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# THE CHEMICAL COMPOSITION AND ESTIMATED MINIMUM THERMAL RESERVOIR TEMPERATURES OF THE PRINCIPAL HOT SPRINGS OF NORTHERN AND CENTRAL NEVADA

By

R. H. Mariner, J. B. Rapp, L. M. Willey, and T. S. Presser

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## ABSTRACT

Fifty-five of the principal hot springs in northern and central Nevada have been sampled for chemical analyses. 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 which may indicate thermal-aquifer temperatures significantly lower than the true thermal-aquifer temperature.

Sodium is the principal cation in almost all the spring waters. Four springs in northern Nye County and adjacent Eureka County have approximately equal amounts of sodium and calcium. Bicarbonate is the principal anion in most of the spring waters. However, the sampled hot springs on the western edge of the State have chloride as the principal anion. A diffuse zone of bicarbonate chloride waters with or without sulfate separates the chloride and bicarbonate regions.

## INTRODUCTION

The chemical composition of thermal spring waters is a valuable aid in exploring for geothermal resources. The principal hot springs of Nevada were sampled for detailed chemical analyses during the summers of 1972 and 1973. The major-element part of the analyses has been completed and is being made available at this time. Complete chemical analyses, isotope data, and mineral equilibrium data will be presented in a later report.

Godwin and others (1971) list 13 KGRA's (known geothermal resource areas) in Nevada. In addition, most of the northwestern part of the State is shown as an area of potential geothermal importance. The KGRA's are Beowawe, Leach Hot Springs, Fly Ranch (flowing well near Gerlach), Steamboat Springs, Brady Hot springs, Stillwater-Soda Lake, Darrough Hot Springs, Gerlach (Great Boiling Spring), Moana Springs, Double Hot Springs, Wabuska, Monte Neva, and Elko Hot Springs. Samples were collected from all KGRA's except Monte Neva, Moana Springs, and Brady Hot Springs. Exploratory drilling has altered Brady Hot Springs so that water does not discharge at the surface.

## SAMPLE SITE SELECTION

Sample sites were selected on the basis of temperature data in Waring, 1965, as well as discussions with R. K. Hose and F. H. Olmsted of the U.S. Geological Survey. We are indebted to R. K. Hose for visiting most of the thermal springs in northern Nevada, determining which were suitable for detailed sampling, and collecting 19 supplementary samples.

Table 1 lists the spring or well name, location, and topographic map coverage. The distribution of thermal springs and wells from which water samples were collected is shown in figure 1. Spring names are taken from U.S. Geological Survey topographic maps and Nevada Bureau of Mines Bulletins, or are local names used by residents near the spring.

## METHODS AND PROCEDURES

Water samples were collected at points as close as possible to the orifice of the thermal springs or wells. If the spring had several orifices, then the discharge from the orifice with the highest temperature and highest specific conductance was sampled. Water was collected in a 12-liter stainless-steel pressure vessel and immediately pressure filtered through a 0.45μm (micrometer) effective pore diameter membrane filter using nitrogen as a pressure source. The filtered water samples were collected and stored in plastic bottles which had been washed with acid to remove any trace contaminants prior to use. Ten milliliters of filtered sample were diluted to one hundred milliliters with distilled deionized water to slow the polymerization of silica.

Field determinations were made of barometric pressure, air temperature, water temperature, conductivity, pH, and alkalinity. Flow rates were estimated based on experience with measured

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°) |

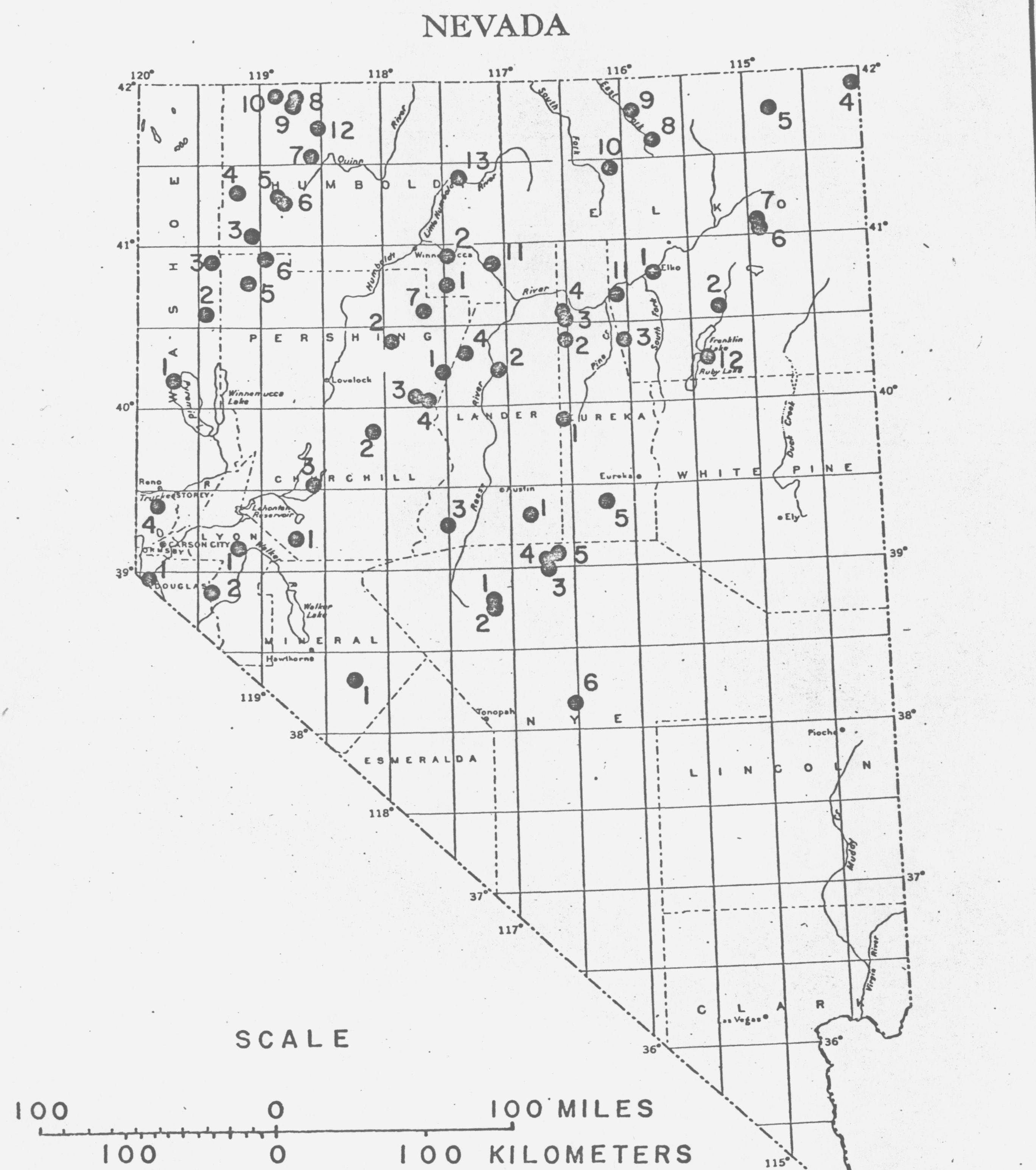


Figure 1. Map of the State of Nevada showing the location of sampled thermal springs and wells. The numbered dots correspond to sampled springs and wells listed by county in tables 1, 2, 3, and 4 of the text.

discharges from springs and wells. Water temperatures were determined with a thermistor probe and a maximum-reading mercury-in-glass thermometer. Conductivity was measured in the spring using a conductivity bridge with a temperature compensator. The pH was measured directly in the spring using the method of Barnes (1964). Alkalinity was determined by the method of Barnes (1964) immediately after the sample was withdrawn from the spring.

The supplementary samples are grab samples collected by Richard K. Hose of the U.S. Geological Survey. These supplementary samples were not filtered, nor was the pH or alkalinity determined in the field. A laboratory determination of pH is reported in table 2, along with the laboratory determination of total carbonate as bicarbonate. The laboratory determined pH's of supplementary samples from Kyle and Spencer hot springs were 1.60 and 1.51 pH units higher than pH's determined in the field. Silica was higher in the supplementary samples, 150 mg/l (milligrams per liter) (filtered) versus 175 mg/l (unfiltered) for water samples collected at Kyle Hot Spring. Only data on filtered samples from Kyle and Spencer hot springs are included in this report.

## WATER COMPOSITION

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

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 |

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.

## CHEMICAL GEOTHERMOMETERS

The chemical composition of thermal spring waters can be used to estimate thermal-aquifer temperatures. Qualitative geochemical indicators include calcium and bicarbonate contents of near-neutral waters (Ellis, 1970); magnesium or magnesium to calcium ratios, low values indicate high thermal-aquifer temperatures (White, 1970); sodium to calcium ratios, high ratios may indicate high temperatures (Mahon, 1970); chloride to total carbonate ratios, highest ratios in related waters indicate the highest subsurface temperatures (Fournier and Truesdell, 1970); and chloride to fluoride ratios, high ratios may indicate high temperature (Mahon, 1970). Quantitative estimates of thermal-aquifer temperatures may be obtained from geothermometers based on silica and sodium to potassium (Na/K) ratios or sodium-potassium-calcium (Na-K-Ca) (Fournier and Rowe, 1966; White, 1965; Fournier and Truesdell, 1973). The basic assumptions in using quantitative geothermometers have been enumerated by Fournier, White, and Truesdell (1974) as follows:

1. Temperature dependent reactions occur at depth.
2. There is an adequate supply of the constituents that are used as a basis for geothermometry.
3. Water-rock equilibrium occurs at the reservoir temperature.
4. There is negligible re-equilibrium at the lower temperatures as the water flows from the reservoir to the surface.
5. There is no dilution or mixing of the hot water coming from depth with shallow water.

The silica geothermometer is based on the solubility of quartz (Fournier and Rowe, 1966). The cation geothermometers are based on exchange reactions between silicates and the aqueous phase (White, 1965; Ellis, 1970; Fournier and Truesdell, 1973). Fournier and Truesdell (1973) have shown that data for most geothermal waters cluster near a straight line when the function log (Na/K) + $\beta$ log ($\sqrt{Ca}$/Na) is plotted versus the reciprocal of absolute temperature. Beta ($\beta$) is 4/3 for solutions that have equilibrated below 100°C and 1/3 for solutions that have equilibrated above 100°C. The Na/K geothermometer should be used only for near-neutral and alkaline waters that do not deposit travertine and have $\sqrt{Ca}$/Na of one or less (Fournier and Truesdell, 1973).

Fournier, White, and Truesdell (1974) present a set of guidelines for determining which subsurface-temperature estimate may best indicate the thermal-aquifer temperature. These authors recommend a procedure based on the temperature and discharge of the spring. A large discharge is taken to be 100 lpm (liters per minute) or more, whereas a small discharge is less than about 20 lpm. Boiling springs having large discharges may be considered to have cooled adiabatically, whereas boiling springs having small discharges may have cooled by conduction. Boiling springs discharging between 20 and 100 lpm are in a range where the selection of the adiabatic or conductive silica estimate of subsurface temperature becomes subjective.

Large discharge springs with temperatures below boiling may be either a mixed water or water which has equilibrated with rock only slightly hotter than the measured spring temperature. The mixed waters are produced by the mixing of high temperature (>100°C) water and cold meteoric water. If the Na-K-Ca geothermometer indicates a temperature of more than 25°C above the measured spring temperature, then the water should be treated as a mixed water by the method of Fournier and Truesdell (1974). Estimated equilibrium temperatures for low discharge springs with temperatures below boiling are difficult to interpret. The discharge may be either a mixed water or water which has cooled by conduction. The equilibrium temperature estimates for the mixed waters, table 3, represent minimum thermal-aquifer temperatures. The underlined numbers in table 3 represent the "best" estimate of thermal-aquifer temperature.

Precipitation of calcium carbonate at the unnamed hot spring (Hot Springs Ranch), the flowing well near Gerlach, Hot Hole, the

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: $CaCO_3$ | Spring deposits: Silica | Comments | Estimated reservoir temperatures (°C): Silica conductive | Silica adiabatic | Na-K | Na-K-1/3Ca | Na-K-4/3Ca |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Churchill County | | | | | |
| 1 Lee Hot Springs | 88 | 130 | X | X | High chloride, near boiling | 173 | 162 | 128 | 162 | 138 |
| 2 Dixie Valley Hot Springs 1/ | 72 | 200 | -- | -- | Low calcium, moderate chloride, moderate silica | 145 | 139 | 86 | 144 | 137 |
| 3 Flowing well in Stillwater | 96 | -- | -- | -- | High chloride, boiling | 169 | 159 | 72 | 140 | 150 |
| | | | | | Douglas County | | | | | |
| 1 Walleys (Genoa) Hot Springs | 61 | 75 | X | -- | Na-K-4/3Ca estimate near the spring temperature | 109 | 109 | 64 | 119 | 85 |
| | | | | | Elko County | | | | | |
| 1 Hot Hole (Elko Hot Springs) | 56 | 75 | X | -- | Calcite ppt., Na-K-Ca meaningless | 114 | 113 | 380 | 234 | 127 |
| 2a Sulphur Hot Springs | 93 | 75 | -- | X | Boiling spring, low chloride and calcium | 183 | 171 | 140 | 181 | 190 |
| 2b Sulphur Hot Springs 2/ | 45 | 500 | -- | X | May be boiling at the orifice (?), large lake with a large cooling surface | 190 | 176 | 139 | 178 | 180 |
| 3 Unnamed hot spring (Hot Creek) | 26 | 6,000 | -- | -- | Na-K-4/3Ca estimate near the spring temperature | 63 | 69 | 282 | 161 | 18 |
| 4 Nile Spring | 43 | Supplementary sample | | | Na-K-4/3Ca estimate near the spring temperature | 81 | 84 | 543 | 220 | 44 |
| 5 Mineral Hot Spring 1/ | 60 | Supplementary sample | | | Low calcium, magnesium, and chloride (?), moderate silica | 127 | 124 | 75 | 129 | 103 |
| 6 Unnamed hot spring near Wells 1/ | 50 | Supplementary sample | | | Low calcium and chloride (?), high silica | 167 | 158 | 184 | 184 | 139 |
| 7 Unnamed hot spring near Wells | 61 | Supplementary sample | | | High calcium and magnesium, low chloride, mixed (?) | 140 | 135 | 188 | 181 | 124 |
| 8 Unnamed hot spring (Wild Horse Reservoir) | 54 | Supplementary sample | | | High calcium and bicarbonate, low chloride | 92 | 94 | 255 | 197 | 111 |
| 9 Unnamed hot spring (SSE Patsville) | 41 | Supplementary sample | | | Na-K-4/3Ca estimate near the spring temperature | 69 | 74 | 153 | 156 | 86 |
| 10 Hot Sulphur Springs | 90 | Supplementary sample | | | High calcium and bicarbonate, low chloride, mixed (?) | 128 | 125 | 190 | 191 | 153 |
| 11 Unnamed hot spring near Carlin | 79 | Supplementary sample | | | Na-K-4/3Ca estimate near the spring temperature | 118 | 117 | 395 | 216 | 81 |
| 12 Unnamed hot spring near Ruby Marsh | 65 | Supplementary sample | | | Na-K-4/3Ca estimate near the spring temperature | 102 | 102 | 314 | 202 | 86 |
| | | | | | Eureka County | | | | | |
| 1 Walti Hot Springs | 72 | 300 | X | -- | Na-K-4/3Ca estimate near the spring temperature | 116 | 115 | 375 | 212 | 79 |
| 2 Hot Springs Point | 54 | 125 | X | -- | High calcium, very low chloride, mixed water (?) | 115 | 115 | 325 | 233 | 159 |
| 3 Beowawe "steam" well | -- | -- | -- | X | Boiling, very low calcium | 252 | 226 | 238 | 242 | 292 |

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

| Spring or well | Spring temperature (°C) | Flow (lpm) | Spring deposits: $CaCO_3$ | Spring deposits: Silica | Comments | Estimated reservoir temperatures (°C): 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: $CaCO_3$ | Spring deposits: Silica | Comments | Estimated reservoir temperatures (°C): 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 | -- /32.1 | T | X | Boiling, high chloride | 167 | 158 | 175 | 205 | 230 |
| 3 Flowing well near Gerlach | 80 | 500 /3.2/ | 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

Steam Geyser at Needle Rocks, and the flowing well in Stillwater, make the Na-K-Ca subsurface-temperature estimates doubtful for these samples. 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.

## 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.

## TYPES OF THERMAL SYSTEMS

White, Muffler, and Truesdell (1971) discussed vapor-dominated and hot-water-dominated systems. They state that thermal springs associated with either vapor-dominated or hot-water-dominated systems have distinctive physical and chemical characteristics. Vapor-dominated systems are found in impermeable rocks while hot-water-dominated systems are found in relatively permeable rocks. The permeability associated with hot-water-dominated systems may be either fracture permeability or distributive permeability. Vapor-dominated systems have thermal springs with low discharges

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) |

(100 lpm or less) of sulfate waters. These sulfate waters are low in chloride and often strongly acidic (pH 2 to 3). The few thermal springs of near-neutral pH discharge sodium bicarbonate waters having chloride contents of less than 20 mg/l. Hot-water-dominated systems have thermal springs with high total discharges (several hundred to several thousand liters per minute) of chloride-rich waters. Individual springs associated with hot-water-dominated systems may have discharge rates as low as a few liters per minute.

The sampled hot springs in Nevada have chemical compositions characteristic of hot-water-dominated systems. Several warm springs having low specific conductances contain less than 20 mg/l chloride and are neutral to slightly acid in pH. These warm springs are in equilibrium with rock at or very near the temperature of the spring.

## SUMMARY

Sixteen of the thermal spring complexes of northern and central Nevada have chemical compositions that indicate thermal-aquifer temperatures of at least 140°C. Sodium is the principal cation in these waters, while the anions may be bicarbonate, chloride, or a mixture of chloride, bicarbonate, and sulfate.

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. Hot springs

having estimated thermal aquifer temperatures of 140°C or more along this trend include Wabuska Hot Springs in Lyon County, Lee Hot Spring, Stillwater flowing well, and Dixie Valley Hot Spring in Churchill County, Kyle, Leach, and an unnamed hot spring (Jersey Valley) in eastern Pershing County, and an unnamed hot spring (Hot Spring Ranch) in southeastern Humboldt County. Eight other areas scattered over the State where estimated thermal-aquifer temperatures exceed 140°C include Sulphur Hot Springs in Ruby Valley, and two unnamed hot springs near Wells in Elko County, Beowawe in Eureka County, Pinto Hot Springs and Baltazor Hot Springs in Humboldt County, Great Boiling Spring and Steamboat Springs in Washoe County, and an unnamed hot spring in southwestern Lander County. Additional hydrologic data may indicate that the springs issuing mixed waters, Mineral Hot Spring in Elko County, Dyke Hot Spring in Humboldt County, and Double Hot Spring in Humboldt County, have significant geothermal potential.

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