERATURE RANGES
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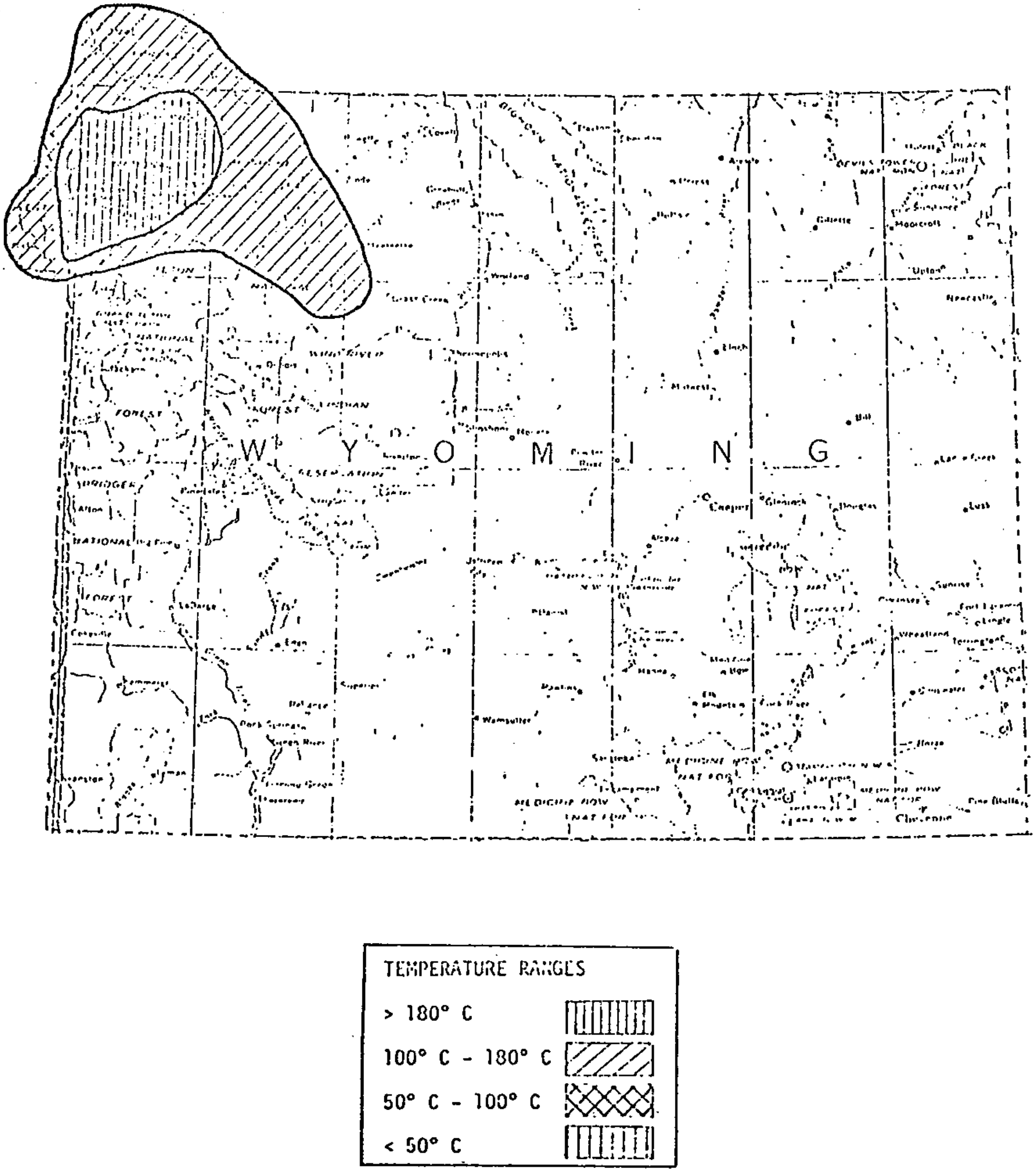
100° C - 180° C
50° C - 100° C
< 50° C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TEMPERATURE RANGES
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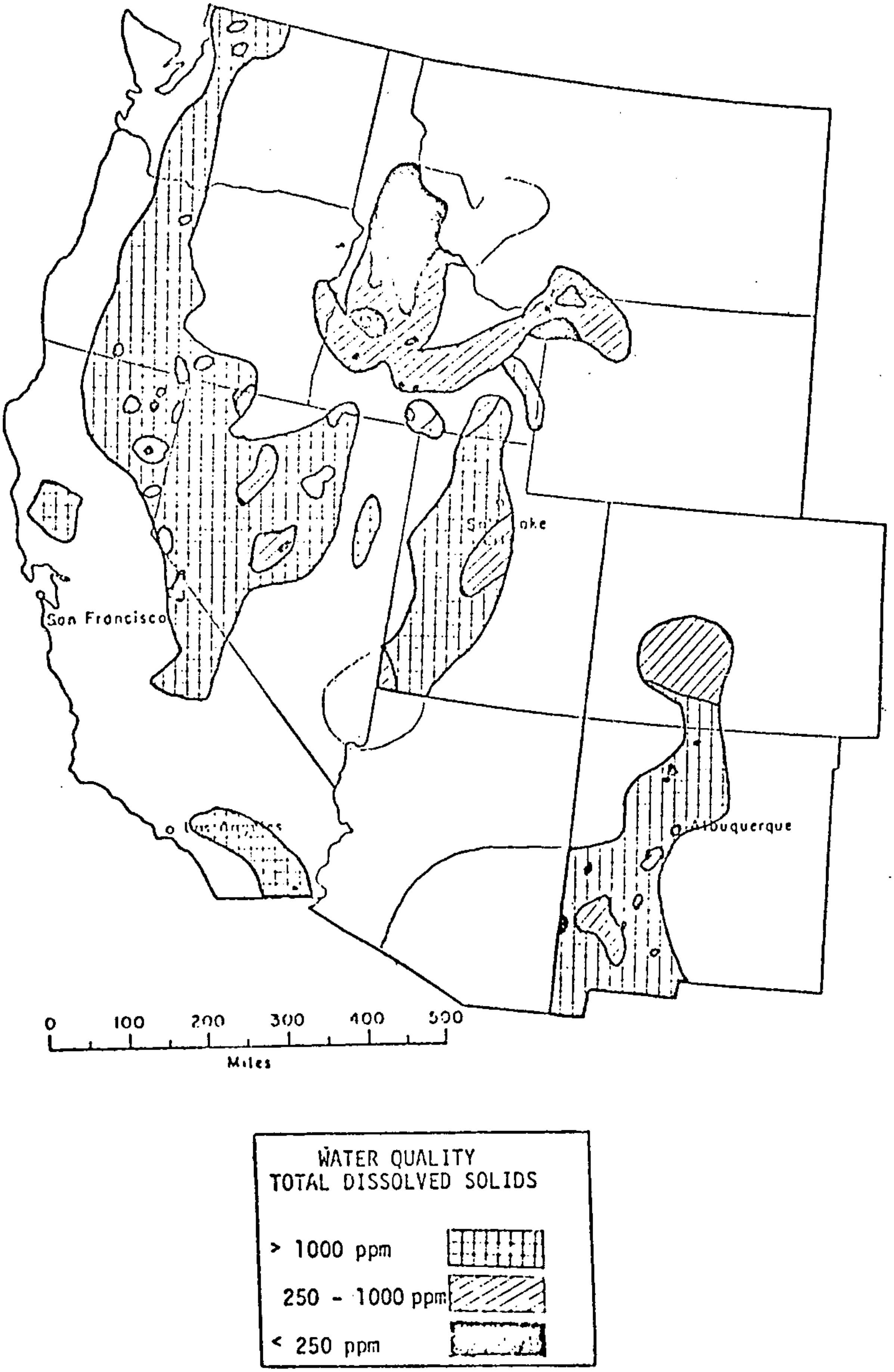
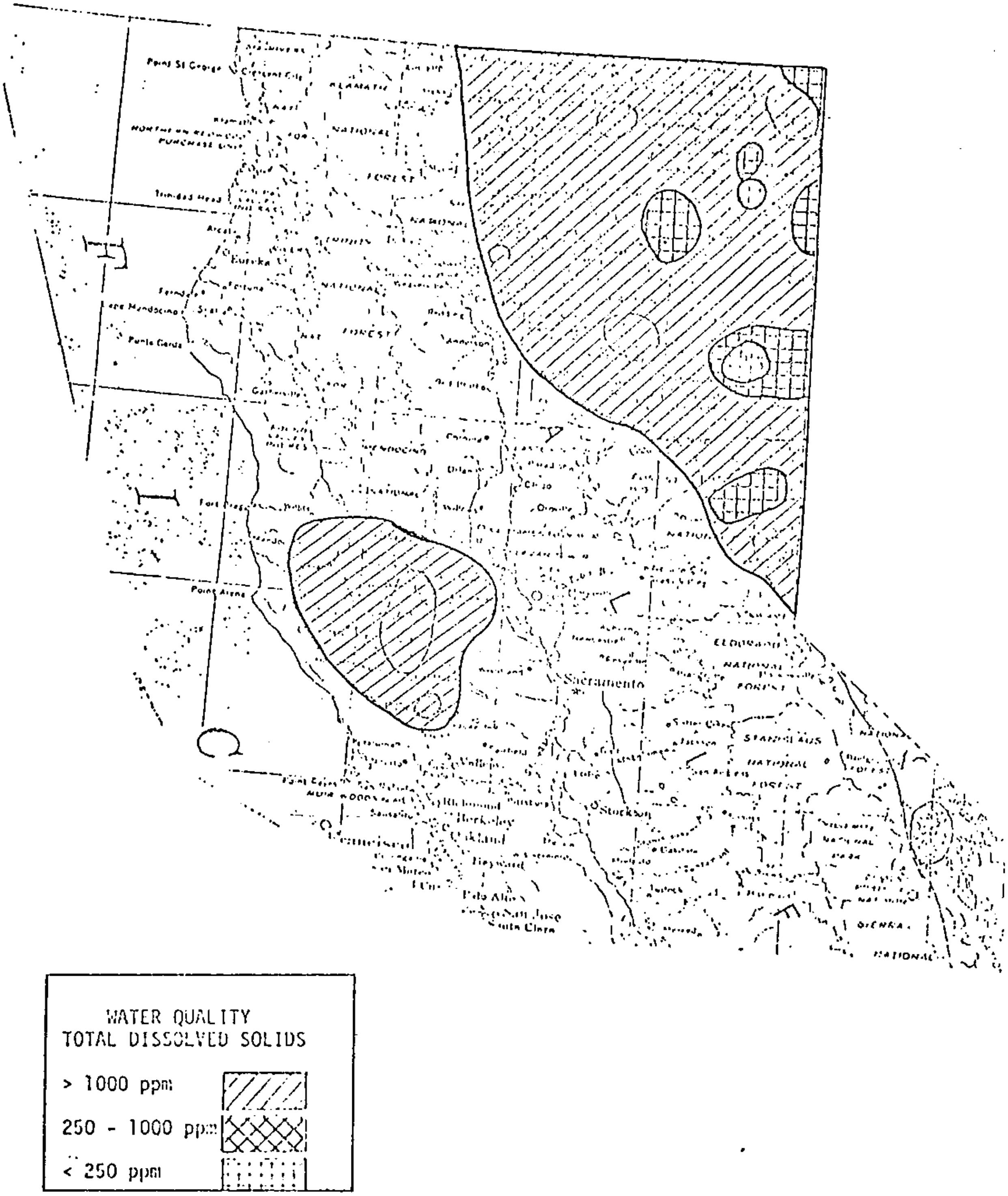
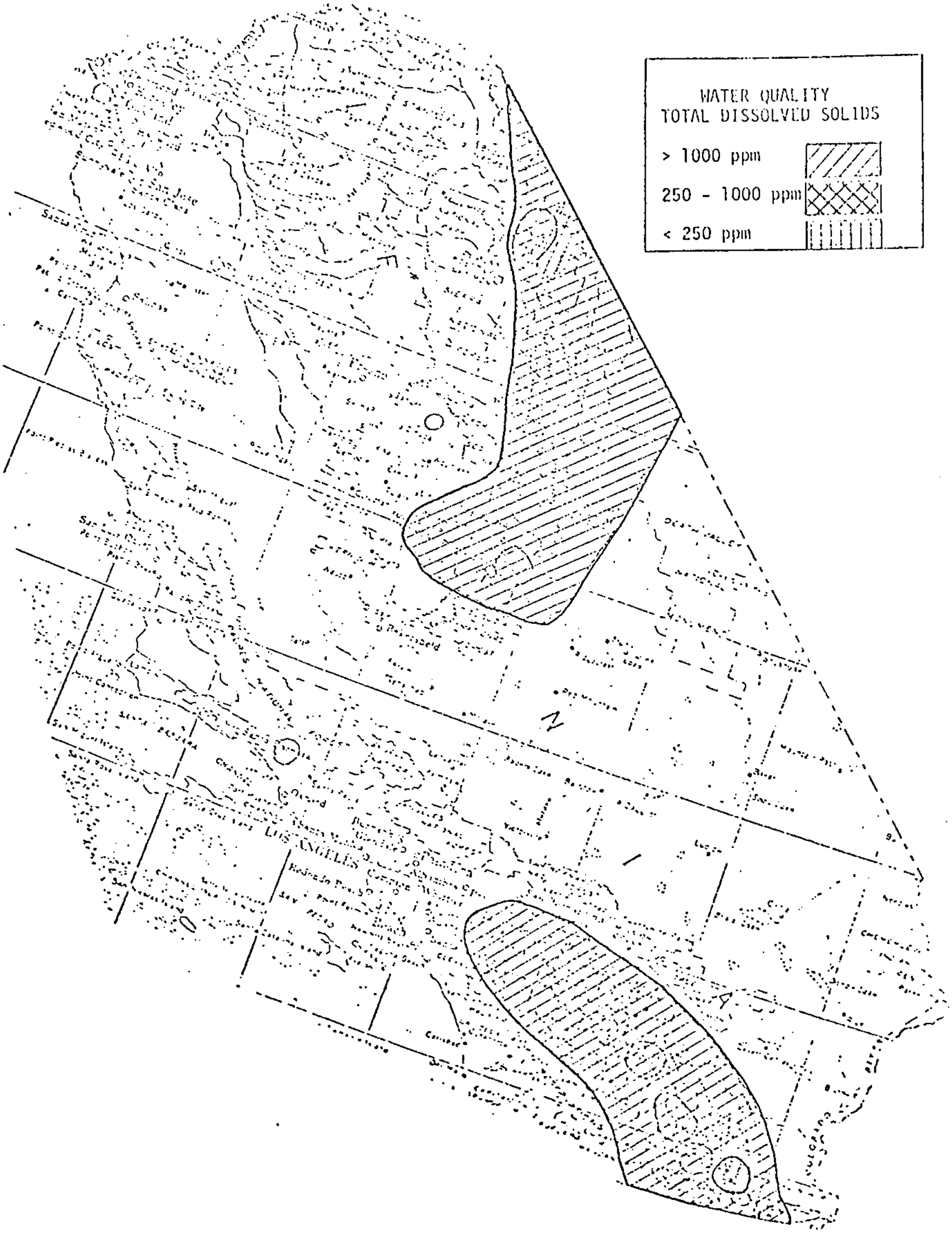
100° C - 180° C
50° C - 100° C
< 50° C


San Francisco
Los Angeles
Salt Lake
Albuquerque
0
100
200
300
400
500
Miles
WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm


WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm
Point St George
Crescent City
Trinidad Head
Eureka
Cape Mendocino
Punta Gorda
Fort Bragg
Point Arena
Sacramento
Vallejo
Richmond
Berkeley
Oakland
Stockton
Hayward
Palo Alto
San Jose
Santa Clara
H
I
C
L
E


WATER QUALITY
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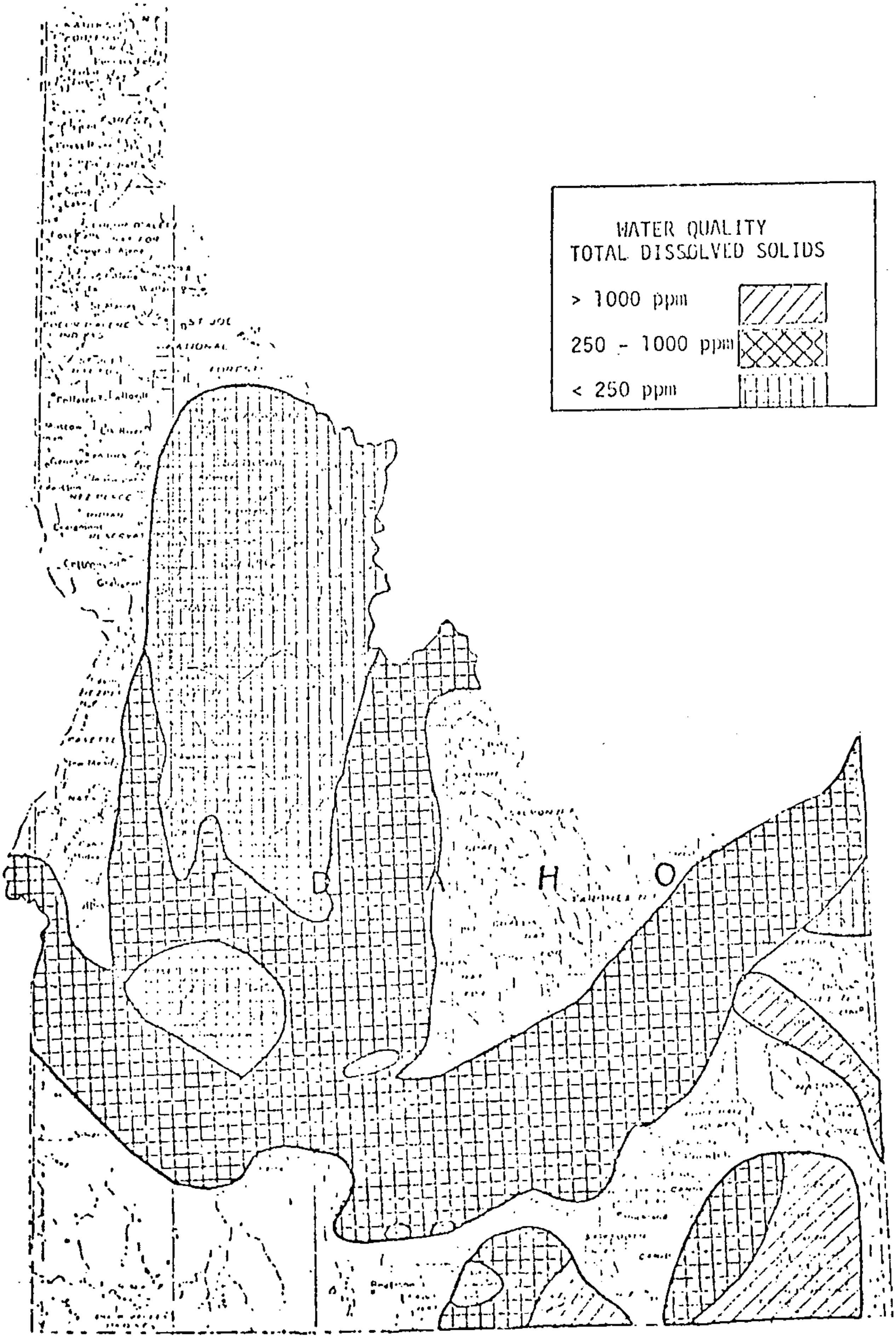
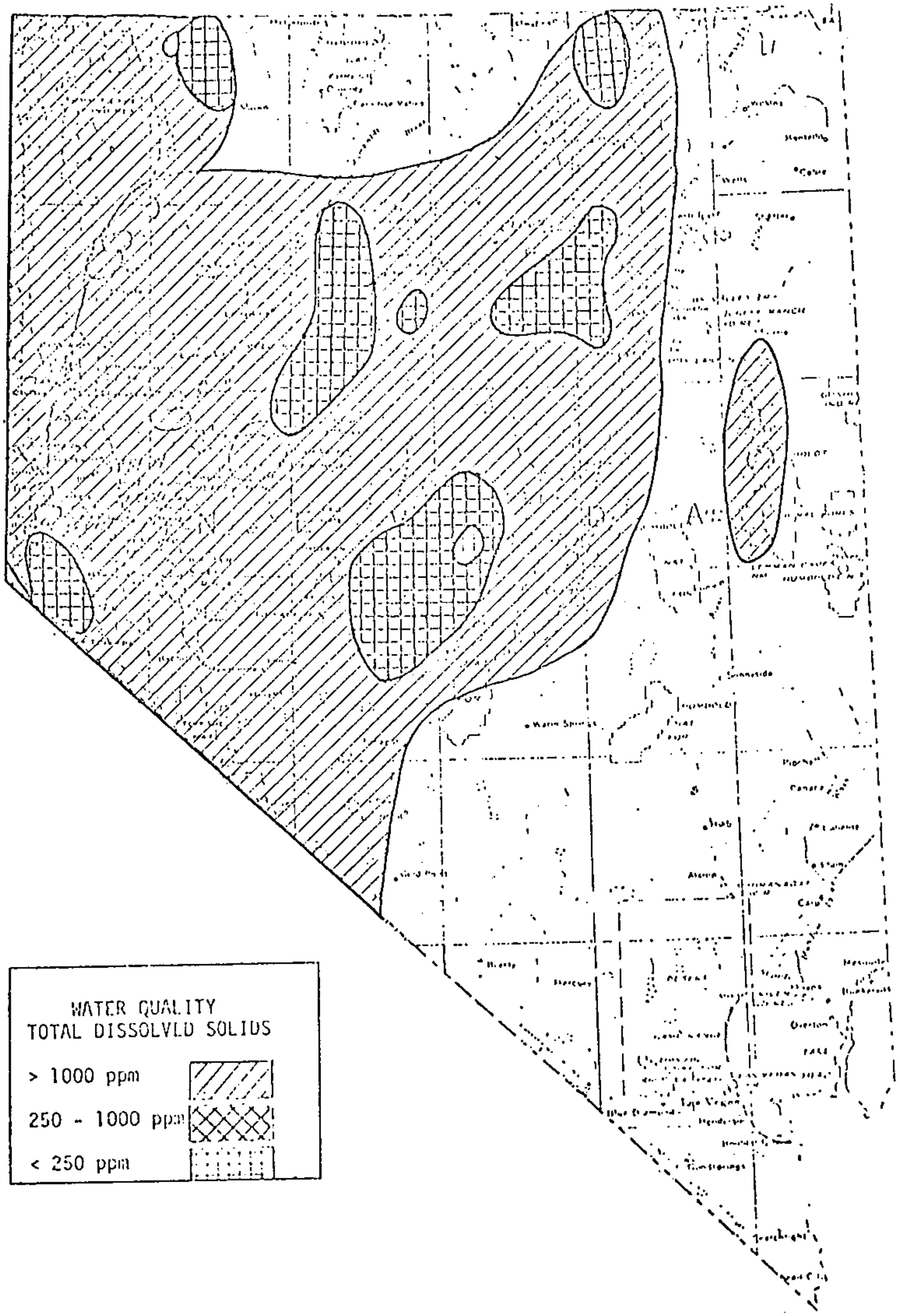
250 - 1000 ppm
< 250 ppm
San Jose
LOS ANGELES


WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm
I
D
A
H
O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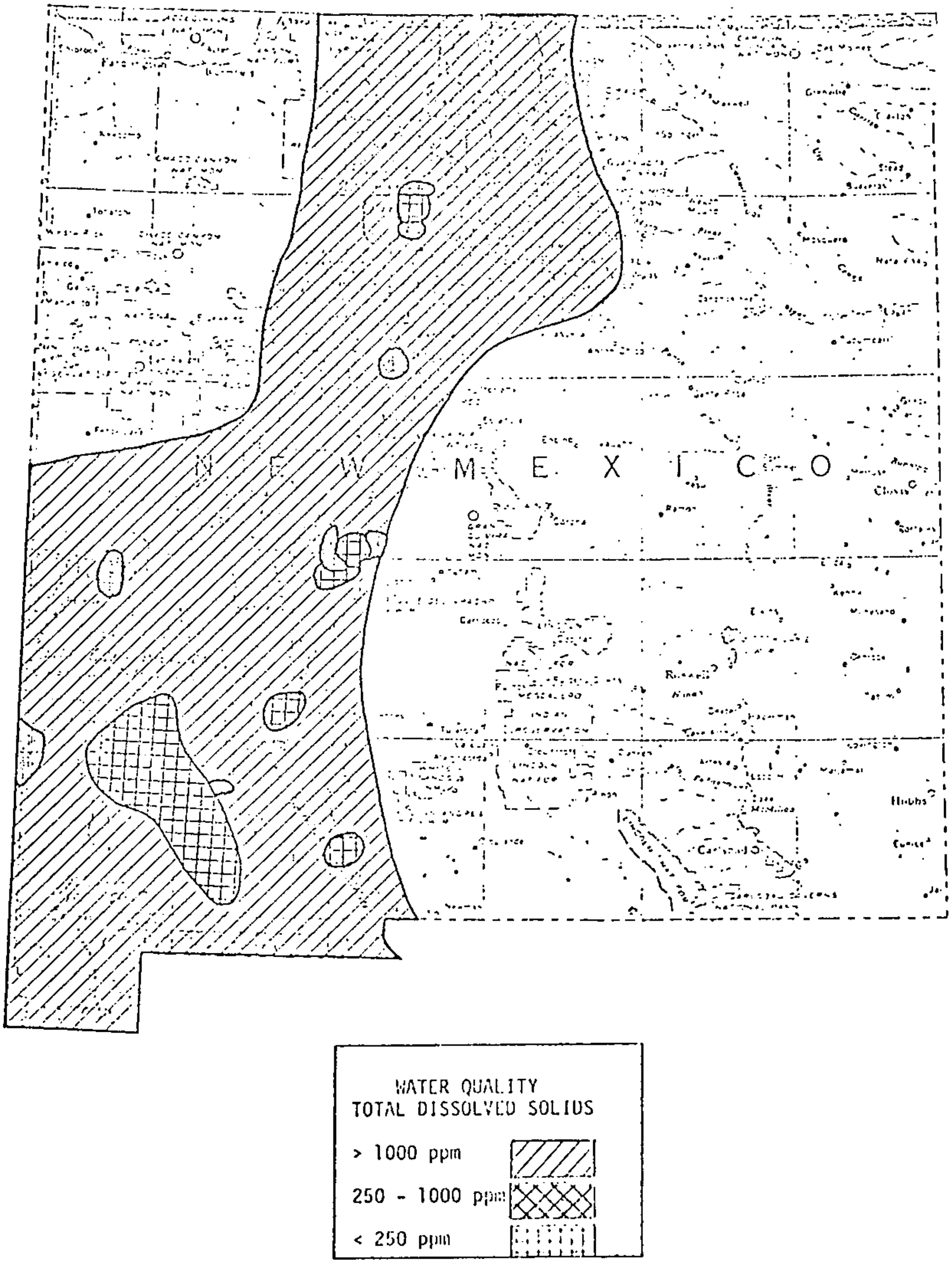
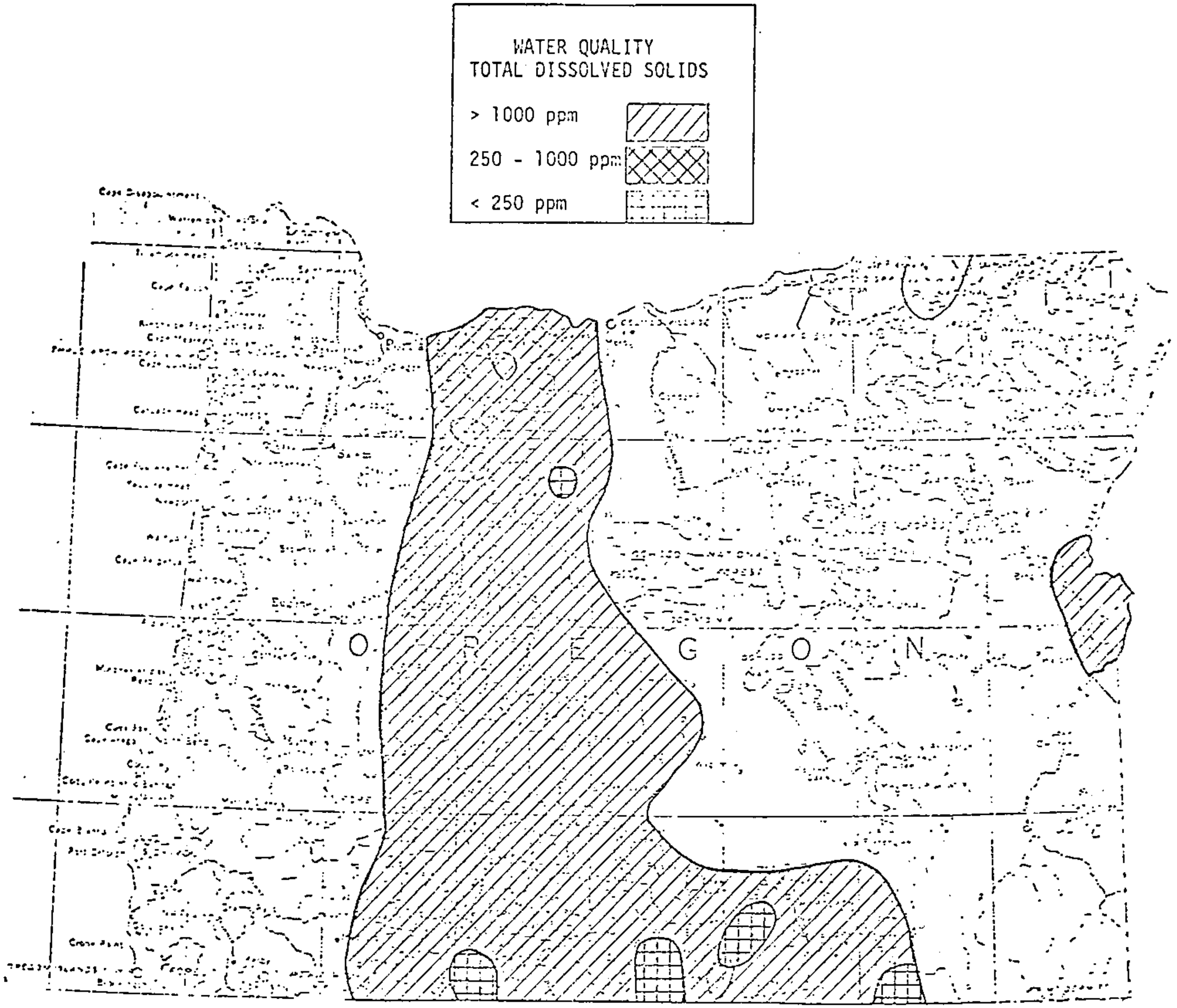

N E W M E X I C O
Farmington
Carlsbad
Hobbs
Roswell
Clovis
WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm


WATER QUALITY
TOTAL DISSOLVED SOLIDS
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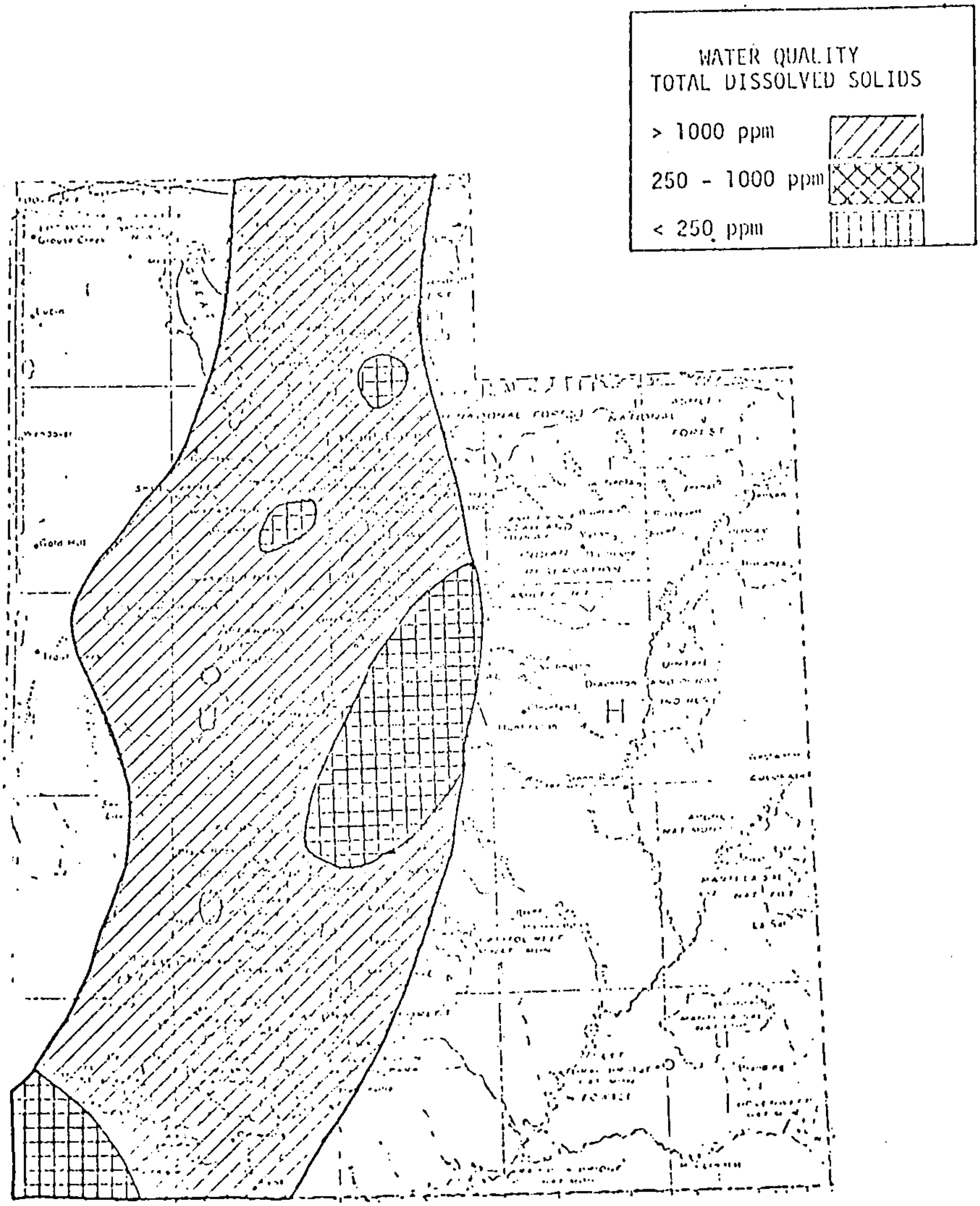
OREGON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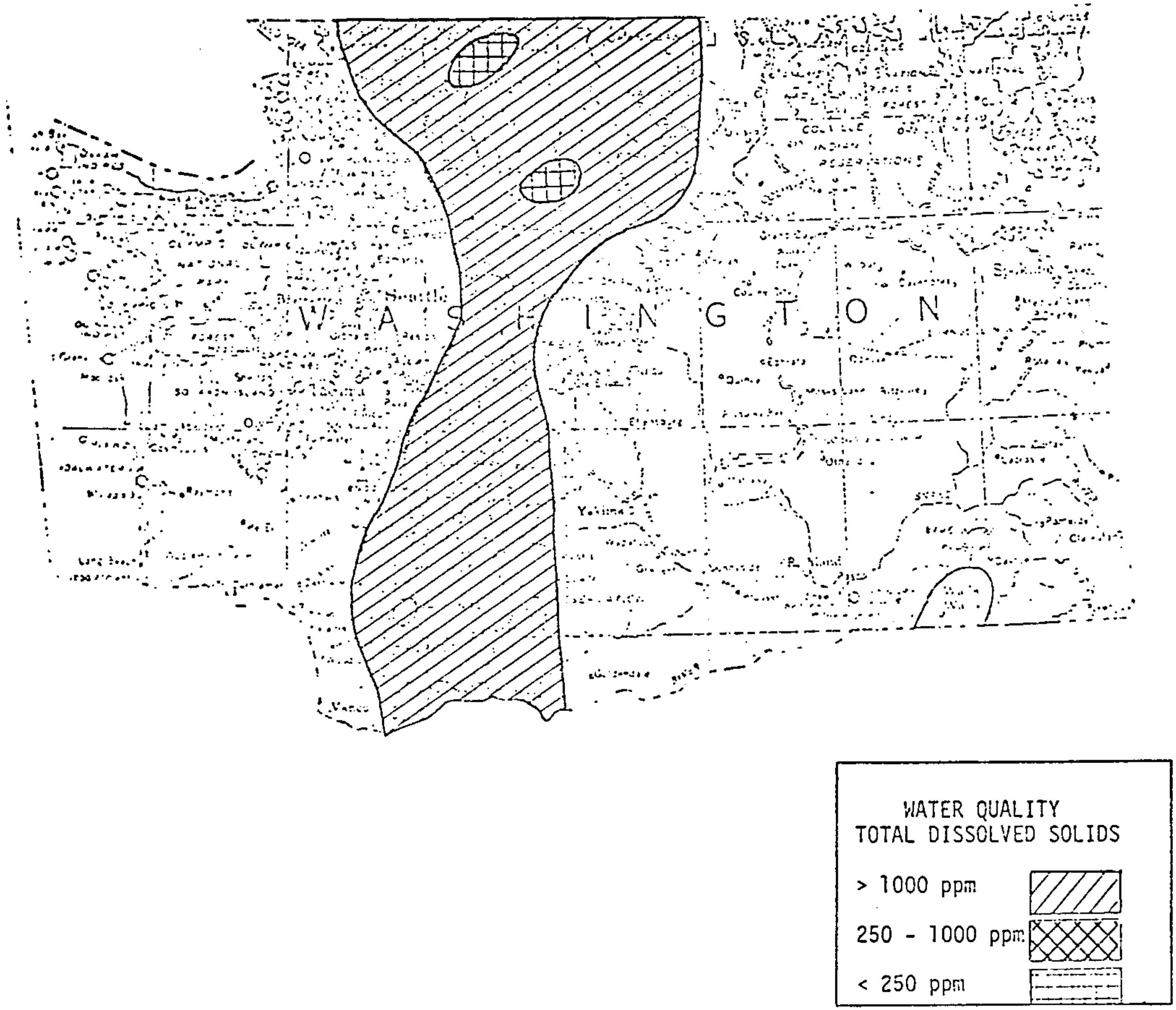
250 - 1000 ppm
< 250 ppm
Grouse Creek
Lucin
Wendover
Gold Hill
H


WASHINGTON
Seattle
Yakima
WATER QUALITY
TOTAL DISSOLVED SOLIDS
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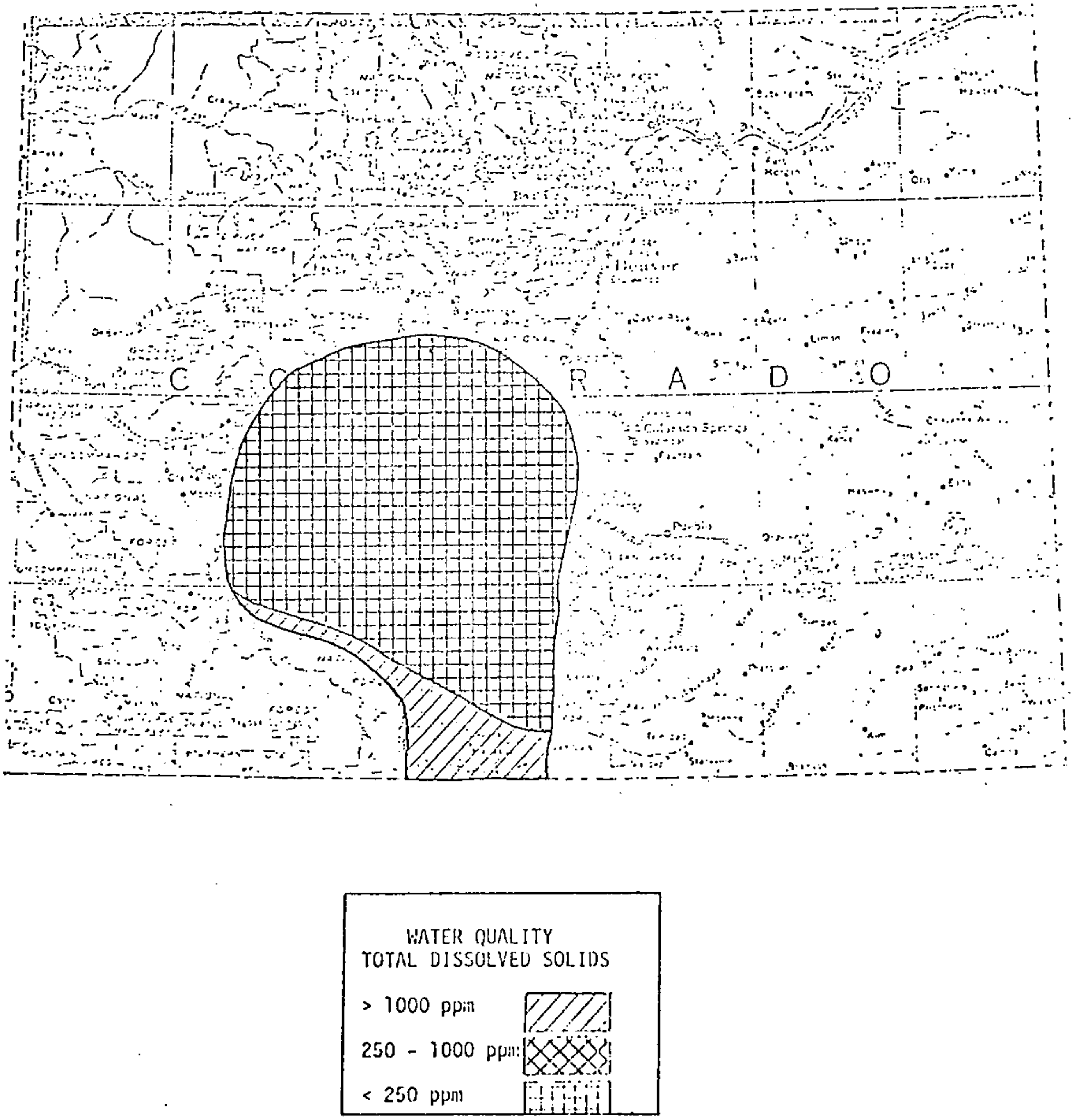
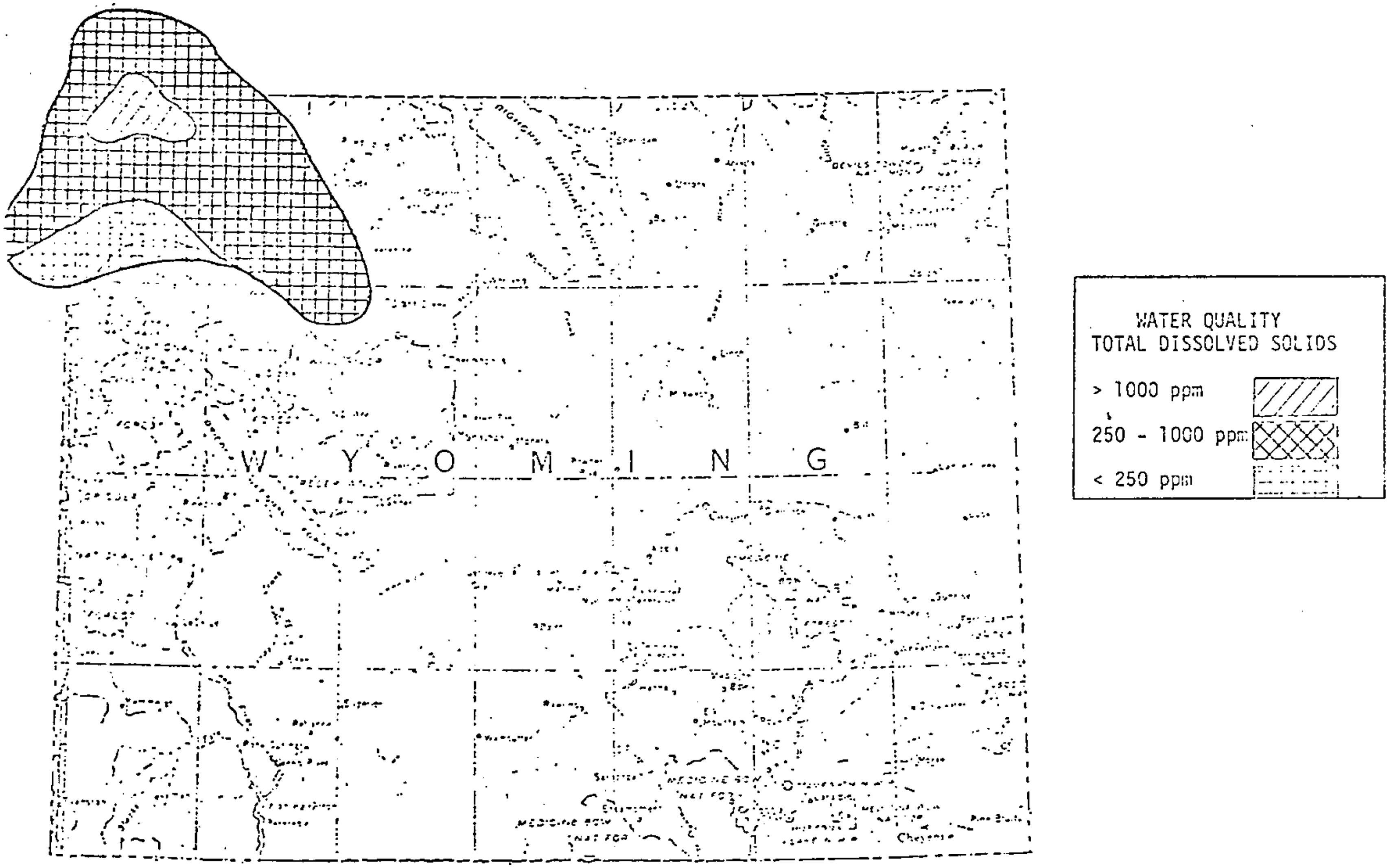
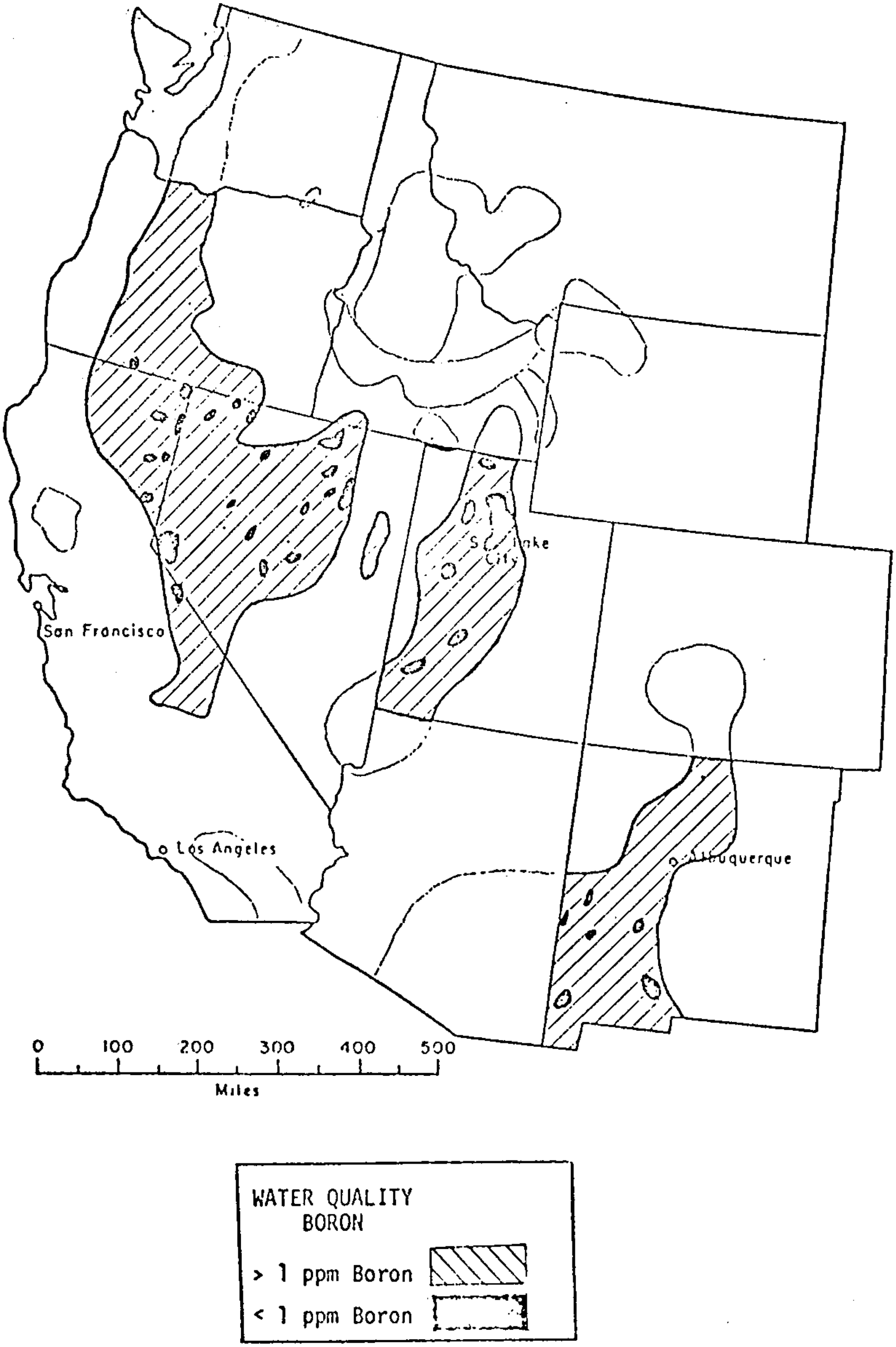
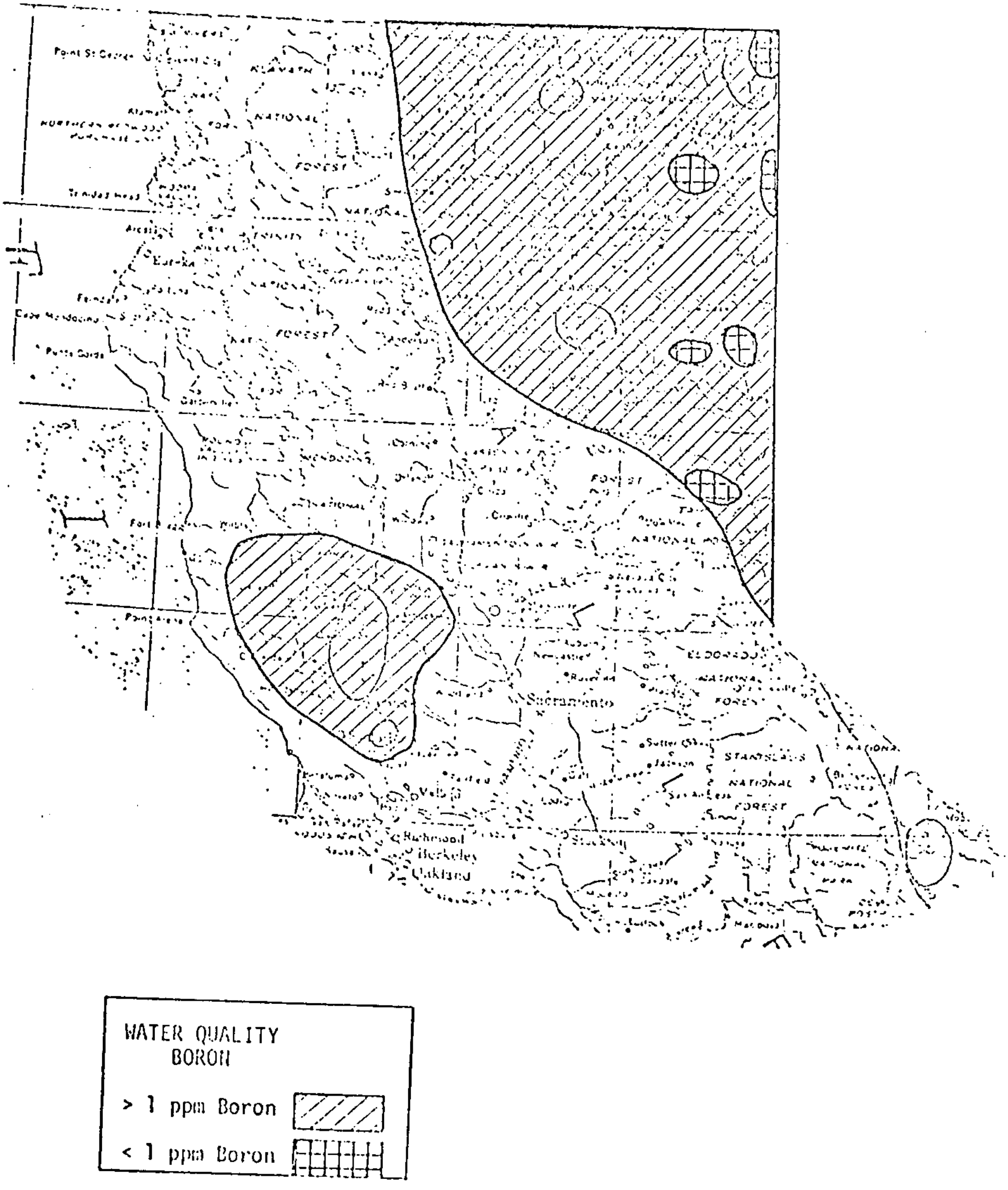
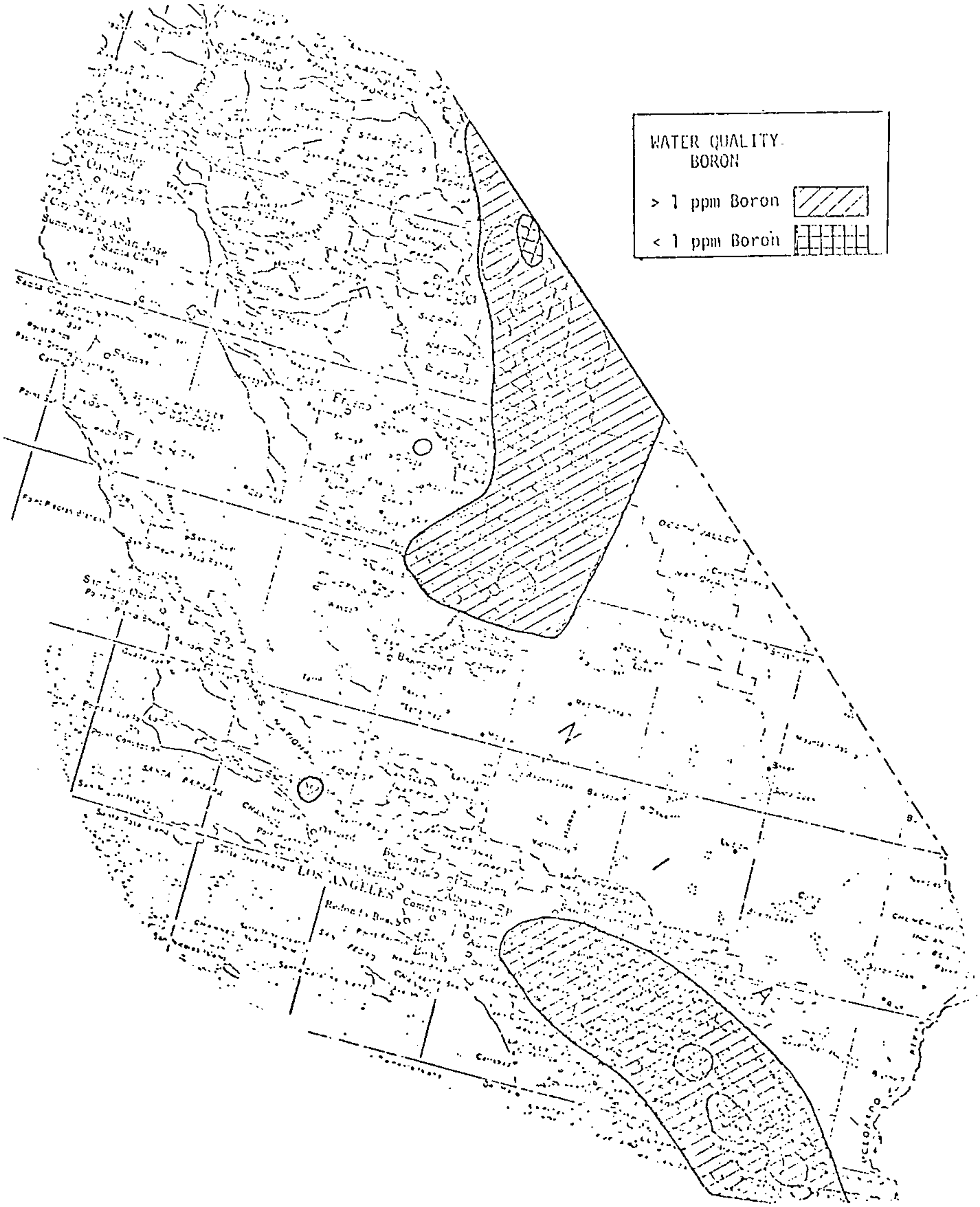
250 - 1000 ppm
< 250 ppm

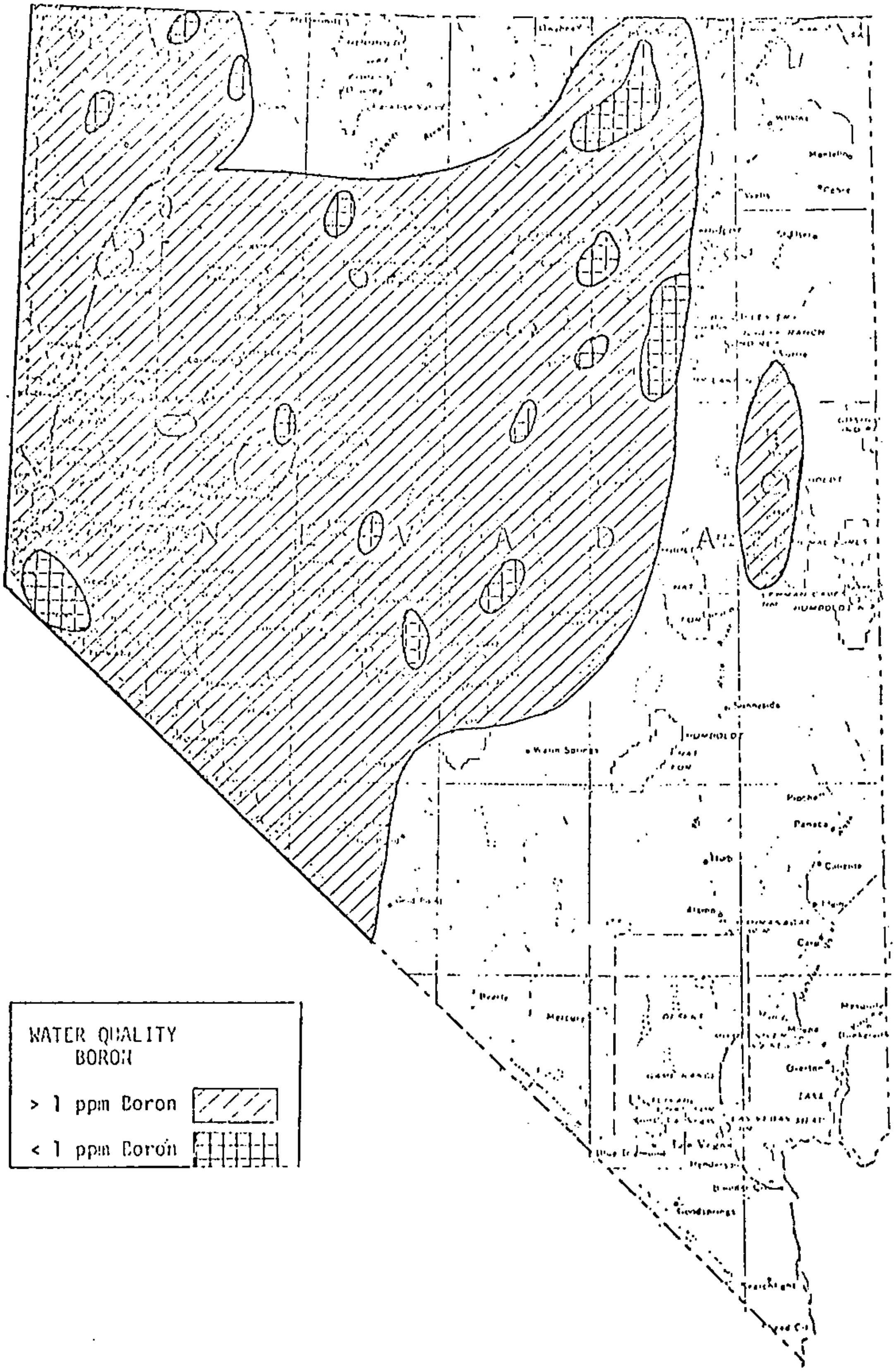

C O L O R A D O
Denver
Colorado Springs
Pueblo
WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm

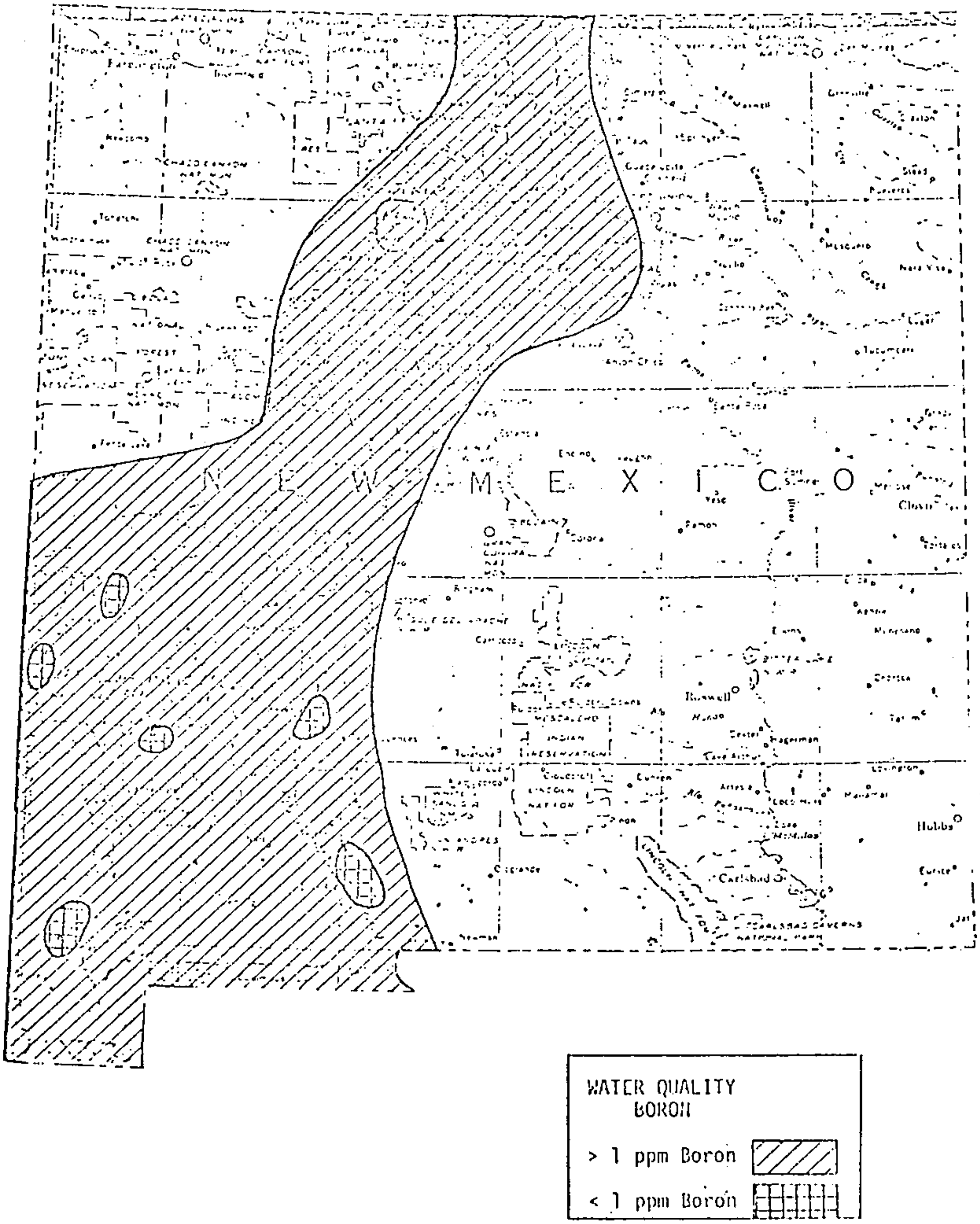

WYOMING
BIGHORN NATIONAL FOREST
WATER QUALITY
TOTAL DISSOLVED SOLIDS
> 1000 ppm
250 - 1000 ppm
< 250 ppm
Cheyenne

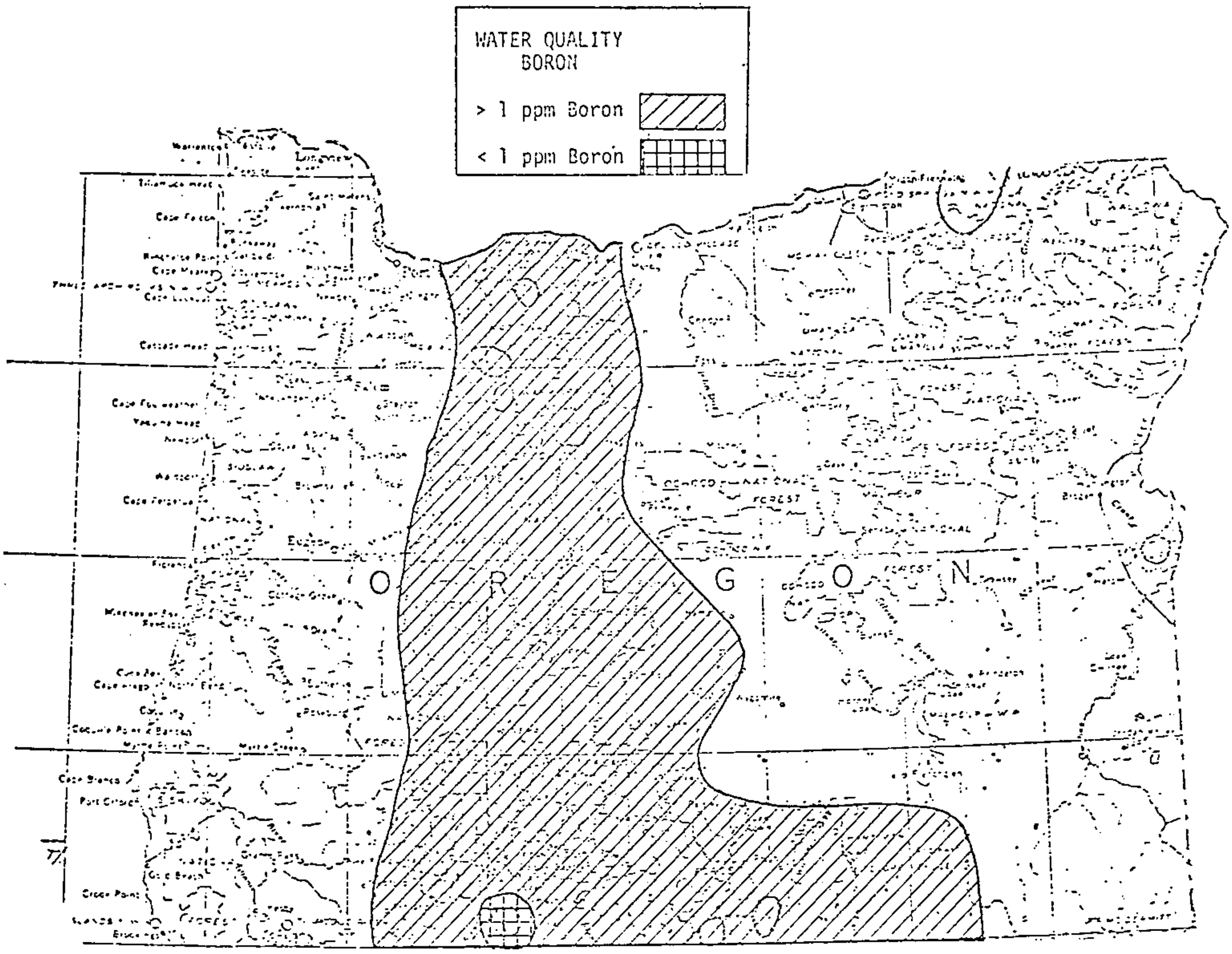

San Francisco
Los Angeles
Salt Lake City
Albuquerque
0
100
200
300
400
500
Miles
WATER QUALITY
BORON
> 1 ppm Boron
< 1 ppm Boron

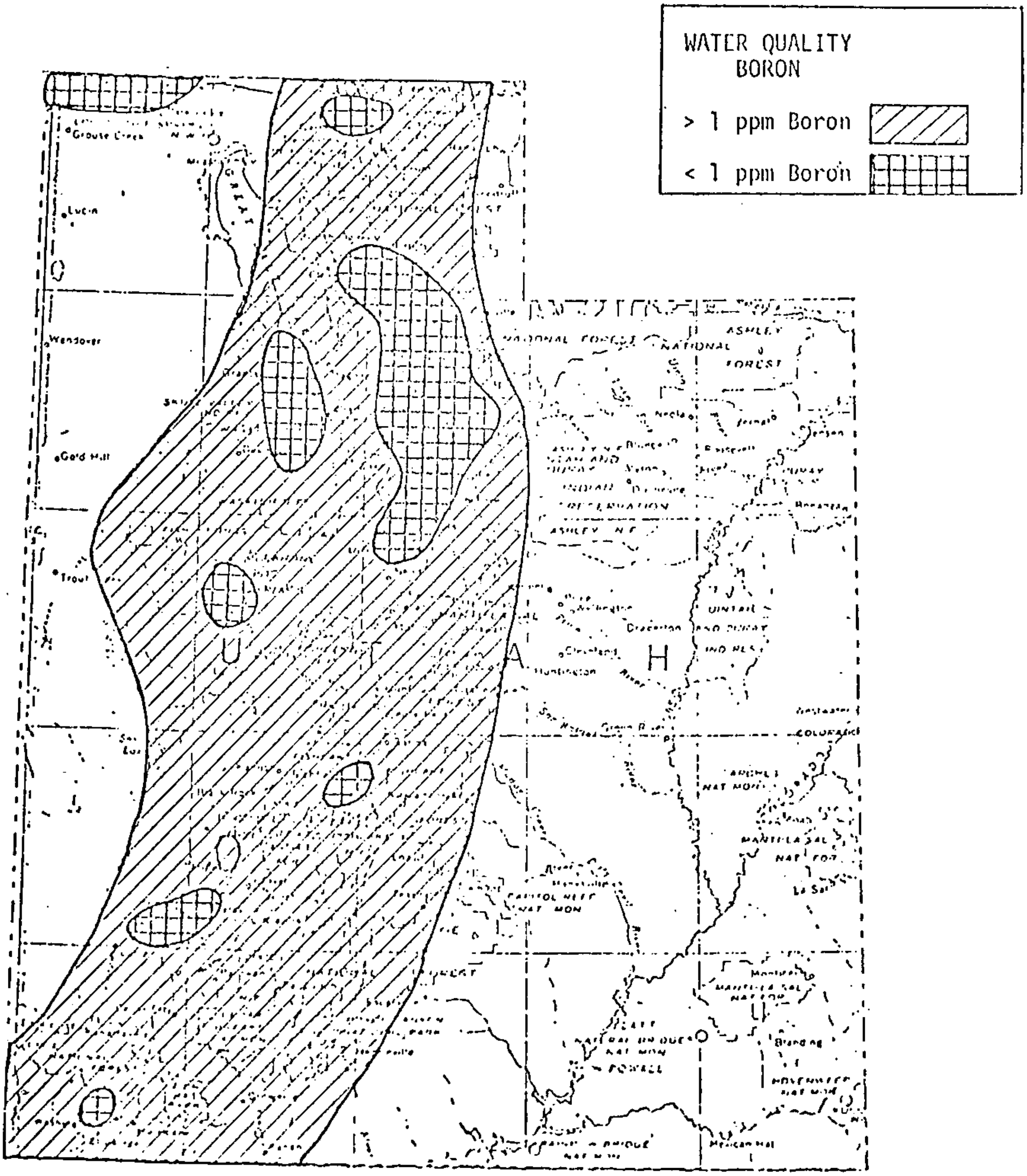

Point St George
Klamath
National
Forest
Trinidad Head
Eureka
Cape Mendocino
Punta Gorda
Mendocino
Fort Bragg
Point Arena
Sacramento
Eldorado
National
Forest
Stanislaus
National
Forest
Stockton
Richmond
Berkeley
Oakland
WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ▦

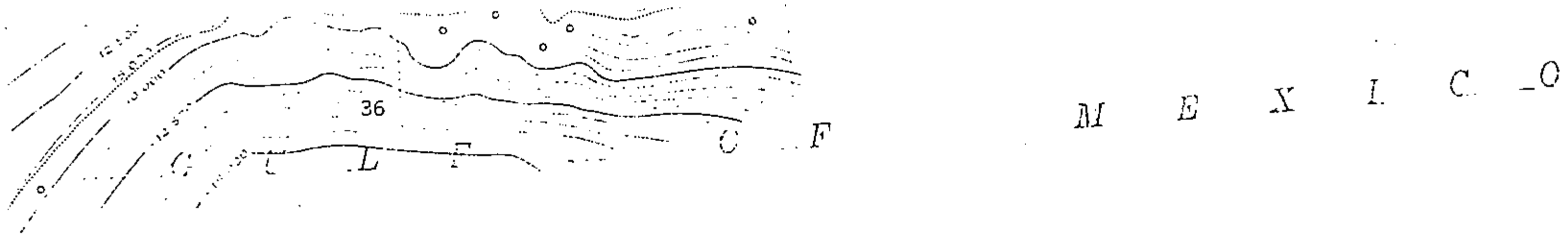

WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ⊞
Sacramento
Berkeley
Oakland
San Jose
Santa Clara
Salinas
Fresno
Bakersfield
LOS ANGELES
SANTA BARBARA
COLORADO


WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ⊞
N E V A D A


N E W M E X I C O
Farmington
Roswell
Carlsbad
Hobbs
Clovis
WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ▦


WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ▦
O R E G O N


WATER QUALITY
BORON
> 1 ppm Boron ▨
< 1 ppm Boron ⊞
Grouse Creek
Lucin
Wendover
Gold Hill
Trout
U
T
A
H
ASHLEY NATIONAL FOREST
Duchesne
Vernal
Roosevelt
UINTAH AND OURAY INDIAN RESERVATION
Price
Huntington
Green River
CAPITOL REEF NAT MON
ARCHES NAT MON
MANTI-LA SAL NAT FOR
La Sal
Monticello
Blanding
NATURAL BRIDGES NAT MON
LAKE POWELL
HOVENWEEP NAT MON
RAINBOW BRIDGE NAT MON
Mexican Hat
NATIONAL FOREST
COLORADO



TECTONIC MAP OF THE UNITED STATES

Exclusive of Alaska and Hawaii

BY THE

UNITED STATES GEOLOGICAL SURVEY

AND

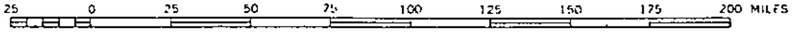
THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Prepared by a Committee composed of: George V. Cohee, Chairman

Paul L. Applin
N. W. Bass
Alfred H. Bell
Marland P. Billings
Ronald K. DeFord
Carrell E. Dobbin
J. R. Donnell
James D. Forrester
James Gilluly
Harold W. Hoots
Philip B. King
Chester R. Longwell
Paul L. Lyons
Grover E. Murray
Aaron C. Waters

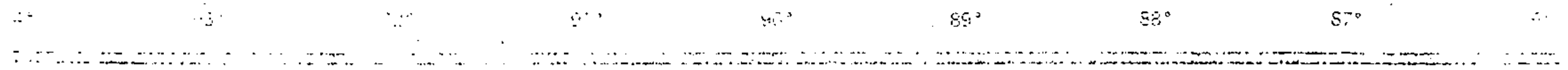
This map is a revision of the Tectonic Map published in 1944 by the American Association of Petroleum Geologists, which was prepared under the direction of the Committee on Tectonics (Chester R. Longwell, Chairman), Division of Geology and Geography, National Research Council. Coordination between the 1944 map and the present edition was provided by King and Longwell

SCALE 1:2,500,000



Approximately 1 inch to 40 miles

1962



EXPLANATION

METAMORPHIC ROCKS

Of sedimentary and igneous origin, forming part of outcrop area of basement rocks

☐

Paleozoic and Mesozoic metamorphic rocks

In western United States. Deformed and metamorphosed during Mesozoic and older orogenies; may be little metamorphosed in some areas; in California includes metasedimentary and metavolcanic rocks of Sierra Nevada and Klamath Mountains. Mesozoic in Arizona

☐

Paleozoic low-grade metamorphic rocks (Rocks of Carolina slate belt)

Slate, graywacke, tuff, and lava, mostly of low-grade metamorphism and moderate deformation. Forms synclinoria in southeast part of Piedmont area

☐

Paleozoic metamorphic rocks

In places known to be of various Paleozoic ages, but elsewhere of poorly determined age; may include some areas of earlier Precambrian basement rocks, and of late Precambrian stratified rocks. Deformed and metamorphosed during Paleozoic orogenies. In New England represent metamorphosed Paleozoic sedimentary and volcanic rocks of the garnet, staurolite and sillimanite zones

☐

Precambrian metamorphic rocks

Undifferentiated as to age, including several subdivisons in some areas; deformed and metamorphosed during one or more orogenies. In places includes minor Precambrian intrusive bodies

INTRUSIVE IGNEOUS ROCKS

☐

Tertiary intrusive bodies

Dikes, plugs, stocks, laccoliths, and small batholiths; may include some granitic bodies of Mesozoic age in Oregon and Washington. In Arizona includes Tertiary and Mesozoic intrusives

☐

Triassic basin deposits

Continental sedimentary rocks with associated basaltic and pyroclastic rocks; in structurally negative areas in eastern United States

☐

Precambrian sedimentary and volcanic rocks

Includes Belt series of northern Rocky Mountains, Keweenawan series of Lake Superior region, and sedimentary and volcanic rocks of southern Appalachians

GEOLOGIC BOUNDARIES

Base of upper Tertiary sedimentary rocks

Base of Miocene (Ogallala and Arikaree formations) in High Plains of west-central United States; base of Oligocene (White River formation) in Nebraska, South Dakota and North Dakota shown dashed

Base of lower Tertiary sedimentary rocks

Base of Eocene series in Atlantic and Gulf Coastal Plains; base of Wasatch formation and equivalents in Rocky Mountains and in North Dakota; commonly underlain by Paleocene rocks

Base of Cretaceous sedimentary rocks

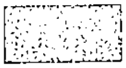
Atlantic and Gulf Coastal Plains; Central Interior region

Base of Pennsylvanian sedimentary rocks

Central Interior region

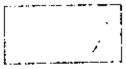
Precambrian boundary in Canada

Along north shore of Lake Superior eastward to Frontenac axis



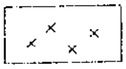
Mesozoic felsic intrusive bodies

Granitic bodies of Mesozoic age in western United States. May include some bodies of early Tertiary age



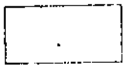
Mesozoic dikes, sills and stocks

Diabase dikes and shallow intrusives of Triassic age in Appalachian area; syenite and peridotite of Cretaceous(?) age in Arkansas



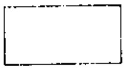
Small dikes and other intrusive bodies

In central and eastern United States; of Paleozoic and younger ages



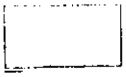
Ultramafic bodies

Peridotite, dunite, serpentine, and related rocks, forming small bodies in Piedmont and Blue Ridge areas. In Appalachian area mostly of Paleozoic age, some may be of Precambrian age; in western United States mostly of Mesozoic age



Paleozoic felsic intrusive bodies

In New England of Late Ordovician, Middle Devonian and Late Pennsylvanian age; some deformed. In eastern Massachusetts may be Precambrian. In the Piedmont of middle Paleozoic and earlier ages; some are little deformed; others have gneissic structure, as suggested by trend lines

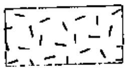


Paleozoic mafic intrusive bodies

In Piedmont area and New England; in eastern Massachusetts may be Precambrian

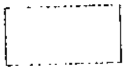
Paleozoic and Mesozoic alkalic rocks

Paleozoic and Mesozoic rocks with alkalic affinities in New England; in Massachusetts and Rhode Island of Mississippian(?) age; in New Hampshire, Maine, and Vermont of Triassic age. In Piedmont area of North Carolina syenite of late Paleozoic (?) age



Precambrian mafic intrusive bodies

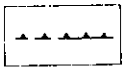
Duluth gabbro lopolith and related bodies of Lake Superior region, and similar smaller bodies elsewhere; anorthosite bodies in Adirondack region and western United States. Diabase in Arizona



Precambrian felsic intrusive bodies

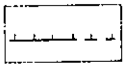
Granitic bodies of various ages; principally in Lake Superior region and western United States

STRUCTURAL FEATURES



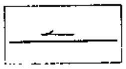
Thrust fault

Saw teeth on upthrown side. Includes low-angle faults, but some may dip at steep angle at surface. Broken line indicates hypothetical faults



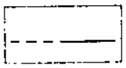
Normal fault

Hachures on downthrown side. Includes some high-angle thrust faults whose dip is indicated by arrows. Broken line indicates hypothetical faults



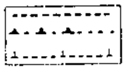
Lateral fault

With dominant strike-slip movement, whose direction is indicated by arrow on one side. Broken line indicates hypothetical faults



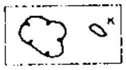
Unclassified faults

Nature of displacement unknown on many



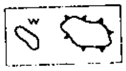
Buried faults

Includes faults of all classes shown above. Direction of displacement shown only in part.



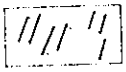
Klippe

Thrust mass outlier



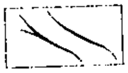
Window

Fenster in thrust mass



En echelon fault system

Direction of displacement not shown on all faults of system

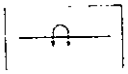


Elongate, closely compressed anticline

Width of line suggests height, steepness, or size of fold

Anticlinal axis

Includes axes of broadly arched uplifts and minor folds. Plunge of some anticlines shown by arrows



Axis of overturned anticline

VOLCANIC ROCKS AND FEATURES

Volcanoes and volcanic cones

Of Quaternary and late Tertiary age; western United States

Tertiary and Quaternary volcanic rocks

In western United States, where only larger areas or areas of tectonic significance are shown. Mainly of various Tertiary ages. Volcanic rocks of Quaternary age distinguished in places by v pattern. Cretaceous volcanic rocks in southern Arizona are included

Tertiary and Quaternary volcanic rocks of Washington and Oregon

Includes Cascade olivine basalt flows and volcanoes of Quaternary and Tertiary age (v pattern); Columbia River basalt of Miocene and Pliocene age (white hachures); altered andesitic and dacitic volcanic rocks of western Cascade (red hachures); basalt flows and pillow complexes of Coast Ranges, chiefly of Eocene age (blue hachures)

SEDIMENTARY ROCKS

Only selected units shown; many units younger than any major orogeny or epirogeny of area; patterns generally omitted in regions of complex structure

Quaternary and upper Tertiary sedimentary rocks

Thick deposits in structurally negative areas, mainly non-marine; includes bolson deposits of Basin and Range province

Tertiary sedimentary rocks

Chiefly marine; in the Coast Ranges of Washington, Oregon and southern California; includes some small areas of Mesozoic rocks

Upper Mesozoic sedimentary and volcanic rocks in California and in Olympic Mountains, Washington

Includes Knoxville formation and younger rocks, exclusive of Franciscan, and Tertiary rocks in some areas

Rocks of Franciscan type

Mainly clastic sedimentary rocks, but including bodies of chert, limestone, schist and basalt; of Jurassic and Cretaceous age, depending on locality. Dothan formation in southwest Oregon included

Monoclinal flexure

Symbol used where feature is not shown by contour lines

Dome

Symbol used where feature is not shown by contour lines

Synclinal axis

Axis of overturned syncline

Ouachita tectonic belt

Northern edge of stippled band indicates edge of tectonic belt; southern limits undetermined

500

Structure contours

Interval of contours is indicated in each area; datum is sea level; where contours are superimposed in the upper part of the Mississippi Embayment and in Georgia and Florida the contours on the lower horizons are indicated by short dashes; for horizons contoured see list and index map. Boundary between areas contoured shown by dotted line

Form lines

Similar to structure contours but not drawn on any definite horizon

Strike and dip of beds

Strike and dip of overturned beds

Trend lines in metamorphic rocks

Strike of bedding or schistosity; in places include contacts between lithologic units

⊕

Intensely disturbed, localized uplift

●

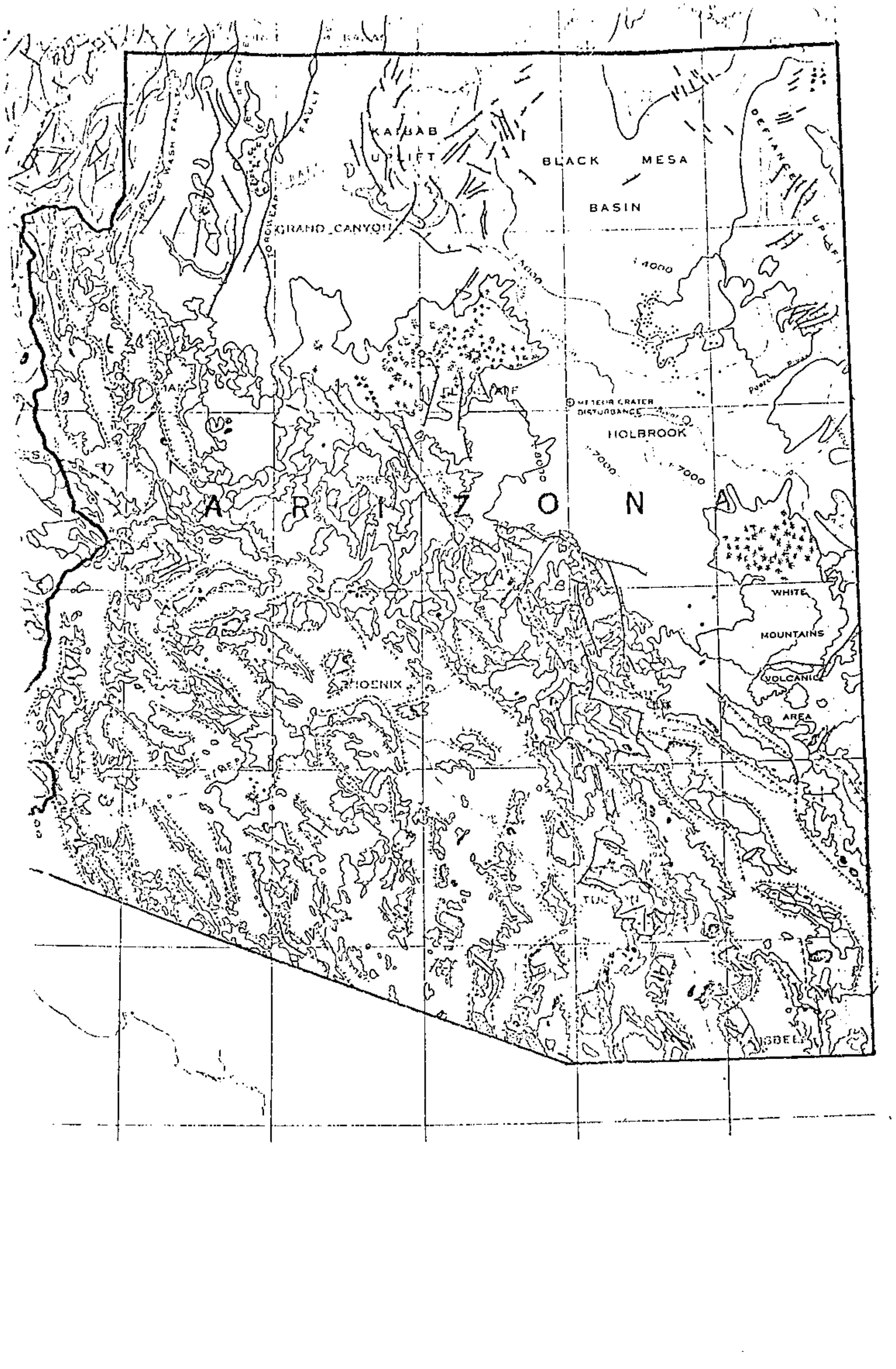
Salt dome

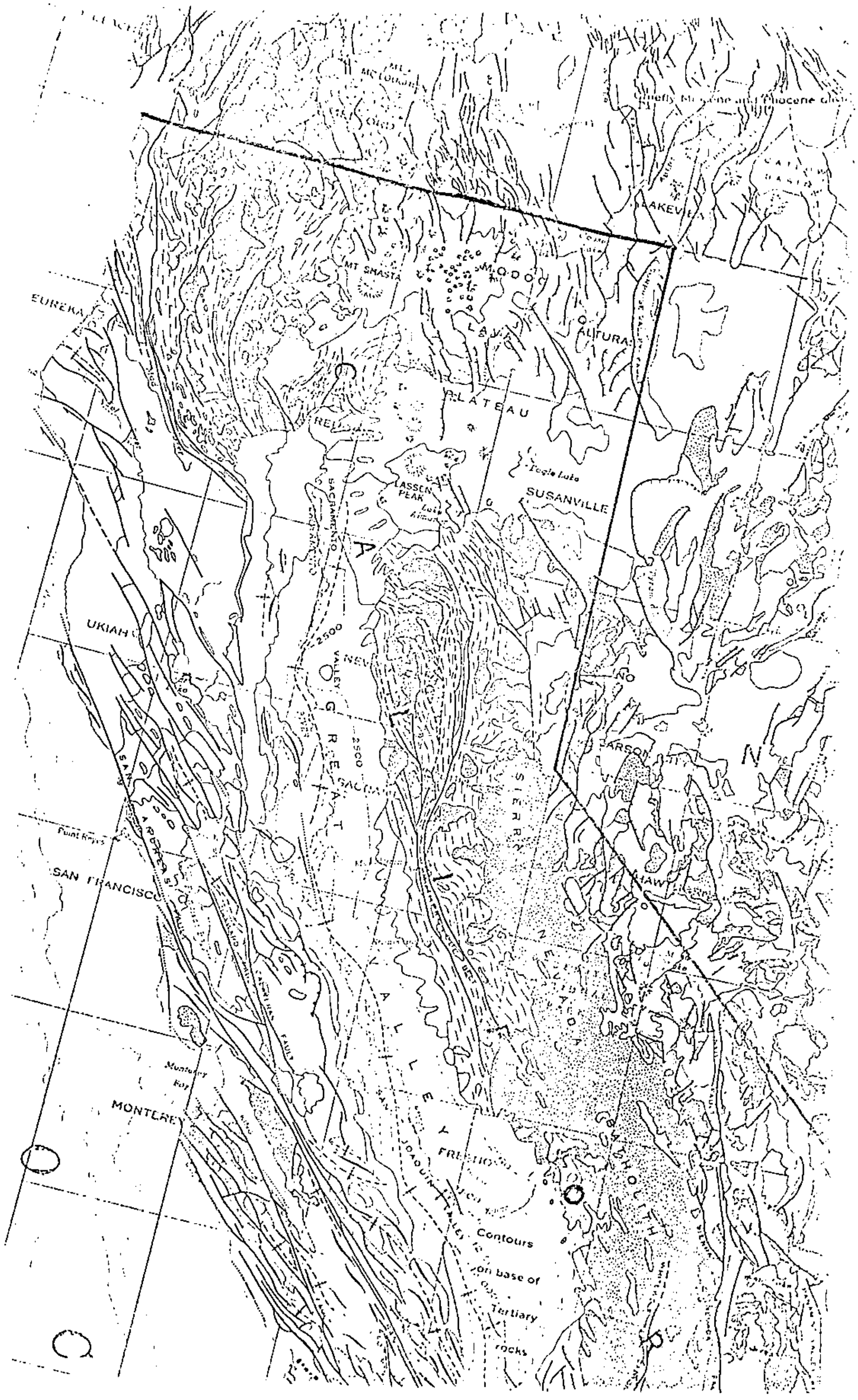
○

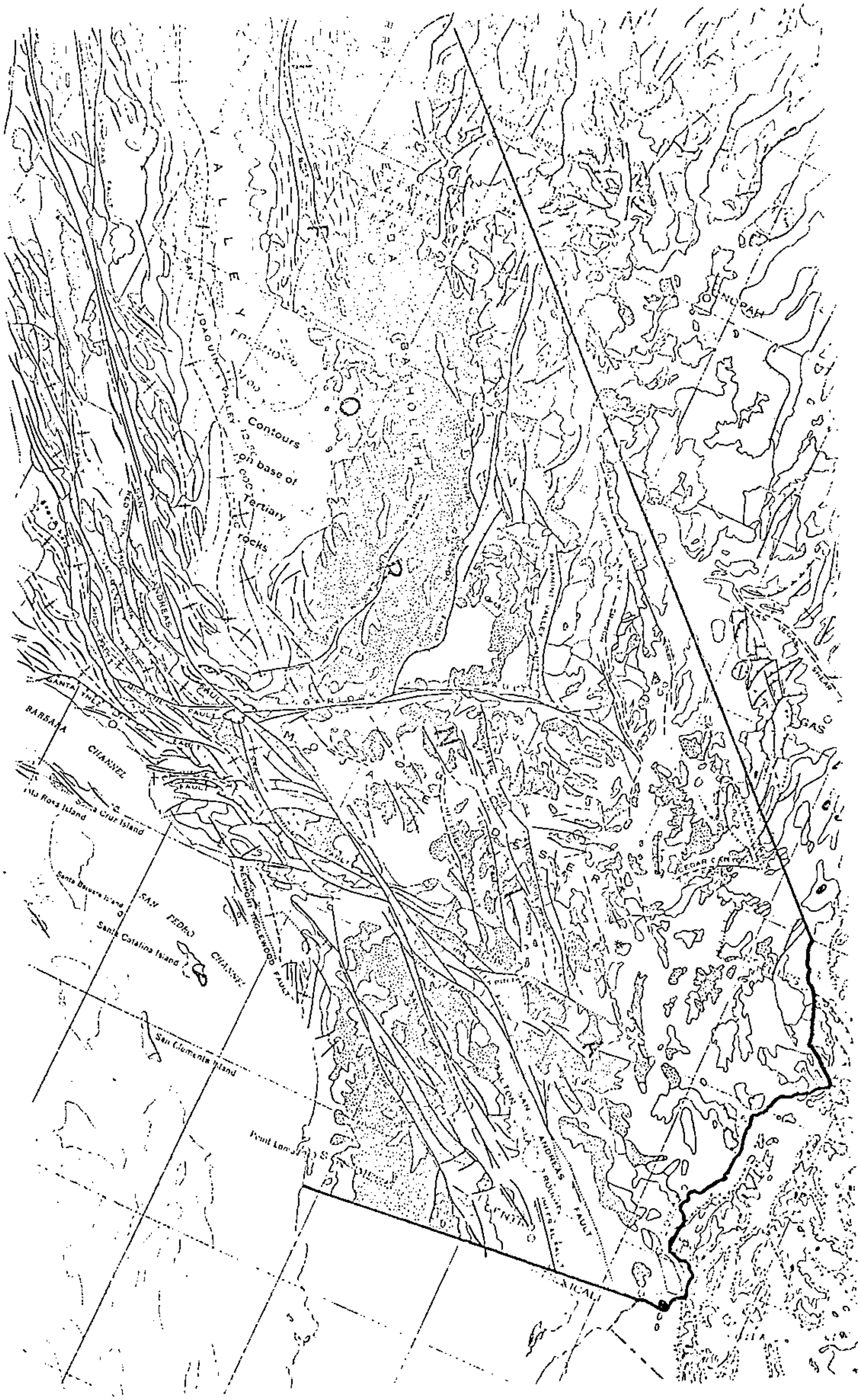
Possible salt dome

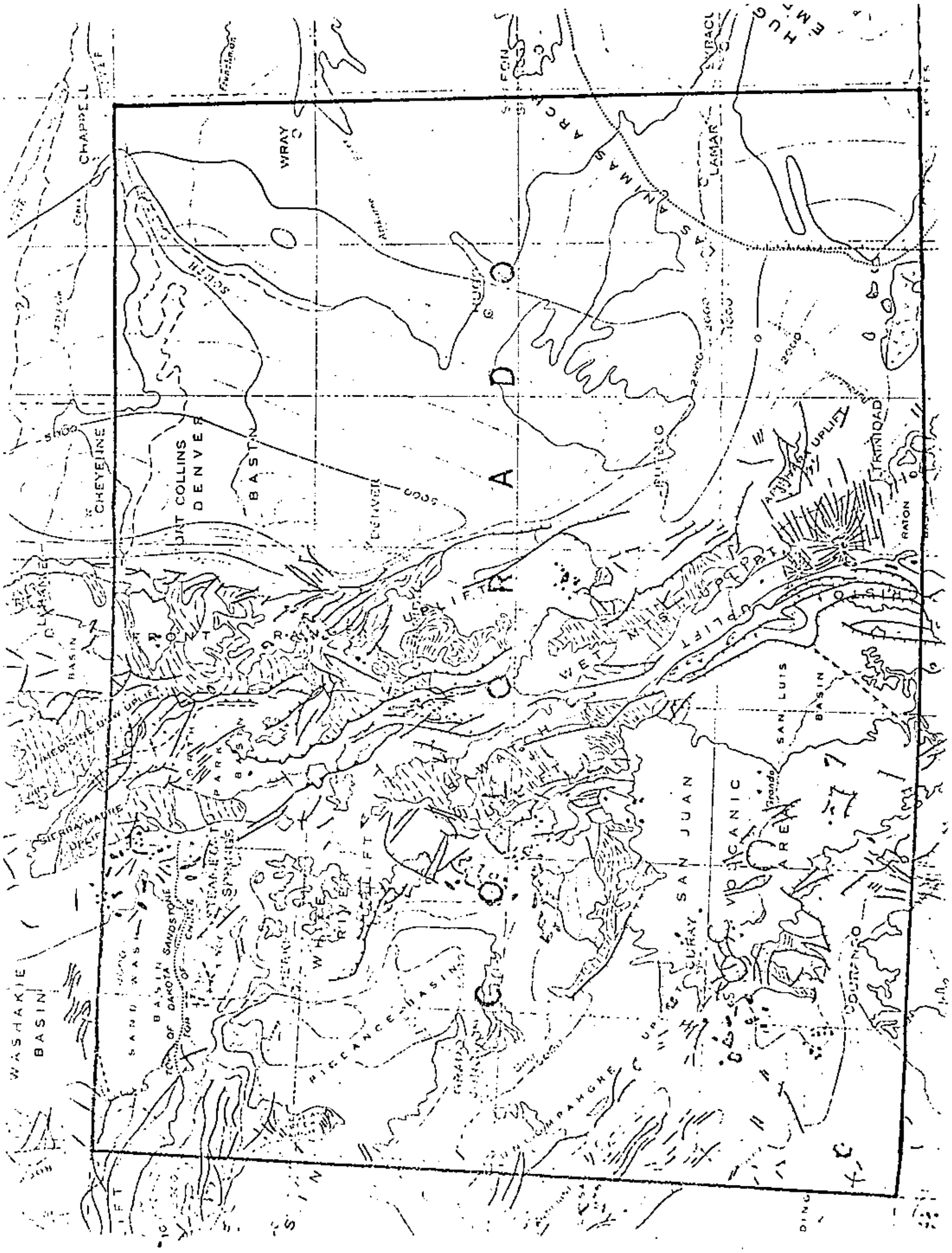
Submarine contours

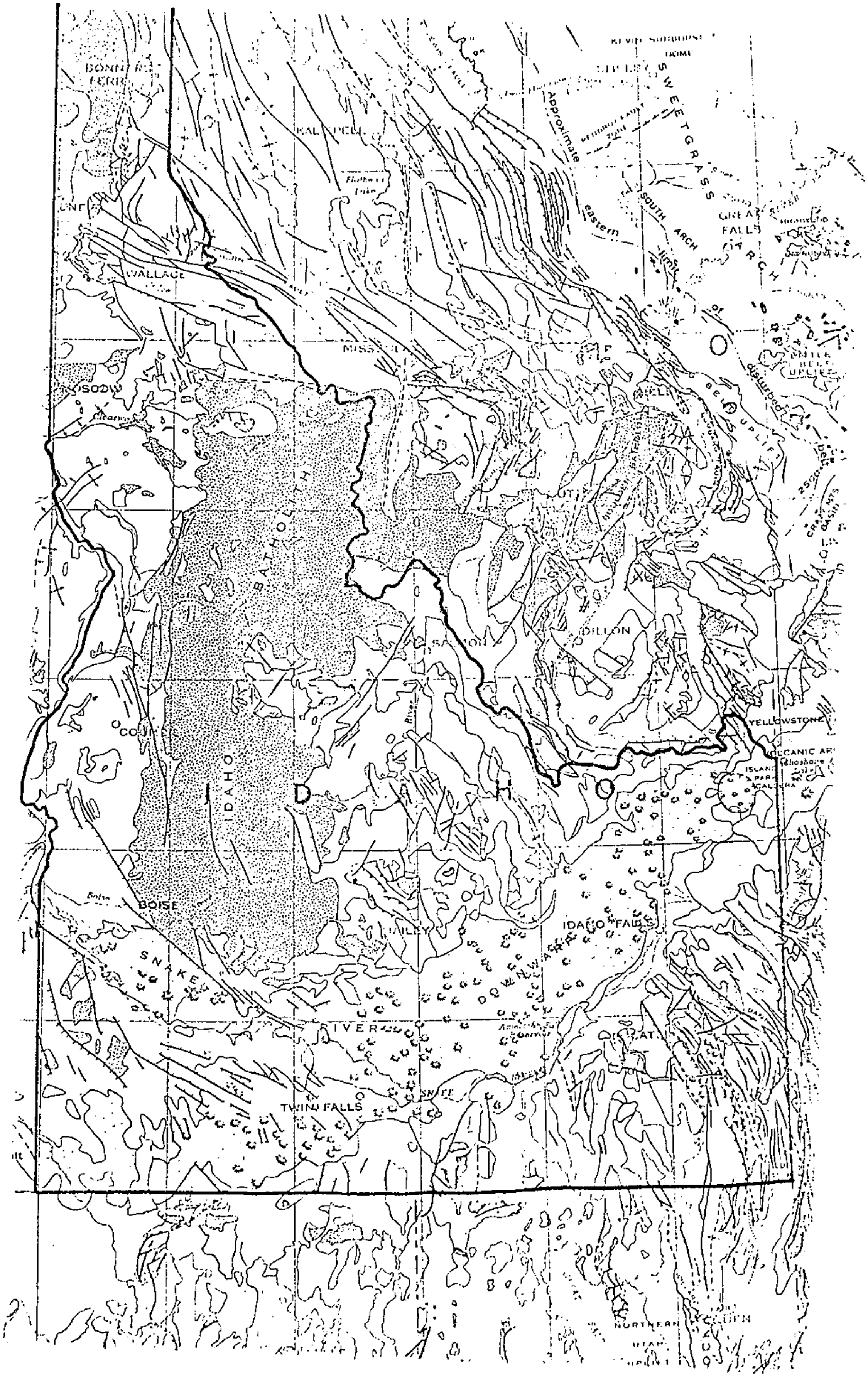
Interval 500 and 1000 feet; datum is sea level

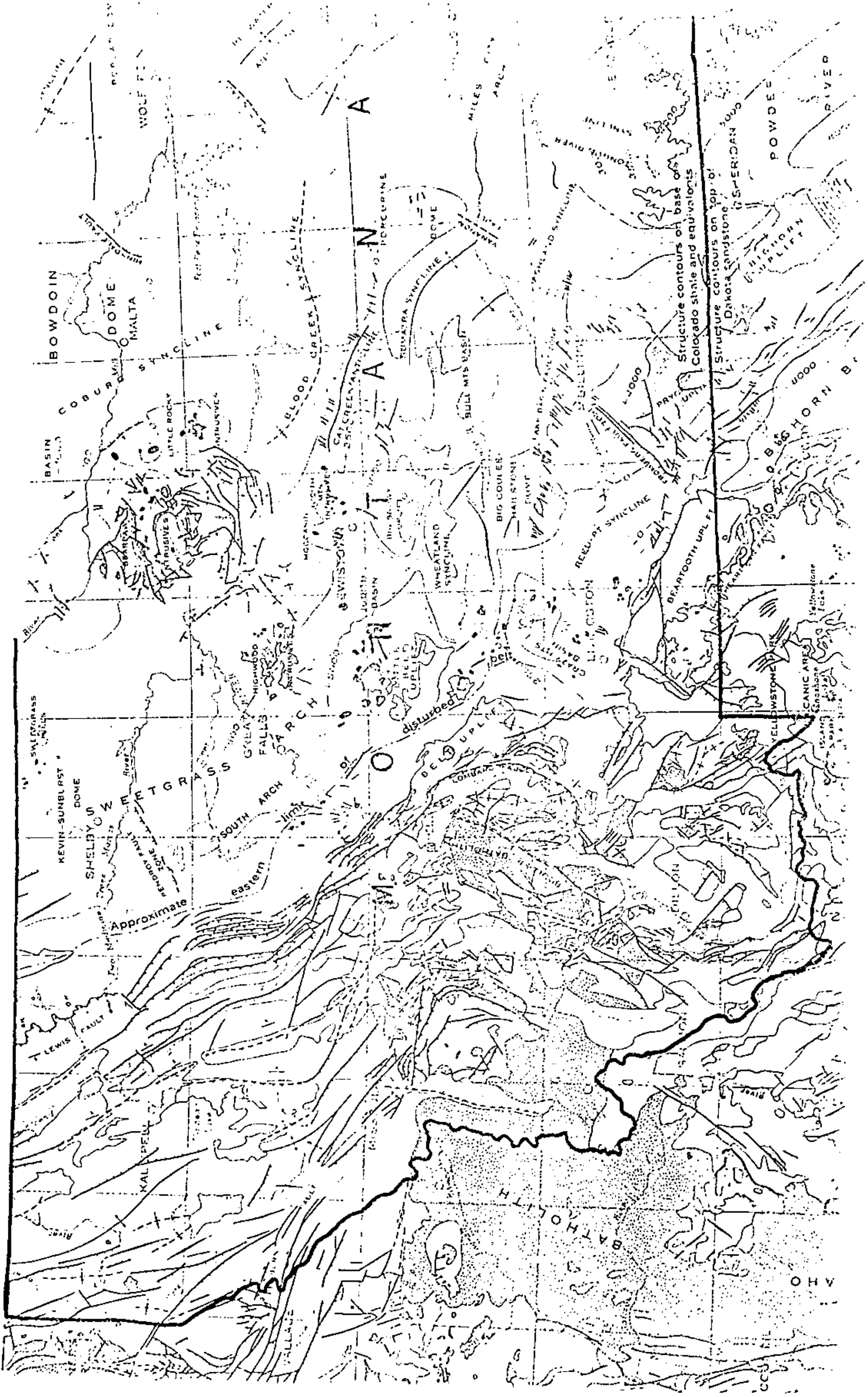

KAIBAB
UPLIFT
BLACK
MESA
BASIN
GRAND CANYON
HURRICANE FAULT
TOROWEAP FAULT
DEFIANCE UPLIFT
METEOR CRATER DISTURBANCE
HOLBROOK
ARIZONA
WHITE
MOUNTAINS
VOLCANIC
AREA
PHOENIX
TUCSON
BISBEE

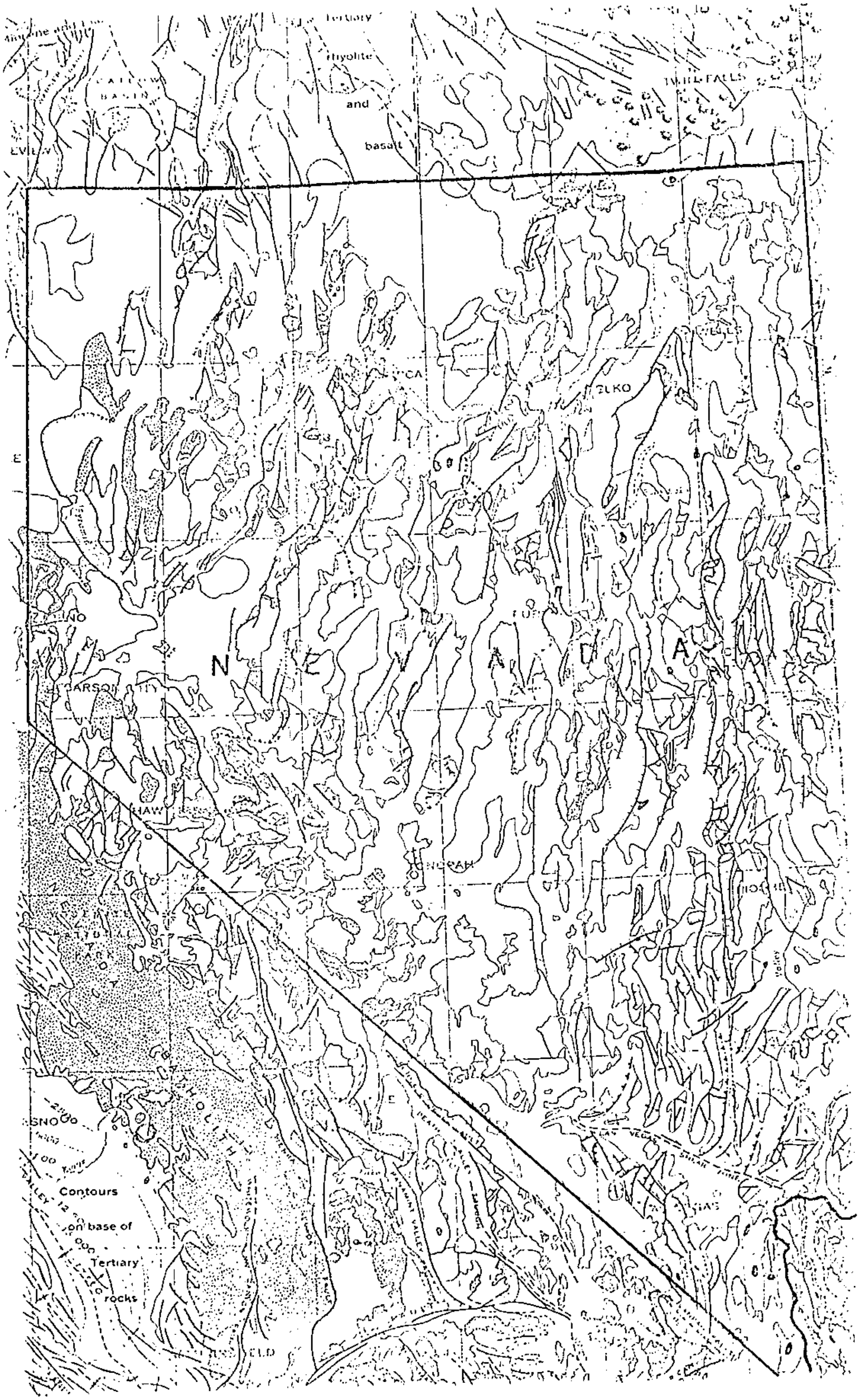

MT McLOUGHLIN
Chiefly Miocene and Pliocene
LAKEVIEW
EUREKA
MT SHASTA
MODOC
ALTURAS
LAVA
PLATEAU
Eagle Lake
LASSEN PEAK
SUSANVILLE
SACRAMENTO
UKIAH
2500
VALLEY
GREAT
CARSON
SIERRA
NEVADA
Point Reyes
SAN FRANCISCO
SAN ANDREAS
Monterey Bay
MONTEREY
VALLEY
FRESNO
SAN JOAQUIN
Contours on base of Tertiary rocks

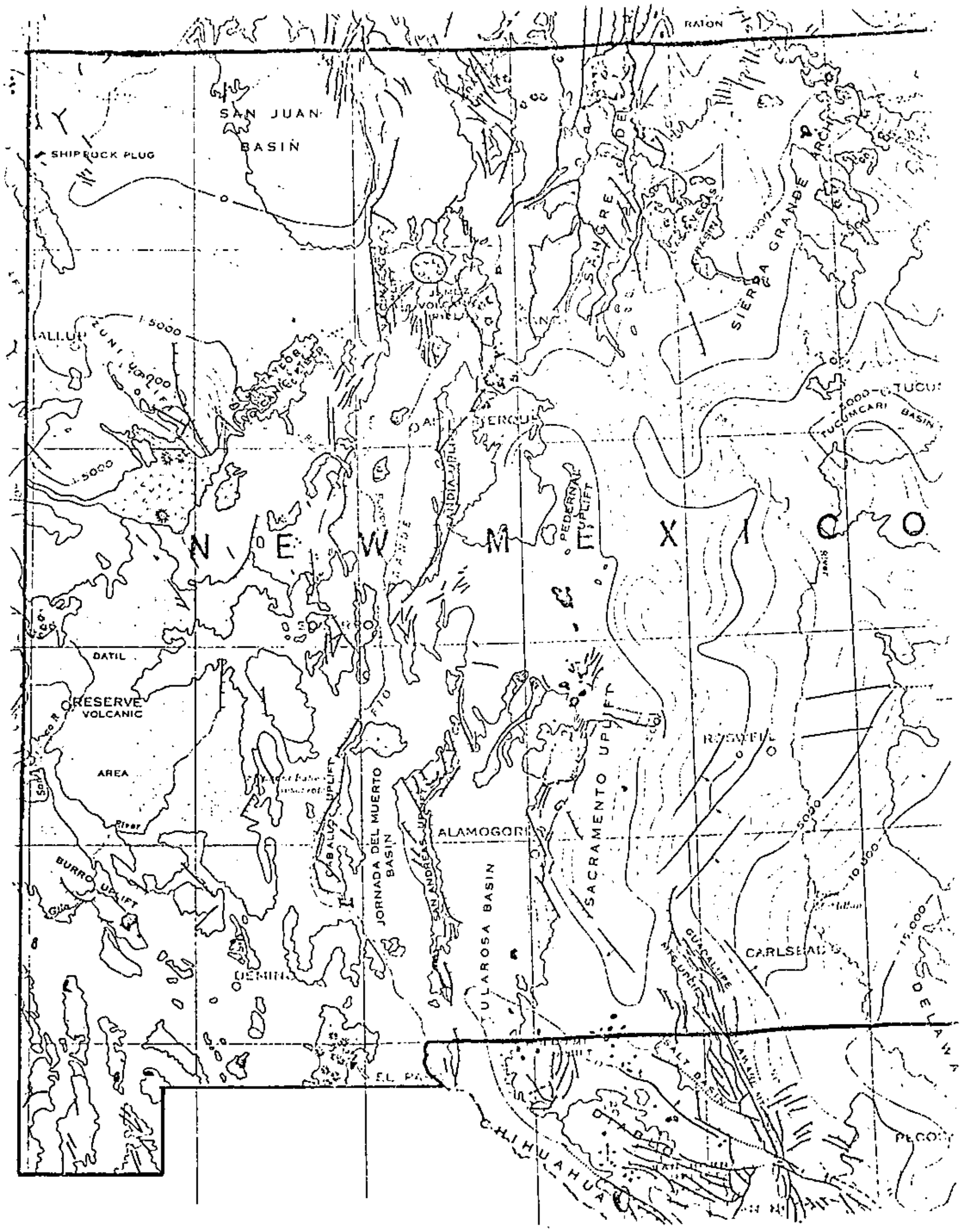

VALLEY
SAN JOAQUIN VALLEY
SIERRA NEVADA
BATHOLITH
FRESNO
Contours on base of Tertiary rocks
SAN ANDREAS
GARLOCK
FAULT
SANTA YNEZ FAULT
SANTA BARBARA CHANNEL
Santa Rosa Island
Santa Cruz Island
Santa Barbara Island
SAN PEDRO CHANNEL
Santa Catalina Island
San Clemente Island
NEWPORT-INGLEWOOD FAULT
Point Loma
SAN ANDREAS FAULT
MOJAVE DESERT
TONOPAH
CEDAR CANYON
LAS VEGAS SHEAR
LAS VEGAS
MEXICALI

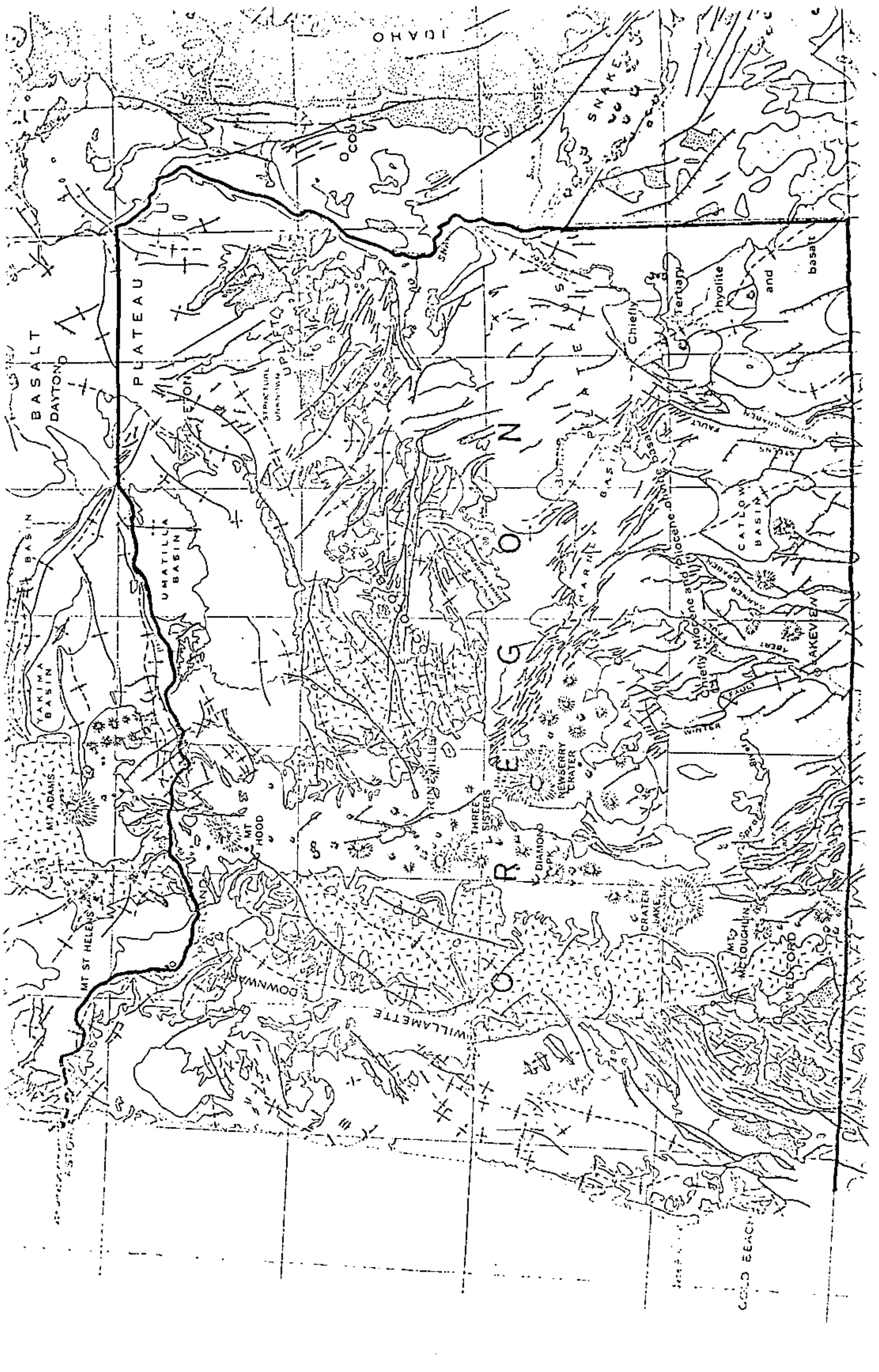

WASHAKIE BASIN
CHEYENNE
FORT COLLINS
DENVER BASIN
WRAY
LAMAR
LAS ANIMAS ARCH
DENVER
PUEBLO
TRINIDAD
RATON
LARAMIE BASIN
MEDICINE BOW UPLIFT
SIERRA MADRE UPLIFT
SAND WASH BASIN
TOP OF DAKOTA SANDSTONE
STEAMBOAT SPRINGS
WHITE RIVER UPLIFT
PICEANCE BASIN
UNCOMPAHGRE UPLIFT
SAN JUAN VOLCANIC AREA
OURAY
DURANGO
SAN LUIS BASIN
UPLIFT
COLORADO

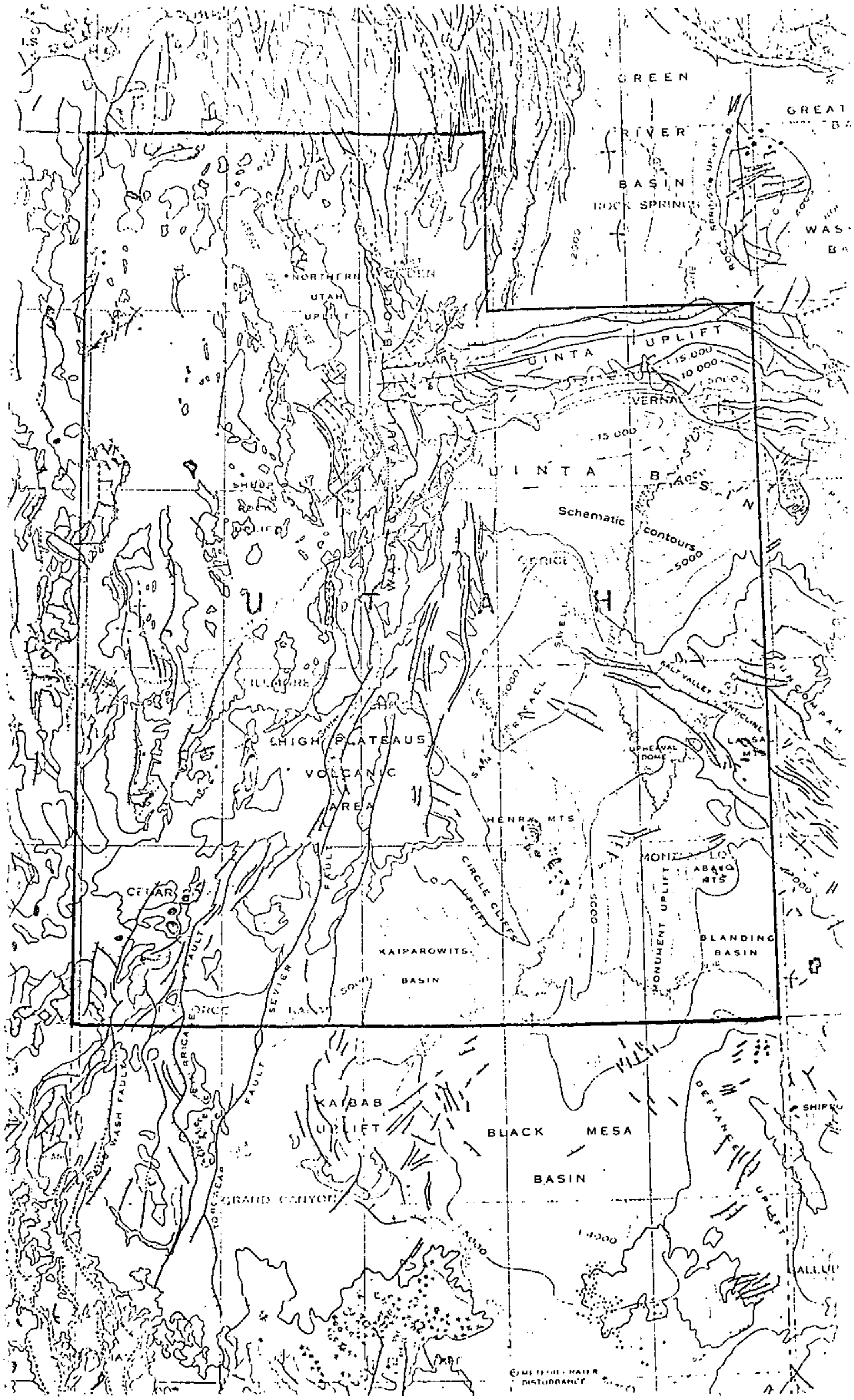

KEVIN-SUNBURST DOME
SWEETGRASS ARCH
Approximate eastern
BONNERS FERRY
KALISPELL
Flathead Lake
GREAT FALLS
SOUTH ARCH
WALLACE
MISSOULA
MOSCOW
Clearwater
BELT UPLIFT
disturbed belt
HELENA
BATHOLITH
BUTTE
BOULDER BATHOLITH
CRAZY MTNS BASIN
IDAHO
DILLON
SALMON
YELLOWSTONE
VOLCANIC ARC
ISLAND PARK CALDERA
I D A H O
IDAHO FALLS
BOISE
Boise
HAILEY
SNAKE RIVER
DOWNWARP
American Falls Reservoir
POCATELLO
TWIN FALLS
NORTHERN UTAH
LOGAN

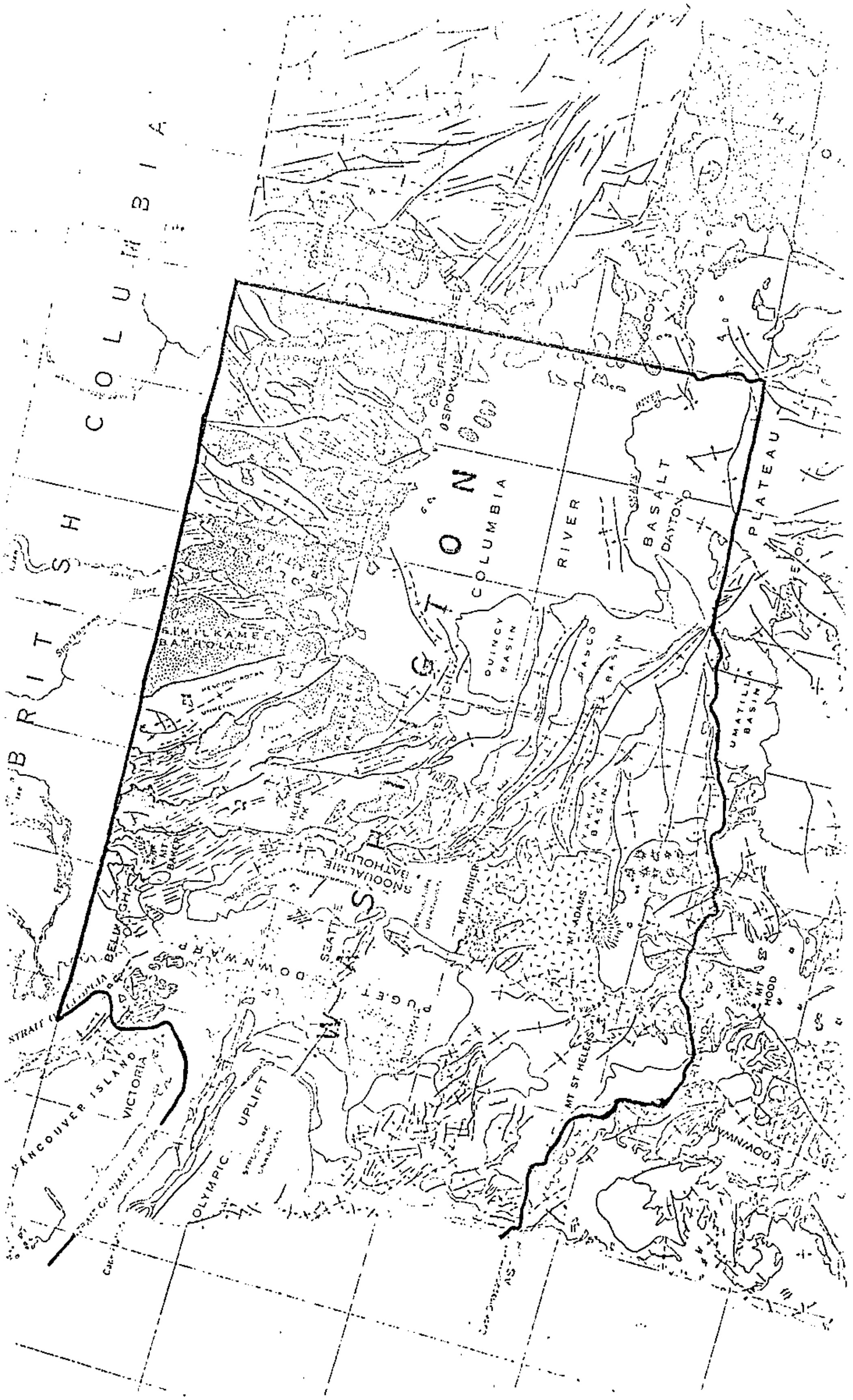

M O N T A N A
BOWDOIN DOME
MALTA
COBURG SYNCLINE
BASIN
LITTLE ROCKY
INTRUSIVES
BEARPAW
BLOOD CREEK SYNCLINE
CAT CREEK ANTICLINE
PORCUPINE DOME
MILES CITY ARCH
WOLF
MOCCASIN
LEWISTOWN
JUDITH BASIN
WHEATLAND SYNCLINE
BULL MTS BASIN
BIG COULEE HAILSTONE DOME
REEDPOINT SYNCLINE
BEARTOOTH UPLIFT
PRYOR UPLIFT
BIGHORN UPLIFT
BIG HORN BASIN
SHERIDAN
POWDER RIVER
Structure contours on base of Colorado shale and equivalents
Structure contours on top of Dakota sandstone
KEVIN-SUNBURST DOME
SHELBY
SWEETGRASS HILLS
SWEETGRASS ARCH
SOUTH ARCH
GREAT FALLS
HIGHWOOD
LITTLE BELT UPLIFT
CRAZY MTS BASIN
BELT UPLIFT
Approximate eastern limit of disturbed belt
LEWIS FAULT
KALISPELL
BATHOLITH
BATHOLITH
YELLOWSTONE PARK
VOLCANIC AREA
OHV

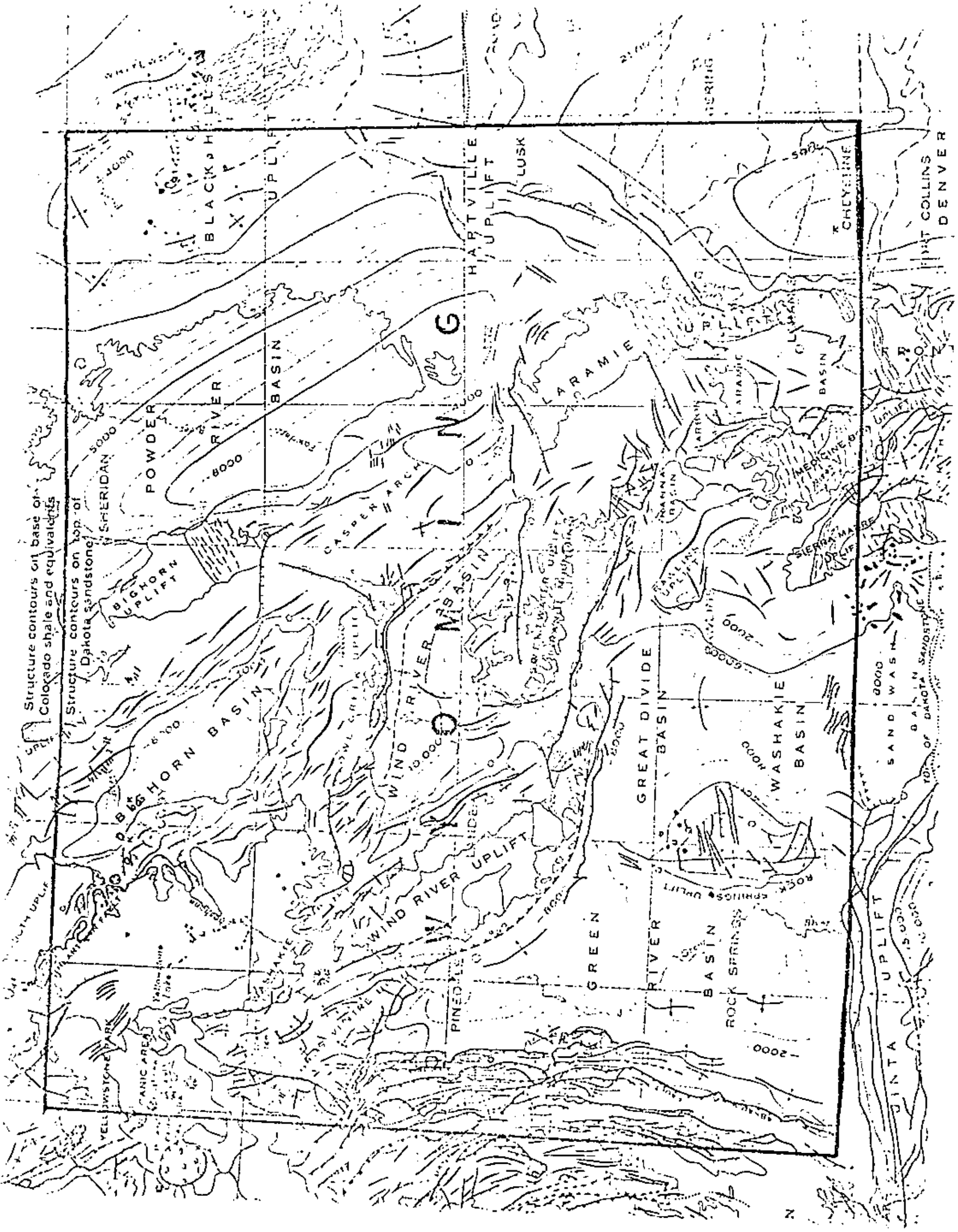

Tertiary
rhyolite
and
basalt
TWIN FALLS
ELKO
WELLS
N E V A D A
CARSON CITY
HAW
TONOPAH
YOSEMITE NATIONAL PARK
Contours
on base of
Tertiary
rocks
ELD


RATON
SAN JUAN BASIN
SHIPROCK PLUG
SANGRE DE
SIERRA GRANDE ARCH
JEMEZ VOLCANIC FIELD
5000
ZUNI UPLIFT
ALBUQUERQUE
TUCUMCARI BASIN
PEDERNAL UPLIFT
N E W M E X I C O
DATIL
RESERVE VOLCANIC AREA
SACRAMENTO UPLIFT
ROSWELL
ALAMOGORDO
CABALLO UPLIFT
JORNADA DEL MUERTO BASIN
SAN ANDRES UPLIFT
TULAROSA BASIN
BURRO UPLIFT
DEMING
CARLSBAD
GUADALUPE UPLIFT
SALT BASIN
DELAWARE
10,000
15,000
PECOS
CHIHUAHUA
EL PASO


IDAHO
SNAKE
BASALT
DAYTON
PLATEAU
UPLIFT
BASIN
UMATILLA BASIN
YAKIMA BASIN
MT ADAMS
MT ST HELENS
MT HOOD
THREE SISTERS
DIAMOND PK
NEWBERRY CRATER
CRATER LAKE
MT McLOUGHLIN
MEDFORD
WILLAMETTE
DOWNWARP
OREGON
PLATEAU
HARNEY BASIN
Chiefly Tertiary rhyolite and basalt
Chiefly Miocene and Pliocene olivine basalt
CATLOW BASIN
LAKEVIEW
ABERT
WINTER
FAULT
GOLD BEACH


GREEN
RIVER
BASIN
ROCK SPRINGS
GREAT
WAS
ROCK SPRINGS UPLIFT
2500
NORTHERN
UTAH
UPLIFT
OGDEN
BLOCK
UINTA UPLIFT
15,000
10,000
5000
VERNAL
15,000
UINTA BASIN
Schematic contours
5000
PRICE
SHOOP
UPLIFT
U T A H
WASATCH FAULT
FILLMORE
HIGH PLATEAUS
VOLCANIC
AREA
SAN RAFAEL SWELL
5000
SALT VALLEY ANTICLINE
LA SAL MTS
UNCOMPAHGRE
UPHEAVAL DOME
HENRY MTS
MONTICELLO
ABAJO MTS
CIRCLE CLIFFS UPLIFT
5000
MONUMENT UPLIFT
BLANDING BASIN
CEDAR
KAIPAROWITS
BASIN
5000
SEVIER FAULT
FAULT
HURRICANE FAULT
GRAND WASH FAULT
TOROWEAP FAULT
KAIBAB
UPLIFT
BLACK MESA
BASIN
DEFIANCE UPLIFT
SHIPROCK
GRAND CANYON
5000
4000
ALLUV
METEOR CRATER DISTURBANCE


BRITISH COLUMBIA
WASHINGTON
COLUMBIA
RIVER
BASALT
PLATEAU
SPOKANE
DAYTON
QUINCY BASIN
PASCO BASIN
YAKIMA BASIN
UMATILLA BASIN
SIMILKAMEEN BATHOLITH
SNOQUALMIE BATHOLITH
GLACIER PK
MT BAKER
MT RAINIER
MT ADAMS
MT ST HELENS
MT HOOD
SEATTLE
PUGET DOWNWARP
OLYMPIC UPLIFT
VANCOUVER ISLAND
VICTORIA
BELLINGHAM
STRAIT
DOWNWARP


Structure contours on base of Colorado shale and equivalents
Structure contours on top of Dakota sandstone
W Y O M I N G
BLACK HILLS UPLIFT
HARTVILLE UPLIFT
LUSK
CHEYENNE
FORT COLLINS
DENVER
POWDER RIVER BASIN
SHERIDAN
BIGHORN UPLIFT
CASPER ARCH
LARAMIE
LARAMIE BASIN
HANNA BASIN
MEDICINE BOW UPLIFT
SIERRA MADRE UPLIFT
RAWLINS UPLIFT
WIND RIVER BASIN
BIGHORN BASIN
WIND RIVER UPLIFT
LANDER
GREAT DIVIDE BASIN
WASHAKIE BASIN
ROCK SPRINGS UPLIFT
GREEN RIVER BASIN
ROCK SPRINGS
PINEDALE
UINTA UPLIFT
SAND WASH BASIN
TOP OF DAKOTA SANDSTONE
YELLOWSTONE PARK
VOLCANIC AREA
5000
8000
10,000
6000
2000
N

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