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CHEMICAL AND ISOTOPIC DATA FOR WATER FROM THERMAL SPRINGS AND WELLS OF OREGON

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DISCLAIMER

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CHEMICAL AND ISOTOPIC DATA FOR WATER FROM THERMAL SPRINGS AND WELLS OF OREGON

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ABSTRACT

The thermal springs of Oregon range in composition from dilute $NaHCO_3$ waters to moderately saline CO_2-charged $NaCl$-$NaHCO_3$ waters. Most of the thermal springs are located in southeastern or south-central Oregon, with a few in northeastern Oregon and near the contact of the Western Cascades with the High Cascades. Thermal springs in the central and northern parts of the Cascades generally issue moderately saline NaCl waters. Farther south in the Cascades, the thermal waters are high in CO_2 as well as chloride. Most thermal springs in northeastern Oregon issue dilute $NaHCO_3$ waters of high pH (>8.5). These waters are similar to the thermal waters which issue from the Idaho batholith, farther east. Most of the remaining thermal waters are Na mixed-anion waters. Based on the chemical geothermometers, Mickey Springs, Hot Borax Lake, Alvord Hot Springs, Neal Hot Springs, Vale Hot Springs, Crump Well, Hunters (Lakeview) Hot Springs, and perhaps some of the springs in the Cascades are associated with the highest temperature systms (>150°C).

INTRODUCTION

Data presented in this paper are stored in the U.S. Geological Survey Geotherm file. Geotherm is a computerized file created and maintained as part of the Geological Survey's Geothermal Research program (Teshin and others, 1979). Geotherm contains information on the physical characteristics, geology, geochemistry, and hydrology of national and some international geothermal resources. The data include published information, data from other computer files, personal communications, and compilations of various government and private organizations. Retrievals are available to the public in a variety of formats: tape, punched cards, listings, or tables. Requests should be sent to: Geotherm Project, Mail Stop 84, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025.

Geotherm is currently composed of three subfiles: geothermal fields/areas, chemistry and physical properties of thermal wells and springs (sample file), and geothermal drill holes. In addition to these subfiles, there is a file containing the references listed in each record. The data retrieved from the sample file were formatted and special programs were written to calculate temperatures using geothermometers and to create the tables. The records in Geotherm contain more data than are listed in the tables. An example of a complete record is illustrated in figure 1.

The physiographic provinces of Fenneman (1946), shown on figure 2, have differing geologic settings which, in large part, determine the chemical character of the thermal fluids. The Basin and Range province is characterized by a thick sequence of nonmarine volcanic and sedimentary rocks of Cenozoic age, broken by faults which bound the major topographic features (Walker and Peterson, 1969). The volcanics range from basalt to rhyolite and the sedimentary rocks contain considerable volcanic debris. The Owyhee Uplands of southeastern Oregon make up a relatively unbroken plateau consisting of basaltic, andesitic, and rhyolitic sheets and their associated pyroclastics of middle to late Cenozoic age (Corcoran and Walker, 1969). The High Lava Plains of southcentral Oregon also consist of basalt, andesite, and rhyolite flows and their associated sedimentary rocks (Walker, 1969). The Blue Mountains are generally made up of intrusive rock, Quaternary basalts, and older sediments and volcanics, some of which are highly metamorphosed. Intrusive rocks of two ages are present, an older Permian to Triassic suite

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GEOTHERM SAMPLE FILE                                                                      GEOTHERM FILE ID: 0000711
  NAME OF SAMPLE SOURCE... HOT LAKE
  WARING NUMBER........... 11
LOCATION                                 TOWNSHIP-RANGE                     COORDINATES
  COUNTRY............  UNITED STATES     04S 039E  05 NW OF SE                LAT/LONG...  45-14.63 N 117-57.51 W
  STATE..............  OREGON
  COUNTY.............  UNION
  MAP REFERENCE......  CRAIG MTN. 1:24000, GRANGEVILLE 1:250000
SAMPLE DESCRIPTION AND CONDITIONS
  DATE/COLLECTOR.......  1972/00/00 BARNES GROUP
  TEMPERATURE (C)......    80.0
   DISCHARGE...........    1500.  L/MIN
  WATER TREATMENT........... PRESSURE-FILTERED THROUGH A .45 MICROMETRE MEMBRANE, PORTION ACIDIFIED, DILUTED.
  DEPOSITS OR ALTERATION.... TRAVERTINE
  PERTINENT LITHOLOGY....... BASALT AND MYLONITE
WATER ANALYSIS
  DATE/ANALYST.............  1972/00/00 BARNES GROUP
  PH.......................    9.21
  SPECIFIC CONDUCTANCE.....    688.
  ANALYSIS IN MG/L                                                              ISOTOPES (0/00)
    AG.... L 0.02     CO3.....     12.       LI...     0.03    SB...  L 0.2      DEL D OF WATER.......       -127.7
    AL....            CR......               MG...  L 0.1      SC...            DEL O(18) OF WATER...       -16.56
    AS....   0.01     CS...... L  0.1        MN...  L 0.02     SE...            DEL O(18) OF SO4.....       4.63
    AU.... L 0.1      CU......     0.01      MO...             SIO2.    48.
    B.....   2.9      F.......     1.7       NA...     130.
    BA.... L 0.1      FE+3....               NA+K.             SO4..    56.
    BE.... L 0.1      FE(TOT). L 0.02        NB...             SR...  L 0.05
    BR....   0.4
    CA....   4.9      HCO3....     75.
    CA+MG.            HG......     0.0032    PB...  L 0.06
    CD.... L 0.01     H2S.....               PO4..     0.09
    CL....   140.     I.......     0.08      RB...  L 0.02
    CO.... L 0.05     K.......     2.7
GAS ANALYSIS
  ANALYSIS IN VOLUME %                                                          ISOTOPES (00/0)
    CH4..    9.
    C2H6.                                    N2...     90.
    CO2..  L 1.
OTHER ANALYTICAL DATA... O2+AR=2
REFERENCE AND IDENTIFICATION
  COMPILED BY...........  SANFORD, LINDA
  COMPILER AFFILIATION...  U.S. GEOLOGICAL SURVEY
  COMPILER CROSS INDEX...  02
  REFERENCE.............  MARINER AND OTHERS, 1974; MARINER AND OTHERS, 1975; NEHRING AND OTHERS, 1979
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Figure 1. Example of a complete Geotherm record

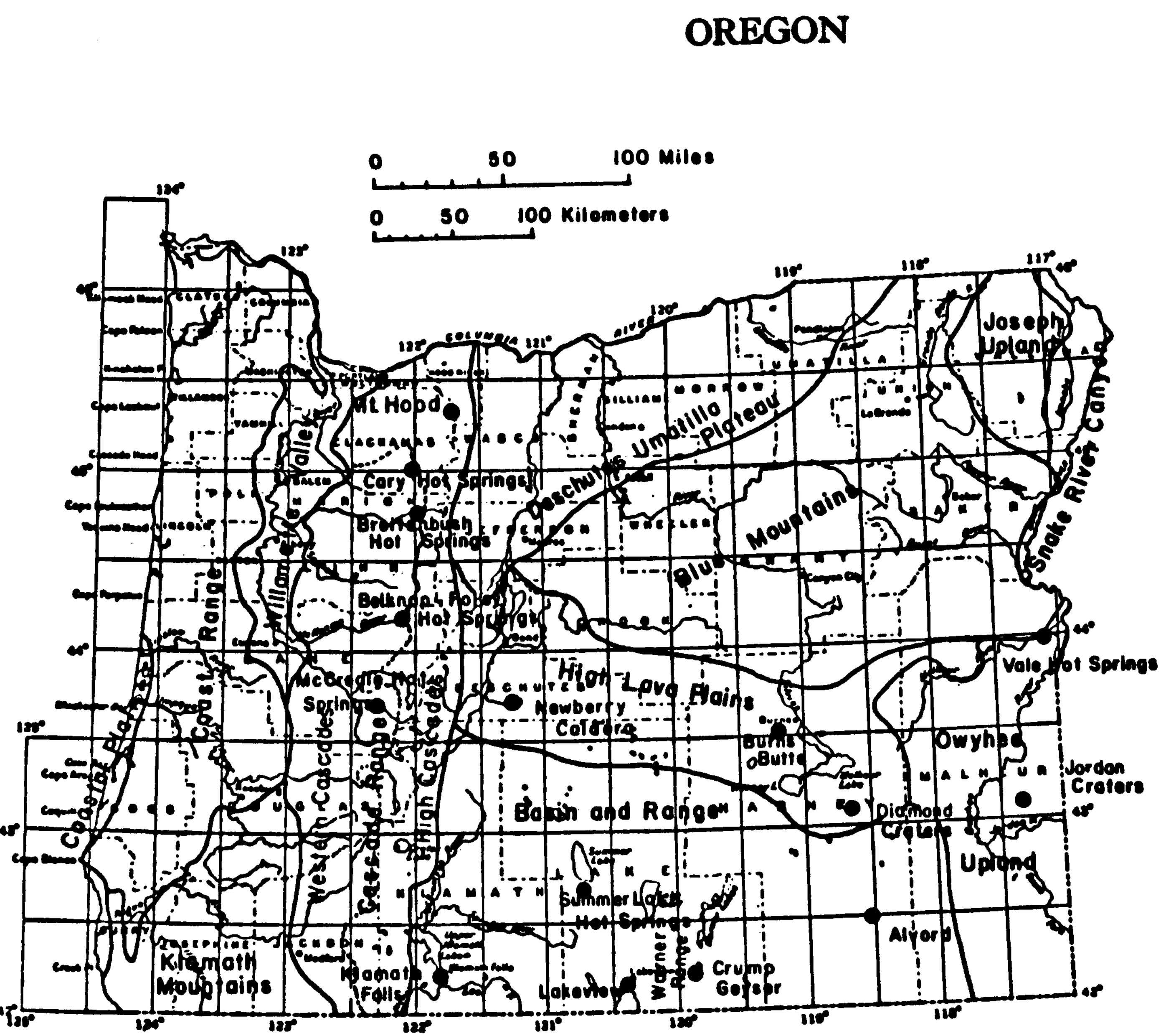

Figure 2. Physiographic Divisions, Known Geothermal Resource Areas, and other features of possible geothermal importance.

which ranges from peridotite to granite, and a Lower Cretaceous suite which ranges from gabbro to granodiorite (Thayer and Wagner, 1969). Several of the younger intrusives are outliers of the Idaho batholith. The Cascade province consists of two subdivisions, the High Cascades and the Western Cascades. The High Cascade Subprovince is a relatively narrow plateau of basalt and andesite flows of Pleistocene and Pliocene Age. The Western Cascade Subprovince is made up of slightly deformed and altered volcanic and pyroclastic rocks that range from late Eocene to late Miocene in age. A few small diorite intrusions also occur in the altered zones of the Western Cascades. The southern end of the Cascades is underlain by a complex of graywacke, siltstone, and interbedded volcanics of Triassic to Cretaceous age, some of which have been regionally metamorphosed. Intrusives associated with these rocks range from granite to peridotite (Griggs, 1969). This type of basement rock extends from the Klamath Mountains in southwestern Oregon to the Blue Mountains in northeastern Oregon. The northern part of the Cascades is underlain by marine and estuarine deposits of Eocene age which are exposed in the Coast Ranges to the west.

Thirteen KGRA's (Known Geothermal Resource Areas) have been designated in Oregon: Mt. Hood, Cary Hot Springs, Breitenbush Hot Springs, Belknap-Foley Hot Springs, and McCredie Hot Springs in the Cascades; Klamath Falls, Lakeview, Crump Geyser, Alvord, and Summer Lake Hot Springs in the Basin and Range province, Newberry Caldera and Burns Butte in the High Lava Plains; and Vale Hot Springs in the Owyhee Uplands. Groh (1966) pointed out several other areas of potential geothermal importance: Jordan Craters in the Owyhee Uplands; Diamond Craters in the Harney Basin; the area southeast of Newberry Caldera in the High Lava Plains; and the Warner Range in the southern part of the Basin and Range province.

Brook and others (1979) list eight areas which they believe have mean reservoir temperatures of more than 150°C: Newberry Caldera (230°C), Crump's Hot Spring (167°C), Mickey Hot Springs (207°C), Alvord Hot Springs (181°C), Hot (Borax) Lake (181°C), Trout Creek Area (154°C), Neal Hot Springs (188°C), and Vale Hot Springs (157°C). These areas are estimated to have an aggregate thermal energy of 90×10^{18} joules, most of which is in the Vale, Alvord, and Newberry areas. About 55×10^{18} joules are estimated to be present in 20 systems of lower temperature (90° to 150°C), with approximately 70 percent of this amount in the Klamath Falls and Lakeview areas. The temperatures used in the estimates are mean temperatures for the respective systems and do not reflect the maximum and minimum temperatures of the reservoirs. Since volumes of the individual systems are more important in determining the amount of stored heat than the temperatures, and since the volume estimates may undergo considerable change as drillhole and geophysical data become available, changes in the estimated quantities of thermal heat available in Oregon are anticipated.

Chemical data exist for many of Oregon's thermal waters, but they are often scattered in the literature or in unpublished files. A compilation of the raw chemical data for Oregon, as it was entered into Geotherm, has recently been published by the Oregon Department of Geology and Mineral Industries as Open-File Report 0-79-3. The data stored in Geotherm cannot be considered to be of uniform quality since they were collected for a myriad of purposes and by different techniques. Anyone considering a sampling program should consult the available literature on general water sampling, such as Brown and others (1970), and the special techniques described for handling geothermal waters such as those given by Presser and Barnes (1974).

The approximately 170 thermal springs and wells identified in Oregon are not distributed uniformly over the state (Bowen, Peterson and Riccio, 1979; Waring, 1965). The largest number of springs issue in the Basin and Range province of southeastern Oregon, with progressively fewer springs in the High Lava Plains, Owyhee Uplands, Blue Mountains, and Cascade Range. The Coastal Plain, Coast Range, Klamath Mountains, and Willamette Valley of western Oregon are devoid of thermal springs. Curiously, most hot springs do not occur in the areas of most recent volcanic activity. Crater Lake, formed some 7,000 years ago by a violent volcanic eruption, has no hot springs associated with it, and the smaller Newberry Caldera has only two areas of weak thermal springs. The springs at Newberry may be drowned fumaroles; they issue in or at the edges of the lakes and appear to be dominantly gas vents. Diamond Craters in the eastern High Lava Plains and Jordan Craters in the Owyhee Uplands are also of Holocene age, but neither has thermal springs nearby. With the exception of Mt. Hood, which has a fumarole on it and a weak thermal spring at its base, the prominent volcanoes of the High Cascades, which have all been formed in the last three million years, do not have thermal springs directly associated with them. Most of the thermal springs in the Cascades issue to the west of the crest, near the contact of the High Cascades and the older Western Cascades.

DATA

Chemical data for the springs and wells (table 1) are arranged by county and numbered to correspond to the thermal springs and wells on a map prepared by Bowen and others (1978). This compilation represents all of the chemical and isotopic data in Geotherm as of October, 1979. Entries for springs that have been analyzed several times are arranged chronologically. Sources of data, topographic map coverage, and year of collection are listed in table 2. Two of the chemical analyses have gross imbalances of ionic charge and hence are incomplete or otherwise inaccurate. Joaquin Miller Hot Springs in Grant County has 25.3 millequivalents cations to 5.5 milliequivalents anions. A sample recently collected by us indicates that the reported alkalinity is low by more than a factor of 10. The sodium concentration of the sample from Camp Collins in Multnomah County seems to be excessively small. If the sodium concentration were greater by a factor of 10, the charge balance would be much better, 4.88 milliequivalents cations to 4.80 milliequivalents anions rather than the 0.95 to 4.80 as reported.

Waters from several geographic areas can be distinguished on the basis of their chemical composition. Thermal waters in the Western Cascades from Austin to Kitson and McCredie Hot Springs are high in chloride, but low in sulfate and bicarbonate. These sodium chloride waters may originate from the Eocene sediments which are thought to underlie this part of the Cascades. Ratios of B/Cl, Br/Cl, and HCO_3/Cl are similar to those reported for connate waters (White, 1960). Connate marine waters have been noted in springs and wells in the Coast Range, the Western Cascades, and at depths of as little as 30 meters in the Willamette Valley (Piper, 1942). Farther south in the Cascades, the water of Umpqua Hot Springs is similarly high in chloride, but is also high in CO_2. Many CO_2-charged mineral springs issue in Douglas County (Wagner, 1959). CO_2-charged thermal waters also issue from Weberg Hot Springs in southwestern Grant County; this area also has many cold CO_2-charged springs. The water issuing from Weberg Hot Springs differs from that of Umpqua Hot Springs in that it contains very little chloride. The rest of Grant County, and the southern part of Umatilla, Union, and western Baker counties, all in the northeastern part of Oregon, have thermal springs which issue dilute, high-pH thermal water similar to waters from thermal springs in granitic rocks of the Idaho batholith. Bagby Hot Springs in the Cascades is another spring that yields the dilute, high-pH waters associated with granitic rock. These waters are high enough in pH to require corrections to the silica concentrations, as discussed in the section on

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
BAKER COUNTY															
01	RADIUM HOT SPRINGS	44-55.82 117-56.36 07S/039E -28 NE	55/05	290	57.2	9.7	80.	63.	2.0	1.6		101	31.	17.	1.0
01	RADIUM HOT SPRINGS	44-55.82 117-56.36 07S/039E -28 NE	72/00	290	58.	9.56	78.	58.	1.1	1.5	0.1	141	34.	17.	1.3
02	SAM-O SPRING	44-46.76 117-48.65 09S/040E -16 SE	77/02	891	27.0	8.1	67.6	171.	12.2	16.2	6.	519	0.7	15.9	1.2
05	KROPP HOT SPRING	45-00.8 117-53.1 06S/039E -25 NW		445	43.0	7.3	58.	93.	1.5	1.1	0.1	52	31.6	80.8	1.19
06	FISHER HOT SPRING	44-58.48 118-02.61 07S/038E -10 NW	72/06	197	37.0	9.8	38.9	40.		1.4	<0.1	83	12.	1.8	0.4
CLACKAMAS COUNTY															
01	ACID-SULFATE SPRING ON MT. HOOD	45-22.3 121-41.8 02S/009E -29	76/06	227		3.8	19.	5.	0.2	13.	2.8		77.	1.	
02	SWIM WARM SPRINGS	45-17.7 121-44.3 03S/8.5E -24 SW	76/12	1300	26.0	7.3	72.3	136.	11.7	60.	48.	218	205.	161.	0.23
03	AUSTIN HOT SPRINGS (CAREY)	45-01.30 122-00.50 06S/007E -30 NW	72/00	1720	86.0	7.63	81.	300.	7.1	35.	0.1	58	140.	430.	1.4
04	BAGBY HOT SPRINGS	44-56.15 122-10.35 07S/005E -26 NW	70/03	290	57.2	9.7	81.5	54.	0.8	3.7	0.1	68	30.7	14.6	0.68
04	BAGBY HOT SPRINGS	44-56.15 122-10.35 07S/005E -26 NW	77/09		58.	9.37	74.	53.	0.74	3.3	<0.05	69	42.	14.	0.66
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	45-01.65 121-57.80 06S/007E -21 SW	76/08	282	35.6	7.6	36.	48.	2.8	12.	2.6	162	0.6	2.	0.71
DESCHUTES COUNTY															
01	EAST LAKE HOT SPRINGS	43-43.1 121-12.2 21S/013E -29 SW	73/00	396	62.0	6.49	36.	32.	3.8	38.	16.	184	58.	0.4	0.2
01	EAST LAKE HOT SPRINGS	43-43.1 121-12.2 21S/013E -29 SW	75/08	767	49.	6.42	199.	53.		70.	34.	547	28.	1.7	0.16
02	PAULINA HOT SPRINGS	43-43.7 121-45.0 21S/012E -26 NE	77/07			6.82	205.	140.	17.	56.	60.	856	<1.	6.0	0.57
02	WARM WELL AT LITTLE CRATER CAMPGROUND	43-42.9 121-14.5 21S/012E -36 NW	75/08	900	35.5	6.46	161.	83.	10.	54.	48.	679	<1.	5.1	0.6
DOUGLAS COUNTY															
01	UMPQUA HOT SPRINGS	43-17.70 121-21.90 26S/004E -20 NE	77/09	11300	46.5	6.37	90.	2400.	63.	340.	41.	1380	190.	3500.	1.5
01	UMPQUA HOT SPRINGS	43-17.70 121-21.90 26S/004E -20 NE	78/06	10920	46.	6.2	96.	2150.	62.	428.	42.4	1120	139.2	3340.	1.2
GRANT COUNTY															
01	RITTER HOT SPRINGS	44-53.60 119-08.50 08S/030E -08 NW	73/00	319	41.0	9.68	70.	72.	0.82	1.4	<0.05	143	9.	29.	4.0
04	BLUE MOUNTAIN HOT SPRINGS	44-21.30 118-34.40 14S/034E -13 S/2	72/00	610	58.0	7.96	47.	140.	3.3	2.2	0.2	329	11.	15.	10.6
05	JOAQUIN MILLER RESORT	44-16.81 118-57.36 15S/031E -11 SE	78/07	2194	40.	6.8		500.	11.2	45.2	12.1	103	1.6	121.	7.1

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
	BAKER COUNTY												
01	RADIUM HOT SPRINGS								0.2	ND	ND	ND	
01	RADIUM HOT SPRINGS	0.42	0.01	<0.02	<0.1	<0.05	0.01	0.007			<0.02	<0.02	0.0005
02	SAM-O SPRING	1.6	0.06							0.43	<0.1	0.05	
05	KROPP HOT SPRING	3.3	<0.1							0.04	<0.03	<0.03	
06	FISHER HOT SPRING	2.8	1.0							0.07	<0.03	<0.03	
	CLACKAMAS COUNTY												
01	ACID-SULFATE SPRING ON MT. HOOD		<0.01										
02	SWIM WARM SPRINGS	0.32	0.13						<0.02	<0.02	<0.05	<0.05	
03	AUSTIN HOT SPRINGS (CAREY)	2.6	0.4	0.03	<0.1	0.33	2.	0.33			<0.02	<0.02	0.0002
04	BAGBY HOT SPRINGS	0.6								0.2			
04	BAGBY HOT SPRINGS	0.07	0.02										
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	0.42	0.01						0.38	<0.05	18.		
	DESCHUTES COUNTY												
01	EAST LAKE HOT SPRINGS	0.93	0.01	<0.02	<0.1	0.14					<0.02	0.10	0.0003
01	EAST LAKE HOT SPRINGS	1.1	0.04	0.03	<0.1					0.008m	0.66	0.90	
02	PAULINA HOT SPRINGS	0.87	0.22	0.04	<0.1								
02	WARM WELL AT LITTLE CRATER CAMPGROUND	2.5	0.12	0.02	<0.1					0.002m	4.	0.25	<0.0001
	DOUGLAS COUNTY												
01	UMPQUA HOT SPRINGS	41.	2.4	0.16	0.2					<0.002m	0.44		<0.0001
01	UMPQUA HOT SPRINGS	41.2	2.4							2.2	6.2		
	GRANT COUNTY												
01	RITTER HOT SPRINGS	2.6	0.01	<0.02	<0.1	<0.05					<0.02	<0.02	0.0005
04	BLUE MOUNTAIN HOT SPRINGS	1.6	0.07	<0.02	<0.1	<0.05	0.04	0.01			<0.02	<0.02	0.0004
05	JOAQUIN MILLER RESORT	12.7	0.25						0.02	0.08	0.1	1.8	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)
GRANT COUNTY															
07	WEBERG HOT SPRING	44-00.1 119-38.8 18S/026E -18	72/00	2570	46.0	6.53	82.	610.	36.	38.	7.8	1712	13.	50.	3.9
HARNEY COUNTY															
01	UNNAMED SPRING	43-39.76 118-44.30 22S/32.5E-14 SW	31/09		22.					16.		86	4.	1.9	
02	O. J. THOMAS	43-37.65 118-51.75 22S/032E -34 NE	68/09	716	72.0	9.5	89.	157.	1.8	1.0	0.2	236	89.	38.	2.8
04	MILLPOND SPRING	43-32.43 119-04.86 23S/030E -35 NE	31/08		26.					14.		109	11.	8.	
05	HARNEY VALLEY DEV CO. OIL TEST WELL	43-30.25 118-54.30 24S/032E -08 SE	68/09	602	46.0	9.6	72.	135.	1.6	0.8	0.2	265	29.	11.	12.
08	ISLAND RANCH WELL	43-25.40 118-55.95 25S/032E -07 NW	69/08	1450	41.0	9.3	54.	386.	4.4	0.5	0.2	967	8.	9.	19.
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	31/08		49.					2.		218	80.	82.	
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	68/09	814	80.0	8.3	80.	170.	3.6	3.8	0.2	211	81.	78.	9.3
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	72/00	810	78.0	8.1	83.	170.	3.9	3.7	0.1	208	86.	79.	9.0
10	WARM SPRING NEAR VENATOR	43-23.7 118-18.4 25S/036E -16 SW	77/06	650	41.0	9.1	370.	100.	1.0	2.7	0.1	134	51.	70.	1.1
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	43-10.6 119-03.6 27S/29.5E-36 SE	31/08		59.		92.	622.	12.	13.	3.0	601	140.	562.	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	43-10.6 119-03.6 27S/29.5E-36	72/00	2970	68.0	7.26	92.	630.	13.	12.	1.8	568	140.	590.	3.3
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	70/07	2200	85.	8.5	167.	478.	20.	1.	1.2		205.	230.	19.6
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	72/00	2490	73.0	8.05	200.	550.	35.	0.9	0.1	796	230.	240.	16.
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	76/09	2200	86.	8.31	214.	550.	31.	1.0	<1.	804	210.	240.	16.
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	76/09	2220	86.	8.31	214.	550.	30.	1.0	0.1	814	220.	240.	17.
22	MICKEY SPRINGS	42-40.54 118-20.67 33S/035E -13	76/09	2290			200.	560.	32.	0.6	<0.1	836	220.	245.	17.
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33 SE	55/11	4490	82.2	7.3	135.	1040.	66.	13.	1.0	1250	211.	760.	7.2
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33 NW	72/00	4590	76.0	6.73	120.	960.	69.	13.	2.2	1198	220.	780.	10.2
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33	76/09	4100	78.5	6.90	129.	990.	64.	12.	2.1	1225	180.	770.	9.6
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33	76/09	4070	78.5	6.89	128.	1000.	63.	12.	2.2	1230	180.	770.	11.
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	53/09	2227	29.4	7.7	184.	488.	23.	17.		424	343.	286.	8.
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	61/06	2410	31.1	7.8	193.	516.	27.	16.	0.5	450	367.	305.	9.7

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
	GRANT COUNTY												
07	WEBERG HOT SPRING	15.	0.7	0.09	<0.1	2.1	0.1	0.1			0.24	0.06	0.0003
	HARNEY COUNTY												
01	UNNAMED SPRING								1.0				
02	O. J. THOMAS	3.99							ND		0.03		
04	MILLPOND SPRING								1.1				
05	HARNEY VALLEY DEV CO. OIL TEST WELL	4.11							0.2		0.20		
08	ISLAND RANCH WELL								0.1				
09	CRANE HOT SPRINGS								1.4				
09	CRANE HOT SPRINGS	6.2							ND		0.02		
09	CRANE HOT SPRINGS	7.9	0.09	0.03	<0.1	0.06	0.1	0.02		0.022m	<0.02	<0.02	0.0005
10	WARM SPRING NEAR VENATOR	2.2									0.03	N	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE								0.5		0.03		
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	11.3	0.45	0.08	<0.1	0.11	29.	0.2		0.005m	0.05	0.04	0.0001
22	MICKEY SPRINGS	9.2	<0.2						0.02	<0.01	0.06	0.02	
22	MICKEY SPRINGS	10.5	1.1	0.20	0.1	0.15	1.	0.09		0.058m	<0.02	<0.02	0.0001
22	MICKEY SPRINGS	11.	0.90	0.18	0.1								
22	MICKEY SPRINGS	11.	0.90	0.14	<0.1					0.068m	<0.02		
22	MICKEY SPRINGS	11.	0.85	0.15	<0.1								
23	ALVORD HOT SPRINGS	28.							1.1		0.09	N	
23	ALVORD HOT SPRINGS	30.	2.1	0.33	0.2	0.92	2.	0.09		0.003m	0.12	0.02	0.0001
23	ALVORD HOT SPRINGS	35.	1.9		0.1								
23	ALVORD HOT SPRINGS	36.	1.9	0.24	0.1								
24	HOT BORAX LAKE	17.9	<1.5						2.5				
24	HOT BORAX LAKE	18.											

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND)not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)
HARNEY COUNTY															
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	72/00	2410	36.0	7.28	190.	500.	31.	16.	0.3	422	353.	300.	9.0
27	UNNAMED HOT SPRING NEAR TROUT CREEK	42-11.3 118-23.0 39S/037E -16	70/08	1060		8.3	79.	230.	25.	18.4	0.9		177.	226.	12.0
27	UNNAMED HOT SPRING NEAR TROUT CREEK	42-11.3 118-23.0 39S/037E -16	72/00	1168	52.0	6.77	105.	270.	10.8	18.	0.8	441	204.	24.	12.8
39	GOODMAN SPRING (HOTCHKISS)	43-31.73 119-04.83 23S/030E -35 SE	68/09	210	22.0	7.5	46.	35.	3.2	8.2	1.4	92	15.	7.	0.6
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	53/09	2050	73.9	7.6	119.	430.	27.	15.		382	319.	255.	7.0
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	53/09	2160	79.4	8.1	173.	456.	30.	14.	0.3	414	339.	270.	7.0
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.08 118-36.11 37S/033E -11	57/05	2190	87.0	7.5	160.	426.	29.	9.6		425	328.	265.	6.5
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	73/06	2020	96.0	7.30	160.	450.	28.	14.	0.3	382	434.	250.	7.2
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	76/09	1990	91.	7.94	189.	460.	29.	15.	0.3	434	320.	270.	7.5
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.08 118-36.11 37S/033E -11	76/09	1840	97.	7.36	169.	435.	24.	13.	0.2	389	300.	250.	7.6
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	1910	90.5	7.04	154.	435.	26.	15.	0.3	420	300.	250.	7.0
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	2040	86.	8.67	157.	450.	26.	14.	0.3	423	300.	250.	7.7
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	76/09	1840	97.	7.26	163.	425.	24.	12.	0.2	372	300.	250.	7.4
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	1890	84.	7.48	164.	440.	25.	12.	0.2	386	310.	250.	7.5
44	HOTCHKISS WELL	43-31.42 119-03.83 24S/030E -01 NE	31/08		27.		51.	30.	2.4	9.6	1.7	95	13.	5.2	
44	HOTCHKISS WELL	43-31.42 119-03.83 24S/030E -01 NE	68/09	194	27.	8.1	46.	31.	2.9	8.8	1.4	93	12.	5.	0.5
45	HINES LUMBER CO. WELL	43-32.34 119-04.80 23S/030E -35 NE	68/07	222	25.0	7.8	55.	33.	4.	11.	2.	105	14.	7.	0.5
46	CITY OF HINES WELL	43-33.57 119-05.31 23S/030E -23 SW	68/07	289	17.0	7.8	60.	35.	6.9	15.	5.7	128	18.	13.	0.5
JACKSON COUNTY															
01	JACKSON HOT SPRING	42-13.30 122-44.65 38S/001E -48 SW	52/04	460	35.0	9.3	65.	95.	1.2	2.8	1.4	84	26.	80.	2.0
KLAMATH COUNTY															
	ALFRED JACOBSEN	42-07.65 121-44.40 39S/009E -34 NE	74/05	290	30.0	7.6	65.	49.	12.	5.7	2.4	160	13.	7.9	0.1
	BILL HILL	42-03.55 121-36.60 40S/010E -26 NW	74/06	245	20.0	7.7	26.	19.	6.4	9.1	13.	140	5.4	4.2	
	CLAUDE SHUCK	42-11.35 121-39.80 39S/010E -08 SE	74/05	220	24.	8.2	57.	25.	6.2	9.7	4.1	112	15.	2.8	0.2

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
HARNEY COUNTY													
24	HOT BORAX LAKE	16.6	0.65	0.23	0.1	0.42	2.	0.2			<0.02	0.03	0.0004
27	UNNAMED HOT SPRING NEAR TROUT CREEK	1.6	<0.5						0.05	<0.01	0.03		
27	UNNAMED HOT SPRING NEAR TROUT CREEK	0.89	0.68	0.10	0.1	0.30				0.002m	0.08	<0.02	0.0003
39	GOODMAN SPRING (HOTCHKISS)	0.23							2.1		0.02		
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	12.	<1.5						1.2				
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	<1.5						1.3				
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	ND			ND	1.8	0.2	ND	ND	ND	0.10	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.51	0.18	0.1	0.60				0.020m	<0.02	0.04	0.0008
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.50	0.23	0.2								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.50	0.17	0.1					0.028m	<0.02	0.05	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.5	0.18	0.2								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.55	0.18	0.1								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.45	0.17	0.1						<0.02		
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.45	0.18	0.1								
44	HOTCHKISS WELL								1.2		0.01		
44	HOTCHKISS WELL	0.06							1.1				
45	HINES LUMBER CO. WELL	0.38							1.5		0.02		
46	CITY OF HINES WELL	0.53							3.8		0.05		
JACKSON COUNTY													
01	JACKSON HOT SPRING	2.9							0.2		0.07		
KLAMATH COUNTY													
	ALFRED JACOBSEN	0.05									0.12	0.050	
	BILL HILL	0.02									0.04	0.030	
	CLAUDE SHUCK	0.02									0.05	0.010	

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[Map code refers to Bowen, Peterson, and Riccio 1978;
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Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
	KLAMATH COUNTY														
	CLYDE DEHILINGER	42-06.75 121-39.65 40S/010E -05 SE	74/06	240	24.0	7.9	72.	40.	6.5	8.1	3.1	150	2.3	4.9	
	FALCON HEIGHTS SCHOOL	42-07.80 121-45.10 39S/009E -34 SW	74/05	350	37.0	7.8	80.	57.	7.1	7.7	4.5	170	24.	8.9	0.2
	GEORGE CARTER	42-00.55 121-36.90 41S/010E -14 NW	74/06	660	22.	8.2	41.	99.	7.9	29.	2.3	100	95.	98.	
	GEORGE STACY CO.	42-08.40 121-39.80 39S/010E -32 NE	74/06	170	25.0	8.3	34.	20.	4.0	13.	2.0	94	11.	2.0	
	JACK O'CONNER	42-02.00 121-42.95 41S/009E -01 NE	74/05	640	38.0	8.3	65.	130.	3.0	7.5	0.6	114	140.	50.	
	LEN DOBRY	42-08.90 121-38.65 39S/010E -28 SE	74/05	195	21.0	7.6	65.	32.	4.5	5.7	1.1	100	14.	3.4	
	LESTER BROOKSHIRE	42-08.70 121-39.70 39S/010E -29	74/05	175	25.0	8.1	35.	21.	3.4	13.	2.0	97	10.	2.8	0.1
	MELVIN MCCOLLUM	42-11.50 121-41.05 39S/010E -07 NE	74/05	300	25.0	7.5	52.	20.	4.0	24.	13.	120	53.	3.1	0.2
	MONTE DEHILINGER	42-07.60 121-40.40 39S/010E -32 SW	74/06	260	26.0	7.6	54.	22.	6.7	17.	11.	160	7.1	3.6	
	O'CONNER LIVESTOCK CO.	42-01.00 121-41.00 41S/010E -07 SE	74/06	1300	30.0	7.8	80.	210.	7.0	58.	6.4	250	213.	160.	
	OREGON WATER CORP.(4)	42-12.10 121-41.40 39S/010E -06 SW	70/08		26.	8.6	63.	36.		8.5	5.8		6.5	3.0	0.32
	POPE'S MEAT CO.	42-01.95 121-37.50 41S/010E -03 NE	74/06	190	22.0	8.5	25.	30.	3.2	8.6	1.4	104	6.0	4.4	
	RAY BIXLER	42-11.55 121-37.95 39S/010E -10 NW	74/05	190	22.0	7.8	49.	16.	3.3	12.	8.4	110	7.9	1.9	0.2
	ROBERT LANGLEY	42-10.75 121-37.90 39S/010E -15 SE	74/05	200	23.	7.4	50.	22.	5.5	10.	6.3	112	14.	2.6	
	TOWN OF MERRILL	42-01.50 121-36.00 41S/010E -02 SE	55/02	316	21.0	8.3	38.	44.	3.8	11.	4.3	114	21.	27.	0.1
	U.S. AIR FORCE(1)	42-08.05 121-45.25 39S/009E -34 NW	72/10	240	31.0	7.0	53.	47.	9.0	3.8	1.2	128	8.	6.0	0.3
	U.S. AIR FORCE(2)	42-08.10 121-45.35 39S/009E -34 NW	72/10	255	30.		51.	48.	8.5	5.6	2.3	145	9.	6.3	0.2
	WEYERHAUSER WELL NO. 4	42-10.70 121-48.10 39S/009E -18 SW	72/08	200	22.	8.3	16.	32.	3.3	10.	1.9	124	4.	4.	0.11
01	EAGLE POINT SPRING	42-25.85 121-57.75 36S/007E -23 SE	72/08	305	35.	8.3	38.	62.	5.7	0.6	<0.1	136	<2.	16.	0.75
02	J. E. FRIESEN	42-13.75 121-46.15 38S/009E -28 SW	55/02	1230	73.0	8.7	87.	221.	4.4	25.		48	431.	56.	1.6
02	LOIS MERRUYS	42-13.65 121-01.45 38S/009E -33 NW	54/12	1100	71.0	8.5	83.	207.	3.8	22.		51	393.	50.	1.4
02	MEDO-BELL DAIRY	42-13.8 121-46.4 38S/009E -28 SW	55/01	1160	81.0	8.8	81.	213.	4.2	23.		48	403.	54.	1.2
02	MILLS SCHOOL	42-13.45 121-45.90 38S/009E -33 NE		1200	89.0	8.3	78.	370.	3.0	27.	<0.2	46	462.	54.	1.2
02	MOYINA WATER CO.	42-12.60 121-42.45 39S/009E -01 NW	66/08	222	50.	7.4	64.	38.	5.0	7.9	2.3		5.6	1.8	0.22

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Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
	KLAMATH COUNTY												
	CLYDE DEHILINGER	0.04									0.02	ND	
	FALCON HEIGHTS SCHOOL	0.1									0.19	0.030	
	GEORGE CARTER	0.15									0.02	0.020	
	GEORGE STACY CO.	0.01									0.04	0.010	
	JACK O'CONNER												
	LEN DOBRY												
	LESTER BROOKSHIRE	0.006									0.02	0.02	
	MELVIN MCCOLLUM	0.02									1.4	0.07	
	MONTE DEHILINGER	0.02									0.02	ND	
	O'CONNER LIVESTOCK CO.	0.69									0.04	0.15	
	OREGON WATER CORP.(4)										0.33	<0.005	
	POPE'S MEAT CO.	0.02									0.02	ND	
	RAY BIXLER	0.02									0.15	1.4	
	ROBERT LANGLEY												
	TOWN OF MERRILL	0.01							ND		0.12		
	U.S. AIR FORCE(1)										0.04	<0.01	
	U.S. AIR FORCE(2)										0.03	<0.01	
	WEYERHAUSER WELL NO. 4	0.09											
01	EAGLE POINT SPRING	0.140											
02	J. E. FRIESEN	0.91							ND		ND		
02	LOIS MERRUYS	0.74							0.2		ND		
02	MEDO-BELL DAIRY	0.96							ND		0.04		
02	MILLS SCHOOL	0.96									0.03	0.03	
02	MOYINA WATER CO.										0.42	<0.05	

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Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
KLAMATH COUNTY															
02	O.I.T. NO. 5	42-13.85 121-46.40 38S/009E -28 SW	67/00	1000	89.0	8.6	73.	331.	3.5	25.1	1.04	55	384.	48.	1.12
02	O.I.T. NO. 6	42-14.90 121-46.85 38S/009E -20 NE	72/08		88.0	8.2	31.	195.	3.9	24.2	<0.1	44	400.	58.	1.45
02	O.I.T. NO. 6	42-14.90 121-46.85 38S/009E -20 NE	75/03		79.		90.								
02	OREGON WATER CORP.(1)	42-13.30 121-47.45 38S/009E -32 NW	30/03	200	21.		46.	29.		10.	4.	117		8.	
02	OREGON WATER CORP.(2)	42-13.30 121-47.45 38S/009E -32 NW	71/09		21.0	8.3	24.	26.		11.2	6.8		1.2	5.3	0.01
02	OREGON WATER CORP.(3)	42-13.30 121-47.45 38S/009E -32 NW	71/09	205	20.0	8.4	25.	26.		11.2	5.8		0.6	5.3	0.02
03	HOWARD HOLLIDAY	42-10.55 121-49.70 39S/008E -13 SW	74/05	220	25.0	7.9	27.	27.	2.9	12.	3.1	122	5.4	5.1	0.1
04	MAZAMA SCHOOL	42-11.85 121-43.90 39S/009E -11 NW		895	61.0	8.3	92.	246.	6.0	5.4	1.0	120	256.	35.	1.0
06	ABE BOEHM	42-04.05 121-45.40 40S/009E -28 NE	74/05	2700	25.0	7.1	100.	480.	18.	180.	47.	1462	300.	170.	0.2
06	ABE BOEHM	42-04.05 121-45.40 40S/009E -28 NE	75/08		25.								308.	205.	
06	DAN O'CONNER	42-04.85 121-43.85 40S/009E -23 NW	74/05	260	24.0	7.6	42.	32.	8.1	12.	6.6	130	14.	9.1	
06	JACK LISKEY	42-02.95 121-44.40 40S/009E -34 NE	74/05	1030	93.0	8.9	90.	200.	4.0	15.	<0.1	52	360.	59.	1.5
06	JACK LISKEY	42-02.25 121-43.60 41S/009E -02 NW	74/05	2400	22.0	7.6	100.	580.	12.	35.	16.	1550	13.	140.	
06	JACK LISKEY	42-02.25 121-43.60 41S/009E -02 NW	75/08		25.								5.	152.	
06	O. H. OSBORN	42-03.30 121-44.70 40S/009E -27 SW	74/05	920	90.0	9.5	90.	190.	4.1	15.		55	270.	56.	1.5
07	OLENE GAP HOT SPRINGS	42-10.45 121-36.90 39S/010E -14 SW	67/00	1000	73.9	7.3	79.	294.	4.5	34.9	1.09	40	346.	58.	1.12
07	OLENE GAP HOT SPRINGS	42-10.45 121-36.90 39S/010E -14 SW	72/00	1140	74.0	7.68	98.	190.	7.2	40.	0.2	55	400.	59.	1.2
07	OLENE GAP HOT SPRINGS	42-10.45 121-36.90 39S/010E -14 SW	75/07		87.								385.	59.	
08	ROENICKE HOT SPRING	42-10.40 121-37.05 39S/010E -14 SW	72/10	1300	65.0	8.2	48.	217.	5.0	35.	0.1	50	430.	65.	1.5
16	MELVIN FEIGI	42-08.20 121-30.10 40S/011E -03 NE	70/10	273	31.0	8.8	110.	66.	1.0	1.2		153	5.8	5.	0.4
22	RAY SMITH WELL	42-27.25 121-25.40 36S/011E -16 NW	70/10	148	25.	8.4	50.	30.	1.9	3.8	0.1	86	3.2	2.5	0.2
23	KLAMATH ICE CO.	42-13.40 121-01.40 38S/009E -33 NW	36/04		51.7	9.0	70.						380.	53.	
24	J. K. O'NEIL	42-08.30 121-38.10 39S/010E -34 NW	72/03	222		7.6	45.2	22.	5.4	6.4	5.2	101	5.5	2.5	0.2
24	J. K. O'NEIL	42-08.30 121-38.10 39S/010E -34 NW	74/05	190	23.0	7.4	50.	26.	5.1	6.1	5.5	112	13.	2.8	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
KLAMATH COUNTY													
02	O.I.T. NO. 5								<0.01	0.03	0.03	<0.02	
02	O.I.T. NO. 6	1.0											
02	O.I.T. NO. 6		0.12										
02	OREGON WATER CORP.(1)										<0.05		
02	OREGON WATER CORP.(2)										0.05	<0.01	
02	OREGON WATER CORP.(3)										0.05	<0.01	
03	HOWARD HOLLIDAY	0.04	0.02								0.05	ND	
04	MAZAMA SCHOOL										0.09		
06	ABE BOEHM	1.4	0.16								0.1	2.4	
06	ABE BOEHM												
06	DAN O'CONNER												
06	JACK LISKEY	0.65	0.08										
06	JACK LISKEY										0.09		
06	JACK LISKEY												
06	O. H. OSBORN	0.77									0.26	ND	
07	OLENE GAP HOT SPRINGS								0.91	0.03	0.03	0.06	
07	OLENE GAP HOT SPRINGS	1.0	0.15	0.02	<0.1	0.58	0.08	0.01			<0.02	<0.02	
07	OLENE GAP HOT SPRINGS												
08	ROENICKE HOT SPRING	1.9											
16	MELVIN FEIGI	ND							2.9		0.02		
22	RAY SMITH WELL								0.3		0.03		
23	KLAMATH ICE CO.										ND		
24	J. K. O'NEIL								0.03	<0.01	0.02	0.02	
24	J. K. O'NEIL												

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potas-sium (K)	Cal-cium (Ca)	Mag-nesium (Mg)	Alka-linity (HCO3)	Sulfate (SO4)	Chlor-ide (Cl)	Fluor-ide (F)
LAKE COUNTY															
05	ANA RIVER SPRING	42-59.8 120-45.3 30S/017E -06	48/12		18.9	8.4	37.	39.	3.2	5.2	3.1	108	6.7	13.	0.2
14	SUMMER LAKE HOT SPRING (WOODWARD)	42-43.53 120-38.75 33S/017E -12 NE	48/10	1760	46.7	8.5	96.	399.	6.8	1.4	0.4	374	111.	285.	2.2
14	SUMMER LAKE HOT SPRING (WOODWARD)	42-43.53 120-38.75 33S/017E -12 NE	72/00	1790	43.0	8.43	94.	390.	4.6	2.1	0.1	426	120.	280.	2.2
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	56/10	1110	98.0	8.3	146.	209.	9.5	12.		74	265.	116.	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	57/10	1140	86.0	8.4	140.	208.	10.	8.0	2.4	74	258.	120.	4.5
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	72/00	1120	96.0	7.77	140.	210.	8.5	13.	<0.1	81	260.	120.	4.4
24	LEITHEAD HOT SPRINGS (JOYLAND PLU	42-09.71 120-20.60 39S/020E -27 NE	48/06	813	69.4	7.7	66.	152.	2.2	15.	0.4	84	152.	99.	3.1
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	42-09.35 120-20.67 39S/020E -27 SE	48/05	1320	85.0	7.3	140.	268.	8.8	8.5	1.4	208	223.	146.	6.9
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	42-09.35 120-20.67 39S/020E -27 SE	72/00	1370	88.0	7.76	130.	280.	9.0	8.8	0.1	236	240.	170.	5.4
28	ANTELOPE HOT SPRINGS	42-29.97 119-41.48 35S/026E -32 NW	48/08	876	40.0	8.3	168.	191.	13.	10.	2.5	376	57.	64.	3.60
32	FISHER HOT SPRINGS	42-17.84 119-46.55 38S/025E -10 NW	72/00	513	68.0	7.93	77.	92.	7.9	8.4	1.0	107	59.	56.	3.5
33	CRUMP SPRING	42-13.60 119-52.78 38S/024E -34 SW	48/09	935	40.0	8.7	125.	175.	8.7	18.	2.	130	116.	150.	1.9
33	CRUMP SPRING	42-13.60 119-52.78 38S/024E -34 SW	72/00	1490	78.0	7.26	180.	280.	11.	16.	0.2	155	200.	240.	4.9
33	CRUMP WELL (1)	42-13.59 119-52.87 38S/024E -34 SW	59/07	1580	99.0	8.7	169.	298.	12.	10.	0.5	143	209.	263.	5.2
33	CRUMP WELL (2)	42-13.59 119-52.87 38S/024E -34 SW	60/09	1460	88.0	8.1		281.	10.					248.	
LANE COUNTY															
01	BELKNAP HOT SPRINGS	44-11.65 122-02.90 16S/006E -11 NE	03/00		86.7		80.9	364.	69.	455.	13.		168.	1343.	
01	BELKNAP HOT SPRINGS	44-11.65 122-02.90 16S/006E -11 NE	72/00	4300	71.0	7.62	96.	690.	15.	210.	0.2	19	170.	1300.	1.2
02	FOLEY SPRINGS	44-09.20 122-05.85 16S/006E -28 NW	76/03	4800	80.6	8.	60.4	475.	11.2	494.	0.8	16	550.	1304.	0.81
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44-04.95 122-14.00 17S/005E -20	73/00	2890	44.0	7.76	50.	392.	6.3	225.	0.1	21	260.	788.	0.8
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44-04.95 122-14.00 17S/005E -20 NW	76/03	2660	42.0	8.2	47.	320.	6.8	196.	0.2	18	185.	693.	0.87
04	WALL CREEK WARM SPRINGS	43-48.45 122-18.55 20S/004E -26 NW	76/03	2340	41.0	7.2	62.7	315.	10.8	130.	1.		108.	602.	4.1
05	MCCREDIE SPRINGS	43-42.35 122-17.20 21S/004E -36 NW	74/00	6730	73.	7.29	79.	1000.	22.	460.	0.9	21	240.	2200.	2.7
05	MCCREDIE SPRINGS	43-42.35 122-17.20 21S/004E -36 NW	76/03	6770	71.0	7.4	65.4	910.	28.	500.	0.9	20		2232.	2.68

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
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Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
LAKE COUNTY													
05	ANA RIVER SPRING	0.5							0.1		0.15		
14	SUMMER LAKE HOT SPRING (WOODWARD)	1.0							0.1		0.03		
14	SUMMER LAKE HOT SPRING (WOODWARD)	6.9	0.15	<0.02	<0.1	0.07	1.				<0.02	<0.02	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	7.2	0.2			0.5			7.2				
23	HUNTERS HOT SPRINGS (LAKEVIEW)	7.1							0.3	ND	0.01	ND	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	6.9	0.15	0.04	<0.1	0.32	0.4	0.08		0.034m	<0.02	<0.02	0.0004
24	LEITHEAD HOT SPRINGS (JOYLAND PLU	7.0							0.2		0.06		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	9.9							0.3		0.02		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	11.2	0.15	0.04	<0.1	0.17	1.	0.1		0.014m	<0.02	<0.02	0.0017
28	ANTELOPE HOT SPRINGS	1.5							0.2		0.02		
32	FISHER HOT SPRINGS	2.2	0.04	0.02	<0.1	0.05	0.4	0.03		0.011m	<0.02	<0.02	<0.0001
33	CRUMP SPRING	7.3							1.5		0.04		
33	CRUMP SPRING	13.6	0.4	0.07	0.1	0.12	0.4	0.1		0.017m	<0.02	0.03	0.0004
33	CRUMP WELL (1)	18.	0.39			0.31	0.9	0.1	1.0	0.65	0.15	N	
33	CRUMP WELL (2)	13.	0.33										
LANE COUNTY													
01	BELKNAP HOT SPRINGS											T	
01	BELKNAP HOT SPRINGS	6.4	0.95	0.05	<0.1	1.4	33.	0.2			0.02	0.02	<0.0001
02	FOLEY SPRINGS	10.2	0.96							<0.01	<0.05		
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	5.1	0.52	0.03	<0.1	2.0					<0.02	<0.02	0.0005
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	6.2	0.64							<0.05	0.1	<0.05	
04	WALL CREEK WARM SPRINGS	6.6	0.57							<0.05		<0.05	
05	MCCREDIE SPRINGS	18.	1.4	0.11	0.1					0.010m	0.02	0.10	
05	MCCREDIE SPRINGS	17.8	1.98								0.1	0.05	

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Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potas-sium (K)	Cal-cium (Ca)	Mag-nesium (Mg)	Alka-linity (HCO3)	Sulfate (SO4)	Chlor-ide (Cl)	Fluor-ide (F)
LANE COUNTY															
06	KITSON SPRINGS	43-41.35 122-22.50 22S/004E -06	58/03	10500	44.4	7.4	47.	1450.	28.	726.	5.7	27	197.	3420.	2.8
06	KITSON SPRINGS	43-41.35 122-22.50 22S/004E -06 NE	78/05	10100	43.	7.31	45.	1500.	26.	710.	1.6	24	210.	3450.	2.4
08	BIGELOW HOT SPRINGS	44-14.35 122-03.50 15S/006E -26 NW	76/03	3800	61.0	7.8	68.9	540.	16.6	188.	1.		102.	1148.	1.37
MALHEUR COUNTY															
03	NEAL HOT SPRINGS	44-01.45 117-27.60 18S/043E -09 NW	72/00	1010	87.0	7.32	180.	190.	16.	8.8	0.2	200	120.	120.	9.4
04	BEULAH HOT SPRINGS	43-56.65 118-08.15 19S/037E -02 SE	72/00	1090	60.0	7.56	170.	200.	6.0	24.	0.2	163	290.	55.	4.7
05	VALE HOT SPRINGS	43-58.96 117-13.98 18S/045E -20 SE	74/00	1530	73.0	7.47	130.	310.	16.	19.	0.8	143	100.	360.	6.1
05	VALE HOT SPRINGS	43-58.96 117-14.98 18S/045E -20 SE	74/08		90.								112.	350.	
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	43-53.48 117-30.00 19S/043E -30 NW	73/00	740	70.0	8.71	115.	160.	3.2	3.2	<0.05	129	110.	74.	6.8
08	MITCHELL BUTTE HOT SPRINGS	43-45.78 117-09.34 21S/045E -12 NE	72/00	559	62.0	8.69	94.	110.	1.6	4.6	<0.1	78	130.	28.	10.4
18	UNNAMED HOT SPRING AT THREE FORKS	42-32.0 117-10.9 35S/045E -03	35/07		35.0		44.	62.		12.	1.6	119	31.	19.	4.9
18	UNNAMED HOT SPRING AT THREE FORKS	42-32.0 117-10.9 35S/045E -03	73/00	338	34.0	8.11	40.	61.	1.2	10.5	0.7	110	34.	18.	4.2
19	UNNAMED HOT SPRING NEAR MCDERMITT	42-04.7 117-45.6 40S/042E -25	57/05	604	53.5	9.2	90.	135.	1.8	1.2		263	46.	15.	7.0
19	UNNAMED HOT SPRING NEAR MCDERMITT	42-04.7 117-45.6 40S/042E -25	72/00	598	52.0	8.79	72.	130.	1.0	0.6	<0.1	263	52.	14.	6.6
23	LUCE HOT SPRINGS	43-28.15 118-12.08 24S/037E -20	72/00	1330	63.0	7.43	110.	240.	9.7	34.	0.5	162	290.	140.	4.8
24	JONESBORO WARM SPRING	43-47.5 117-57.5 20S/039E -29 SE			44.5	9.6	70.	72.	0.7	1.0	<0.1	148	38.	11.	0.8
25	JUNTURA WARM SPRING #1	43-45.5 118-04.0 21S/038E -09 SW			25.0	9.4	55.	24.	8.2	48.	21.	204	15.	120.	1.0
26	JUNTURA WARM SPRING #2	43-45.5 118-05.5 21S/038E -17 NW			35.0	9.7	79.	78.	0.8	1.0	<0.1	133	43.	140.	1.3
27	ARTESIAN WELL	43-41.8 117-05.7 21S/046E -33 SE	77/03	670	46.0	9.5	43.7	124.	0.8	1.8	0.1	94	164.	12.2	2.7
28	ALKALI FLAT GRADIENT WELL	44-06.60 117-13.60 17S/045E -08 NE	75/05	2400	24.0	8.3	32.0	482.	6.7	16.4	0.5	140	135.2	598.	2.2
29	NORTH HARPER BLM WELL	43-55.76 117-12.72 19S/045E -09 SE	76/06	714	36.0	8.0	39.7	134.	2.2	3.0	0.5	192	121.	4.3	1.61
30	UNNAMED WARM SPRING NEAR BULLY CREEK	44-01.95 117-26.95 18S/043E -04 SE	77/06	115	37.0	7.8	99.	1.	0.4	36.6	14.7	45	1.0	0.5	0.7
MARION COUNTY															
01	BREITENBUSH HOT SPRINGS	44-46.86 121-58.54 09S/007E -20 NE	72/00	4030	92.0	7.31	83.	720.	31.	100.	1.3	144	140.	1300.	3.4

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Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
LANE COUNTY													
06	KITSON SPRINGS	25.	1.8				6.6	0.9	2.7	0.27	0.01	ND	
06	KITSON SPRINGS	22.	2.0	0.10	0.1					0.002m	<0.04	0.15	<0.0001
08	BIGELOW HOT SPRINGS	6.5	1.1							<0.05	0.1	<0.005	
MALHEUR COUNTY													
03	NEAL HOT SPRINGS	4.1	0.3	0.09	0.1	0.16	0.5	0.06		0.008m	<0.02	0.06	0.0001
04	BEULAH HOT SPRINGS	4.7	0.24	<0.02	<0.1	0.17	0.1	0.03		0.006m	<0.02	0.03	0.0001
05	VALE HOT SPRINGS	9.4	0.28	0.09	<0.1					0.017m	<0.02	0.04	
05	VALE HOT SPRINGS												
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	4.7	0.11	0.02	<0.1	<0.05					<0.02	<0.02	0.0007
08	MITCHELL BUTTE HOT SPRINGS	0.49	0.03	<0.02	<0.1	<0.05	0.2	0.01		0.015m	<0.02	<0.02	0.0001
18	UNNAMED HOT SPRING AT THREE FORKS								2.9		0.02		
18	UNNAMED HOT SPRING AT THREE FORKS	0.11	0.04	<0.02	<0.1	0.06					<0.02	<0.02	
19	UNNAMED HOT SPRING NEAR MCDERMITT	0.70	ND						ND				
19	UNNAMED HOT SPRING NEAR MCDERMITT	1.1	0.06	<0.02	<0.1	<0.05	0.4	0.008		0.013m	<0.02	<0.02	0.0001
23	LUCE HOT SPRINGS	6.6	0.27	0.04	<0.1	0.42	0.5	0.03			<0.02	0.04	0.0001
24	JONESBORO WARM SPRING	<0.1	<0.1										
25	JUNTURA WARM SPRING #1	<1.0	<0.1										
26	JUNTURA WARM SPRING #2	<1.0	<0.1										
27	ARTESIAN WELL	0.31	0.04						0.02	0.1	<0.1	<0.05	
28	ALKALI FLAT GRADIENT WELL	14.	0.4						0.03	0.01	0.1	0.05	
29	NORTH HARPER BLM WELL	0.26	0.21						0.14	<0.05	<0.05	<0.05	
30	UNNAMED WARM SPRING NEAR BULLY CREEK	0.15	0.04						0.06	0.28	0.4	0.05	
MARION COUNTY													
01	BREITENBUSH HOT SPRINGS	4.1	1.8	0.18	0.1	0.73	5.	0.1			0.02	0.22	0.0002

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Concentrations in mg/l; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO_2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)
MARION COUNTY															
01	BREITENBUSH HOT SPRINGS - WELL	44-46.86 121-58.54 09S/007E -20 NE	78/02		110.0	8.5	182.	690.	34.	90.	1.3	88	96.	1170.	4.0
MULTNOMAH COUNTY															
01	CORBETT WARM SPRING	45-32.5 122-17.5 01N/004E -27 SE		570	18.0	8.2	44.2	85.	8.9	21.7	0.8	127	5.9	77.4	2.4
02	YMCA CAMP COLLINS	45-30.2 122-18.3 01S/004E -10 NW	56/09	517	23.3	8.6	60.	10.	9.6	5.2	0.2	124	1.2	92.	3.2
UMATILLA COUNTY															
01	BINGHAM SPRINGS	45-44.47 118-13.96 03N/037E -18 NE	54/04	765	34.4	8.6	68.	133.	7.6	14.	3.5	82	0.2	192.	4.0
03	LEHMAN SPRINGS	45-09.06 118-39.55 05S/033E -12 NE	72/00	252	61.0	9.18	44.	53.	0.7	0.9	0.1	127	23.	5.4	2.1
UNION COUNTY															
01	COVE WARM SPRING	45-17.67 117-48.38 03S/040E -22 NW	57/06	150	29.4	9.8	29.	30.	0.5	1.6		70	5.8	5.0	0.3
01	WELL	45-19.89 118-05.43 03S/038E -05 SW	55/01		27.	7.9	84.	27.	5.	5.	0.3		3.3	3.2	0.5
01	WELL	45-19.89 118-05.43 03S/038E -05 SW	55/01		25.	7.9	72.	30.	5.	4.8	1.3	63	4.8	2.1	0.5
01	WELL	45-20.07 118-05.83 03S/038E -06 NE	57/05	146	27.		71.	19.	5.	10.	0.2	84	4.5	1.	0.5
02	HOT LAKE	45-14.63 117-57.51 04S/039E -05 SE	72/00	688	80.0	9.21	48.	130.	2.7	4.9	<0.1	99	56.	140.	1.7
05	WAGNER WELL	45-27.43 117-59.84 01S/038E -24 SE	50/08	148	29.	8.0		28.	4.0	3.6	0.8	72	8.3	3.1	2.0
07	MEDICAL HOT SPRINGS	45-01.08 117-37.48 06S/041E -25 NE			60.0		97.	191.	3.4	62.	1.2	22	432.	77.	
07	MEDICAL HOT SPRINGS	45-01.08 117-37.48 06S/041E -25 NE	73/00	1173	60.0	8.23	80.	190.	7.0	72.	0.2	28	400.	77.	1.2
WALLOWA COUNTY															
01	COOK CREEK WARM SPRING	45-53.49 116-52.41 05N/048E -30 NW	74/11	610	36.0	7.95	46.1	61.	2.5	36.	1.1	44	163.8	20.	0.09
WASCO COUNTY															
01	KAHNEETAH HOT SPRINGS	44-51.72 121-12.05 08S/013E -20 NE	73/00	1370	52.0	8.32	104.	325.	3.4	3.2	<0.05	511	34.	155.	21.
02	MILTON MARTIN WELL	45-31.70 121-12.95 01N/013E -32 NE	58/07	279	22.2	8.5	84.	41.	7.2	15.	2.9	167	2.4	6.0	0.9
03	J. SANDOZ WELL	45-33.8 121-16.6 01N/012E -38	58/07	378	27.8	7.9	95.	62.	11.	16.	4.6		1.5	7.5	1.6

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
MARION COUNTY													
01	BREITENBUSH HOT SPRINGS - WELL	5.43	1.9										
MULTNOMAH COUNTY													
01	CORBETT WARM SPRING	1.2	0.03						0.01	0.16	0.20	0.10	
02	YMCA CAMP COLLINS	0.38							0.5		0.06		
UMATILLA COUNTY													
01	BINGHAM SPRINGS	10.							0.2		0.20		
03	LEHMAN SPRINGS	0.12	0.03	<0.02	<0.1	<0.05	0.006	0.001			<0.02	<0.02	0.0003
UNION COUNTY													
01	COVE WARM SPRING	0.08							ND				
01	WELL												
01	WELL												
01	WELL												
02	HOT LAKE	2.9	0.03	<0.02	<0.1	<0.05	0.4	0.08			<0.02	<0.02	0.0032
05	WAGNER WELL	0.1							0.2				
07	MEDICAL HOT SPRINGS												
07	MEDICAL HOT SPRINGS	2.2	0.05	0.02	<0.1	0.80	0.2				<0.02	<0.02	0.0004
WALLOWA COUNTY													
01	COOK CREEK WARM SPRING		<0.01						0.13	0.16	0.15	<0.05	
WASCO COUNTY													
01	KAHNEETAH HOT SPRINGS	2.6	0.52	0.02	<0.1	<0.05					<0.02	<0.02	0.0003
02	MILTON MARTIN WELL								ND	1.0	0.03	ND	
03	J. SANDOZ WELL									ND	0.04	ND	

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geoogical Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
BAKER COUNTY				
01	RADIUM HOT SPRINGS	55/05	HAINES 1:24000	SCOTT AND BARKER, 1962
01	RADIUM HOT SPRINGS	72/00	HAINES 1:24000, BAKER 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
02	SAM-O SPRING	77/02	BAKER 1:24000, BAKER 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
05	KROPP HOT SPRING		NORTH POWDER 1:24000, GRANGEVILLE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
06	FISHER HOT SPRING	72/06	ROCK CREEK 1:24000, CANYON CITY 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
CLACKAMAS COUNTY				
01	ACID-SULFATE SPRING ON MT. HOOD	76/06	MT. HOOD SOUTH 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01	MT. HOOD FUMAROLES	35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01	MT. HOOD FUMAROLES	35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01	MT. HOOD FUMAROLES	35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01	MT. HOOD FUMAROLES	51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
02	SWIM WARM SPRINGS	76/12	MT. HOOD SOUTH 1:24000, THE DALLES 1:250000	OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY, UNPUBLISHED DATA
03	AUSTIN HOT SPRINGS (CAREY)	72/00	FISH CREEK MTN. 1:62500, VANCOUVER 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
04	BAGBY HOT SPRINGS	70/03	BATTLE AX 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
04	BAGBY HOT SPRINGS	77/09	BATTLE AX 1:62500	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	76/08	HIGH ROCK 1:62500, THE DALLES 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
DESCHUTES COUNTY				
01	EAST LAKE HOT SPRINGS	73/00	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	MARINER AND OTHERS, 1975
01	EAST LAKE HOT SPRINGS	75/08	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01	EAST LAKE HOT SPRINGS	77/07	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02	PAULINA HOT SPRINGS		NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02	PAULINA HOT SPRINGS	77/07	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02	WARM WELL AT LITTLE CRATER CAMPGROUND	75/08	NEWBERRY CRATER 1:125000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
DOUGLAS COUNTY				
01	UMPQUA HOT SPRINGS	77/09	TOKETEE FALLS 1:62500	MARINER AND OTHERS, 1978
01	UMPQUA HOT SPRINGS	78/06	TOKETEE FALLS 1:62500	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
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Map Code	Name	Sample Date	Map Reference	Analysis Reference
GRANT COUNTY				
01	RITTER HOT SPRINGS	73/00	RITTER 1:62500, CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
04	BLUE MOUNTAIN HOT SPRINGS	72/00	PRAIRIE CITY 1:62500, CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
05	JOAQUIN MILLER RESORT	78/07	CANYON MTN. 1:24000, JOHN DAY 1:62500	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
07	WEBERG HOT SPRING	72/00	CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
HARNEY COUNTY				
01	UNNAMED SPRING	31/09	BUCHANAN 1:24000	PIPER AND OTHERS, 1939
02	O. J. THOMAS	68/09	HARNEY 1:62500	LEONARD, 1970
04	MILLPOND SPRING	31/08	BURNS 1:24000	PIPER AND OTHERS, 1939
05	HARNEY VALLEY DEV CO. OIL TEST WELL	68/09	HARNEY 1:62500	LEONARD, 1970
08	ISLAND RANCH WELL	69/08	LAWEN 1:62500	LEONARD, 1970
09	CRANE HOT SPRINGS	31/08	CRANE 1:62500, BURNS 1:250000	PIPER AND OTHERS, 1939
09	CRANE HOT SPRINGS	68/09	CRANE 1:62500	LEONARD, 1970
09	CRANE HOT SPRINGS	72/00	CRANE 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
10	WARM SPRING NEAR VENATOR	77/06	BURNS 1:250000	GONTHIER AND OTHERS, 1977
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	31/08	BURNS 1:250000	PIPER AND OTHERS, 1939
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	72/00	CRANE 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
22	MICKEY SPRINGS	70/07	ADEL 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
22	MICKEY SPRINGS	72/00	ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	55/11	ADEL 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	72/00	ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
23	ALVORD HOT SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
24	HOT BORAX LAKE	53/07	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
24	HOT BORAX LAKE	61/06	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA

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Map Code	Name	Sample Date	Map Reference	Analysis Reference
HARNEY COUNTY				
24	HOT BORAX LAKE	72/00	BORAX LAKE 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
27	UNNAMED HOT SPRING NEAR TROUT CREEK	70/08	ADEL 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
27	UNNAMED HOT SPRING NEAR TROUT CREEK	72/00	ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
39	GOODMAN SPRING (HOTCHKISS)	68/09	BURNS 1:24000	LEONARD, 1970
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	53/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	53/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	57/05	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73/06	BORAX LAKE 1:24000, ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
44	HOTCHKISS WELL	31/08	BURNS 1:24000	PIPER AND OTHERS, 1939
44	HOTCHKISS WELL	68/09	BURNS 1:24000	LEONARD, 1970
45	HINES LUMBER CO. WELL	68/07	BURNS 1:24000, BURNS 1:62500	LEONARD, 1970
46	CITY OF HINES WELL	68/07	BURNS 1:24000, BURNS 1:62500	LEONARD, 1970
JACKSON COUNTY				
01	JACKSON HOT SPRING	52/04	ASHLAND 1:62500	ROBISON, 1972
KLAMATH COUNTY				
	ALFRED JACOBSEN	74/05	MERRILL 1:62500	SAMMEL, 1976
	ANNIE SPRING		CRATER LAKE NATIONAL PARK AND VICINITY 1:62500	SAMMEL, 1976
	BILL HILL	74/06	MERRILL 1:62500	SAMMEL, 1976
	CLAUDE SHUCK	74/05	MERRILL 1:62500	SAMMEL, 1976
	CLYDE DEHILINGER	74/06	MERRILL 1:62500	SAMMEL, 1976
	FALCON HEIGHTS SCHOOL	74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
	GEORGE CARTER	74/06	MERRILL 1:62500	SAMMEL, 1976
	GEORGE STACY CO.	74/06	MERRILL 1:62500	SAMMEL, 1976
	JACK O'CONNER	74/05	MERRILL 1:62500	SAMMEL, 1976
	LEN DOBRY	74/05	MERRILL 1:62500	SAMMEL, 1976

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Map Code	Name	Sample Date	Map Reference	Analysis Reference
KLAMATH COUNTY				
	LESTER BROOKSHIRE	74/05	MERRILL 1:62500	SAMMEL, 1976
	MELVIN MCCOLLUM	74/05	MERRILL 1:62500	SAMMEL, 1976
	MONTE DEHILINGER	74/06	MERRILL 1:62500	SAMMEL, 1976
	O'CONNER LIVESTOCK CO.	74/06	MERRILL 1:62500	SAMMEL, 1976
	OREGON WATER CORP.(4)	70/08	MERRILL 1:62500	SAMMEL, 1976
	POPE'S MEAT CO.	74/06	MERRILL 1:62500	SAMMEL, 1976
	RAY BIXLER	74/05	MERRILL 1:62500	SAMMEL, 1976
	ROBERT LANGLEY	74/05	MERRILL 1:62500	SAMMEL, 1976
	S. AND C. KILGORE		GERBER RESERVOIR 1:62500	SAMMEL, 1976
	TOWN OF MERRILL	55/02	MERRILL 1:62500	NEWCOMB AND HART, 1958
	U.S. AIR FORCE(1)	72/10	KLAMATH FALLS 1:62500	SAMMEL, 1976
	U.S. AIR FORCE(2)	72/10	KLAMATH FALLS 1:62500	SAMMEL, 1976
	WEYERHAUSER WELL NO. 4	72/08	KLAMATH FALLS 1:62500	SAMMEL, 1976
01	EAGLE POINT SPRING	72/08	MODOC POINT 1:62500	SAMMEL, 1976
02	J. E. FRIESEN	55/02	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02	LOIS MERRUYS	54/12	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02	MEDO-BELL DAIRY	55/01	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02	MEDO-BELL DAIRY	75/07	KLAMATH FALLS 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
02	MILLS SCHOOL		KLAMATH FALLS 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
02	MOYINA WATER CO.	66/08	MERRILL 1:62500	SAMMEL, 1976
02	O.I.T. NO. 5	67/00	KLAMATH FALLS 1:62500	PETERSON AND GROH, 1967
02	O.I.T. NO. 6	72/08	KLAMATH FALLS 1:62500	SAMMEL, 1976
02	O.I.T. NO. 6	75/03	KLAMATH FALLS 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
02	OREGON WATER CORP.(1)	30/03	KLAMATH FALLS 1:62500	SAMMEL, 1976
02	OREGON WATER CORP.(2)	71/09	KLAMATH FALLS 1:62500	SAMMEL, 1976
02	OREGON WATER CORP.(3)	71/09	KLAMATH FALLS 1:62500	SAMMEL, 1976
03	HOWARD HOLLIDAY	74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
04	MAZAMA SCHOOL		MERRILL 1:62500	SAMMEL, 1976
06	ABE BOEHM	74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
06	ABE BOEHM	75/08	KLAMATH FALLS 1:62500	NEHRING AND OTHERS, 1979
06	DAN O'CONNER	74/05	MERRILL 1:62500	SAMMEL, 1976
06	JACK LISKEY	74/05	MERRILL 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
06	JACK LISKEY	74/05	MERRILL 1:62500	SAMMEL, 1976
06	JACK LISKEY	75/08	MERRILL 1:62500	NEHRING AND OTHERS, 1979
06	O. H. OSBORN	74/05	MERRILL 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
07	OLENE GAP HOT SPRINGS	67/00	MERRILL 1:62500	PETERSON AND GROH, 1967
07	OLENE GAP HOT SPRINGS	72/00	MERRILL 1:62500, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974
				MARINER AND OTHERS, 1975
07	OLENE GAP HOT SPRINGS	75/07	MERRILL 1:62500	SAMMEL, 1976
				NEHRING AND OTHERS, 1979
08	ROENICKE HOT SPRING	72/10	MERRILL 1:62500	SAMMEL, 1976
16	MELVIN FEIGI	70/10	MERRILL 1:62500	LEONARD AND HARRIS, 1974
22	RAY SMITH WELL	70/10	BEATTY 1:62500	LEONARD AND HARRIS, 1974
23	KLAMATH ICE CO.	36/04	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
24	J. K. O'NEIL	72/03	MERRILL 1:62500	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

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[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geoogical Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
KLAMATH COUNTY				
24	J. K. O'NEIL	74/05	MERRILL 1:62500	SAMMEL, 1976
LAKE COUNTY				
05	ANA RIVER SPRING	48/12	KLAMATH FALLS 1:250000	TRAUGER, 1950
14	SUMMER LAKE HOT SPRING (WOODWARD)	48/10	SLIDE MTN. 1:24000	TRAUGER, 1950
14	SUMMER LAKE HOT SPRING (WOODWARD)	72/00	SLIDE MTN. 1:24000, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
23	HUNTERS HOT SPRINGS (LAKEVIEW)	56/10	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	HUNTERS HOT SPRINGS (LAKEVIEW)	57/10	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	HUNTERS HOT SPRINGS (LAKEVIEW)	72/00	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
24	LEITHEAD HOT SPRINGS (JOYLAND PLUNGE, LEO	48/06	LAKEVIEW NE 1:24000	TRAUGER, 1950
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	48/05	LAKEVIEW NE 1:24000	TRAUGER, 1950
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	72/00	LAKEVIEW NE 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
28	ANTELOPE HOT SPRINGS	48/08	WARNER PEAK 1:24000	TRAUGER, 1950
32	FISHER HOT SPRINGS	72/00	CRUMP LAKE 1:24000, ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
33	CRUMP SPRING	48/09	ADEL 1:24000	TRAUGER, 1950
33	CRUMP SPRING	72/00	ADEL 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
33	CRUMP WELL (1)	59/07	ADEL 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
33	CRUMP WELL (2)	60/09	ADEL 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
LANE COUNTY				
01	BELKNAP HOT SPRINGS	03/00	MCKENZIE BRIDGE 1:62500	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01	BELKNAP HOT SPRINGS	72/00	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
02	FOLEY SPRINGS	76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	73/00	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
04	WALL CREEK WARM SPRINGS	76/03	SARDINE BUTTE 1:62500, ROSEBERG 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
05	MCCREDIE SPRINGS	74/00	OAKRIDGE 1:62500, ROSEBERG 1:250000	MARINER AND OTHERS, 1975
05	MCCREDIE SPRINGS	76/03	OAKRIDGE 1:62500, ROSEBERG 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

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Map Code	Name	Sample Date	Map Reference	Analysis Reference
LANE COUNTY				
06	KITSON SPRINGS	58/03	OAKRIDGE 1:62500	MADISON, 1966
06	KITSON SPRINGS	78/05	OAKRIDGE 1:62500	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
08	BIGELOW HOT SPRINGS	76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
MALHEUR COUNTY				
03	NEAL HOT SPRINGS	72/00	JAMIESON 1:62500, BAKER 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
04	BEULAH HOT SPRINGS	72/00	BEULAH 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
05	VALE HOT SPRINGS	74/00	VALE EAST 1:24000, BOISE 1:250000	MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
05	VALE HOT SPRINGS	74/08	VALE EAST 1:24000	NEHRING AND OTHERS, 1979
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	73/00	HARPER 1:62500, BOISE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
08	MITCHELL BUTTE HOT SPRINGS	72/00	MITCHELL BUTTE 1:24000, BOISE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
18	UNNAMED HOT SPRING AT THREE FORKS	35/07	JORDAN VALLEY 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
18	UNNAMED HOT SPRING AT THREE FORKS	73/00	JORDAN VALLEY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
19	UNNAMED HOT SPRING NEAR MCDERMITT	57/05	JORDAN VALLEY 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
19	UNNAMED HOT SPRING NEAR MCDERMITT	72/00	JORDAN VALLEY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
23	LUCE HOT SPRINGS	72/00	MCEWEN BUTTE 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
24	JONESBORO WARM SPRING		WESTFALL BUTTE 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
25	JUNTURA WARM SPRING #1		BEULAH 1:62500, BURNS 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
26	JUNTURA WARM SPRING #2		BEULAH 1:62500, BURNS 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
27	ARTESIAN WELL	77/03	ADRIAN 1:24000, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
28	ALKALI FLAT GRADIENT WELL	75/05	MOORES HOLLOW 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
29	NORTH HARPER BLM WELL	76/06	JAMIESON 1:62500, BAKER 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
30	UNNAMED WARM SPRING NEAR BULLY CREEK	77/06	JAMIESON 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
MARION COUNTY				
01	BREITENBUSH HOT SPRINGS	72/00	BREITENBUSH HOT SPRINGS 1:62500	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
01	BREITENBUSH HOT SPRINGS - WELL	78/02	BREITENBUSH HOT SPRINGS 1:62500	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA NEHRING AND OTHERS, 1979

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geoogical Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
MULTNOMAH COUNTY				
01	CORBETT WARM SPRING		WASHOUGAL 1:24000, VANCOUVER 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
02	YMCA CAMP COLLINS	56/09	WASHOUGAL 1:24000, VANCOUVER 1:250000	NEWCOMB, 1972
UMATILLA COUNTY				
01	BINGHAM SPRINGS	54/04	BINGHAM SPRINGS 1:24000, PENDLETON 1:250000	HOGENSON, 1964
03	LEHMAN SPRINGS	72/00	LEHMAN SPRINGS 1:24000, PENDLETON 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
UNION COUNTY				
01	COVE WARM SPRING	57/06	COVE 1:24000, GRANGEVILLE 1:250000	HAMPTON AND BROWN, 1964
01	WELL	55/01	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
01	WELL	55/01	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
01	WELL	57/05	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
02	HOT LAKE	72/00	CRAIG MTN. 1:24000, GRANGEVILLE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
05	WAGNER WELL	50/08	IMBLER 1:24000	HAMPTON AND BROWN, 1964
07	MEDICAL HOT SPRINGS		FLAGSTAFF BUTTE 1:24000, GRANGEVILLE 1:250000	LINDGREN, 1901
07	MEDICAL HOT SPRINGS	73/00	FLAGSTAFF BUTTE 1:24000, GRANGEVILLE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
WALLOWA COUNTY				
01	COOK CREEK WARM SPRING	74/11	WAPSHILLA CREEK 1:24000, GRANGEVILLE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
WASCO COUNTY				
01	KAHNEETAH HOT SPRINGS	73/00	EAGLE BUTTE 1:24000, BEND 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
02	MILTON MARTIN WELL	58/07	THE DALLES 1:62500, THE DALLES 1:250000	NEWCOMB, 1972
03	J. SANDOZ WELL	58/07	WHITE SALMON 1:62500,THE DALLES 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

geothermometry. The only other waters which "stand out" as chemically different are from the base of Mt. Hood and Newberry Caldera. These waters have unusually large concentrations of magnesium for thermal fluids, probably due to water-rock reaction at low tempertures. The rest of the samples are from southeastern and southcentral Oregon where volcanic flows are interbedded with tuffaceous sediments. The waters from these springs contain more nearly equal proportions of sulfate, chloride, and bicarbonate.

Table 3 contains gas and isotopic data for the relatively small number of springs for which data exist. The data from Mt. Hood and East Lake are misleading. The Mt. Hood analyses are from fumaroles which discharged principally water vapor. Air contamination appears to be a problem in all of these samples. However, it is probable that carbon dioxide is the principal gas rising from depth. The water vapor is probably from the vaporization of liquid water in fractures and pore spaces. The East Lake-Paulina Lake gas samples are also contaminated by air and altered by gas-water reaction. The thermal "springs" at East and Paulina lakes issue in or at the shoreline of the respective lakes. The proportions of the various gases in these samples appear to be controlled by the discharge rates. Vents with the largest gas discharges have the highest proportions of carbon dioxide. The slower the discharge rate, the cooler the water in contact with the gas, and the more CO_2 will dissolve. The methane and carbon dioxide do not appear to have a common origin since the carbon dioxide appears to be of deep origin (δC13 = -6 permil) while the methane appears to be of biologic origin (δC13 about -50 permil). It is probable that the methane originates from the anaerobic decay of plant material trapped in the lava and ash flows. Finally, some air contamination may be unavoidable in these samples since nitrogen and oxygen may be exsolving from the cold lake water as the hot CO_2-charged gas from depth contacts it.

In terms of the deuterium and oxygen(18) isotopic compositions (table 3) of the thermal waters, four samples appear to have undergone considerable evaporation: East Lake, Hot Borax Lake, and samples from the Abe Boehm and Jack Liskey wells near Klamath Falls. These samples are all greatly enriched (>10 permil) relative to nearby fresh and thermal waters, and have appreciable oxygen shifts relative to meteoric water.

The O^{18} compositions of dissolved sulfate range from +15 to -10 permil. Marine sulfates are typically about +15 permil, while high-temperature hydrothermal systems are usually about -10 permil.

Table 3: GAS AND ISOTOPIC COMPOSITION OF THERMAL SPRING AND WELL DISCHARGES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Isotopic compositions in the standard notation and are relative to SMOW;
Gas concentrations in volume percent; (*) Ar + O2]

Map Code	Name	Date	Temp (C)	Argon (% Ar)	Methane (% CH4)	Carbon Dioxide (% CO2)	Nitrogen (% N2)	Oxygen (% O2)	Del D of H2O (o/oo)	Del O(18) of H2O (o/oo)	Del O(18) of SO4 (o/oo)
BAKER COUNTY											
01	RADIUM HOT SPRINGS	72/00	58.						-138.3	-17.85	
CLACKAMAS COUNTY											
01	MT. HOOD FUMAROLES	35/00	89.4		0.0011	1.13	0.116	0.011			
01	MT. HOOD FUMAROLES	35/00	71.1			0.68	78.5	19.5			
01	MT. HOOD FUMAROLES	35/00	89.4			1.27	0.057	0.001			
01	MT. HOOD FUMAROLES	51/00			0.0005	1.49	0.035	0.004			
01	MT. HOOD FUMAROLES	51/00	89.4		0.0010	2.23	0.041	0.004			
01	MT. HOOD FUMAROLES	51/00			0.0014	2.12	0.044	0.003			
01	MT. HOOD FUMAROLES	51/00	91.1		0.0011	1.81		0.006			
01	MT. HOOD FUMAROLES	51/00	86.1			17.4	9.8	2.48			
01	MT. HOOD FUMAROLES	51/00	89.4		0.0006	1.43	0.032	0.003			
02	SWIM WARM SPRINGS	76/12	26.0							-14.01	1.52
03	AUSTIN HOT SPRINGS (CAREY)	72/00	86.0						-94.5	-12.22	-2.41
DESCHUTES COUNTY											
01	EAST LAKE HOT SPRINGS	73/00	62.0		9.	56.	30.	6*	-76.2	-9.42	
01	EAST LAKE HOT SPRINGS	75/08	49.		2.9	91.	5.1	0.9			
01	EAST LAKE HOT SPRINGS	77/07			1.95	95.55		2.72*			
02	PAULINA HOT SPRINGS				5.41	71.37					
02	PAULINA HOT SPRINGS	77/07		0.09	0.55	93.45	4.74	0.03			
DOUGLAS COUNTY											
01	UMPQUA HOT SPRINGS	77/09	46.5	<0.02	<0.005	99.38	0.49	0.04			
GRANT COUNTY											
01	RITTER HOT SPRINGS	73/00	41.0						-119.	-14.83	
04	BLUE MOUNTAIN HOT SPRINGS	72/00	58.0						-126.6	-16.13	
07	WEBERG HOT SPRING	72/00	46.0		2.	95.	1.	1*	-122.1	-15.14	
HARNEY COUNTY											
09	CRANE HOT SPRINGS	72/00	78.0						-133.5	-16.17	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	72/00	68.0		1.	9.	91.	1*	-128.5		
22	MICKEY SPRINGS	72/00	73.0		1.	23.	60.	18*	-124.3	-13.42	-7.91
23	ALVORD HOT SPRINGS	72/00	76.0						-123.6	-13.23	-6.05
24	HOT BORAX LAKE	72/00	36.0						-115.8	-11.57	-7.95
27	UNNAMED HOT SPRING NEAR TROUT CREEK	72/00	52.0						-127.4	-16.17	-9.22
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73/06	96.0						-125.4	-14.36	-8.58
KLAMATH COUNTY											
	ANNIE SPRING		25.0							-14.40	
	FALCON HEIGHTS SCHOOL	74/05	37.0						-120.5	-15.69	
	MELVIN MCCOLLUM	74/05	25.0						-113.2	-14.71	
	S. AND C. KILGORE		20.0							-16.30	
	WEYERHAUSER WELL NO. 4	72/08	22.						-109.1	-14.60	
01	EAGLE POINT SPRING	72/08	35.						-109.7	-15.22	
02	MEDO-BELL DAIRY	75/07	81.						-119.4	-14.95	-5.45
02	MILLS SCHOOL		89.0						-121.8	-14.83	-4.94
02	O.I.T. NO. 6	75/03	79.						-118.7	-14.99	-5.45

Table 3: GAS AND ISOTOPIC COMPOSITION OF THERMAL SPRING AND WELL DISCHARGES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Isotopic compositions in the standard notation and are relative to SMOW;
Gas concentrations in volume percent; (*) Ar + O2]

Map Code	Name	Date	Temp (C)	Argon (% Ar)	Methane (% CH4)	Carbon Dioxide (% CO2)	Nitrogen (% N2)	Oxygen (% O2)	Del D of H2O (o/oo)	Del O(18) of H2O (o/oo)	Del O(18) of SO4 (o/oo)
KLAMATH COUNTY											
06	ABE BOEHM	74/05	25.0						-73.2	-7.38	
06	ABE BOEHM	75/08	25.							-6.78	15.42
06	JACK LISKEY	74/05	93.0						-116.6	-14.95	-2.13
06	JACK LISKEY	74/05	22.0						-87.2	-8.83	
06	JACK LISKEY	75/08	25.							-8.57	8.69
06	O. H. OSBORN	74/05	90.0						-117.0	-14.95	-1.85
07	OLENE GAP HOT SPRINGS	72/00	74.0						-113.3	-13.00	
07	OLENE GAP HOT SPRINGS	75/07	87.						-115.3	-13.73	-4.82
16	MELVIN FEIGI	70/10	31.0							-16.80	
LAKE COUNTY											
14	SUMMER LAKE HOT SPRING (WOODWARD)	72/00	43.0						-115.0	-13.32	-4.00
23	HUNTERS HOT SPRINGS (LAKEVIEW)	72/00	96.0						-119.0	-14.32	-3.69
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	72/00	88.0		42.	2.	54.	2*	-119.4	-13.72	
32	FISHER HOT SPRINGS	72/00	68.0						-117.0		
33	CRUMP SPRING	72/00	78.0		6.	14.	75.	5*	-115.5	-13.28	-4.71
LANE COUNTY											
01	BELKNAP HOT SPRINGS	72/00	71.0						-95.8	-11.74	0.35
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	73/00	44.0						-92.5	-11.97	
05	MCCREDIE SPRINGS	74/00	73.		<1.	<1.	98.	1*	-94.0		
MALHEUR COUNTY											
03	NEAL HOT SPRINGS	72/00	87.0		6.		62.	12*	-138.7	-16.52	-8.37
04	BEULAH HOT SPRINGS	72/00	60.0						-131.7	-13.22	
05	VALE HOT SPRINGS	74/00	73.0						-135.0	-15.18	-6.56
05	VALE HOT SPRINGS	74/08	90.							-15.30	-3.91
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	73/00	70.0						-139.7	-16.52	-8.63
08	MITCHELL BUTTE HOT SPRINGS	72/00	62.0						-137.3	-16.58	
18	UNNAMED HOT SPRING AT THREE FORKS	73/00	34.0						-127.4	-16.09	
19	UNNAMED HOT SPRING NEAR MCDERMITT	72/00	52.0						-134.6	-16.95	
23	LUCE HOT SPRINGS	72/00	63.0						-134.0	-15.15	
MARION COUNTY											
01	BREITENBUSH HOT SPRINGS	72/00	92.0						-97.5	-11.66	-2.67
01	BREITENBUSH HOT SPRINGS - WELL	78/02	110.0							-12.59	-3.28
UMATILLA COUNTY											
03	LEHMAN SPRINGS	72/00	61.0		<0.1	<0.1	94.	4*	-121.3	-16.52	
UNION COUNTY											
02	HOT LAKE	72/00	80.0		9.	<1.	90.	2*	-127.7	-16.56	4.63
07	MEDICAL HOT SPRINGS	73/00	60.0						-130.2	-16.99	
WASCO COUNTY											
01	KAHNEETAH HOT SPRINGS	73/00	52.0						-118.9	-14.75	

GEOTHERMOMETRY

The chemical composition of the thermal waters can be used, under certain conditions, to provide estimates of the last temperature of equilibrium of the water and the country rock. The variables which are most often used include silica concentration, and relative proportions among sodium, potassium, calcium, and magnesium. Sufficient isotopic data on sulfate and water are available on some of the samples to calculate temperatures of equilibrium from the sulfate-water isotope geothermometer. The silica, Na-K-Ca, and sulfate-water geothermometers, which are used to estimate most of the temperatures, are valid only for hot-water systems and only when certain assumptions are met. These assumptions, discussed in detail by Fournier and others (1974), are listed below:

1. Temperature-dependent reactions at depth control the concentration of the constituents used in the geothermometer.
2. The reservoir contains an adequate supply of the reactants.
3. Water-rock equilibrium is established in the reservoir.
4. The constituents used in the geothermometer do not re-equilibrate with the confining rock as the water flows to the surface.
5. Mixing of thermal and nonthermal groundwater does not occur.

The concentration of silica in a thermal water depends prinipally on the temperature-dependent solubility of quartz, chalcedony, alpha-cristobalite, or amorphous silica (Fournier, 1973; Fournier and Rowe, 1966). The dissolved silica is generally present as H_4SiO_4, which is the silica species in equilibrium with the respective silica mineral:

$$\underset{\text{silicic acid}}{H_4SiO_4} = \underset{\text{silica mineral}}{SiO_2} + \underset{\text{water}}{2H_2O} \qquad (1)$$

This is the reaction on which all of the silica geothermometers are based. We may make the following practical generalizations:

1. The solubility of quartz limits silica concentrations in all high-temperature reservoirs (>180°C) and quartz may be the

limiting mineral in granitic aquifers down to temperatures at least as low as 90°C (R. O. Fournier, oral communication).

2. Chalcedony limits silica concentrations in lower-temperature reservoirs and may be the limiting mineral in basaltic rock up to 180°C (Arnorsson, 1975).

The silica geothermometers give apparently good results in thermal systems which are associated with springs of neutral to slightly acid pH. However, several thermal systems listed in the tables discharge dilute alkaline waters with anamolously large silica concentrations. These dilute thermal waters contain little or no dissolved carbon dioxide and typically occur in granitic terrains. Since the silica geothermometers are based on equilibrium with H_4SiO_4, the concentration of this dissolved species must be calculated to obtain an accurate estimate of the temperature in the thermal reservoir. At any temperature and pH, the total dissolved silica concentration is distributed among H_4SiO_4, $H_3SiO_4^-$, and $H_2SiO_4^{-2}$:

$$H_4SiO_4 = H_3SiO_4^- + H^+ \qquad (2)$$

and

$$H_3SiO_4^- = H_2SiO_4^{-2} + H^+ \qquad (3)$$

Equation (3) is important only at very alkaline pH's (>10) and is not important for the thermal waters encountered in Oregon. Equation (2), however, is important in waters with pH's above 8. For example, at a temperature of 80°C and pH of 9, approximately 44 percent of the dissolved silica is in the dissociated form ($H_3SiO_4^-$); while, at a pH of 7, less than 1 percent of the dissolved silica is in the dissociated form. For example, if total dissolved silica is 100 mg/L, and chalcedony is the limiting silica mineral then temperature estimates should be reduced from 111°C (pH 7) to 78°C (pH 9). To correct for the dissociation of silica, we have used a correction which requires that the pH of the thermal spring is approximately the same as that in the thermal reservoir. This assumption requires that the equilibrium constants for the weak acids remain approximately constant despite temperature changes. The concentration of silicic acid (H_4SiO_4) is calculated at the spring temperature and pH. This concentration, recast as SiO_2, is used in the appropriate geothermometer. This correction works best in systems which have aquifer-temperatures near the measured spring temperature. Corrected values for the waters with high pH's are shown in parentheses in table 4. Changes in the dissociation constants of the weak acids as functions of temperature will result in temperature estimates which are slightly too low for systems in which the true aquifer temperature is appreciably above the spring temperature.

Mixing of thermal (high silica) and nonthermal (low silica) waters can sharply reduce the temperatures estimated from the silica geothermometers. However, it is possible to calculate the temperature of the thermal aquifer if sufficient chemical and isotopic data are available for both the thermal and cold waters, if chemical equilibrium has not taken place at or below the mixing temperature, and if there has been no conductive heat loss (Fournier and Truesdell, 1974). The problem with any unexplored system is in proving that the water issuing at the surface is mixed. The simplest proof would be a linear trend between measured spring temperatures and chloride concentration. Normal groundwater usually has low chloride concentrations, while thermal waters from high-temperature systems contain at least several hundred milligrams per liter chloride. A linear trend between the isotopic compositions of the water (deuterium and oxygen(18)) and dissolved chloride is also definitive proof of mixing. Thermal and shallow groundwaters do not usually originate from the same precipitation area and so they have different deuterium concentrations. Since deuterium concentrations do not usually change as a result of water-rock reactions, source waters are isotopically "tagged" and change composition only by mixing or evaporation (boiling). The oxygen isotopic compositions of thermal and fresh waters usually differ by several parts per mil. As water-rock reaction proceeds, the water becomes progressively enriched in the heavier oxygen atoms. Very few areas have a sufficient number of springs of differing chemical and isotopic composition to prove mixing by the rigorous criteria discussed above. Mixing models were not used in preparing table 4, since mixing has not been demonstrated at most sites.

The Na-K-Ca geothermometer (Fournier and Truesdell, 1973) is based on an empirical relationship between the proportions of sodium to potassium, square root of calcium to sodium, and measured reservoir temperatures. Temperatures estimated from the Na-K-Ca geothermometer can be sharply increased by loss of calcium after the thermal fluid leaves the reservoir. Sensitivity of the geothermometer to loss of calcium can be tested in a specific water by doubling the measured calcium concentration and recalculating the estimated reservoir temperature. A change of only a few degrees indicates that the loss of calcium does not appreciably alter the estimated reservoir temperature. High magnesium concentrations or large magnesium

Table 4: GEOTHERMOMETER CALCULATIONS(C)
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Numbers in parentheses are calculated from silicic acid (H4SiO4) concentration calculated at the spring temperature;
Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate-water
BAKER COUNTY											
01	RADIUM HOT SPRINGS	57.2	106	130	97		125(65)	122	97(33)	6	
01	RADIUM HOT SPRINGS	58.0	81	108	77		124(69)	121	96(37)	5	
02	SAM-O SPRING	27.0	152	165	120	52	116	115	88	-1	
05	KROPP HOT SPRING	43.0	74	110	100		109	109	79	-8	
06	FISHER HOT SPRING	37.0					90(44)	93	60(11)	-24	
CLACKAMAS COUNTY											
01	ACID-SULFATE SPRING ON MT. HOOD		114	90	-16		62	67	29	-48	
02	SWIM WARM SPRINGS	26.0	165	159	83	cold	120	118	91	2	109
03	AUSTIN HOT SPRINGS (CAREY)	86.0	91	118	87	90	126	123	98	7	181
04	BAGBY HOT SPRINGS	57.2	70	93	49		126(65)	123	98(33)	7	
04	BAGBY HOT SPRINGS	58.0	68	91	49		121(78)	119	93(47)	3	
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	35.6	140	137	61		87	90	56	-27	
DESCHUTES COUNTY											
01	EAST LAKE HOT SPRINGS	62.0	188	155	44		87	90	56	-27	
01	EAST LAKE HOT SPRINGS	49.0					180	168	158	56	
02	PAULINA HOT SPRINGS		190	178	98	cold	182	170	161	58	
02	WARM WELL AT LITTLE CRATER CAMPGROUND	35.5	189	169	75	cold	166	156	142	43	
DOUGLAS COUNTY											
01	UMPQUA HOT SPRINGS	46.5	96	135	141	100	131	128	104	12	
01	UMPQUA HOT SPRINGS	46.0	101	136	132	108	135	131	108	15	
GRANT COUNTY											
01	RITTER HOT SPRINGS	41.0	60	92	71		118(68)	117	90(31)		
04	BLUE MOUNTAIN HOT SPRINGS	58.0	91	126	118		99	100	69	-16	
05	JOAQUIN MILLER RESORT	40.0	89	121	104	61					
07	WEBERG HOT SPRING	46.0	140	169	162	92	126	124	99	7	
HARNEY COUNTY											
02	O. J. THOMAS	72.0	60	104	116	102	131(71)	127	103(39)	11	
05	HARNEY VALLEY DEV CO. OIL TEST WELL	46.0	61	105	115	96	120	118	91	1	
08	ISLAND RANCH WELL	41.0	60	120	196	115	105(76)	106	76(45)	-11	
09	CRANE HOT SPRINGS	80.0	86	120	109		125	122	97	6	
09	CRANE HOT SPRINGS	78.0	90	124	113		127	124	99	8	
10	WARM SPRING NEAR VENATOR	41.0	55	88	67		226(192)	205	213(173)	101	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	59.0	82	126	144	82	133	129	105	13	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	68.0	85	130	150	105	133	129	105	13	
22	MICKEY SPRINGS	85.0	120	179	272	111	168	158	145	45	
22	MICKEY SPRINGS	73.0	145	207	330	204	180	168	159	56	273

Table 4: GEOTHERMOMETER CALCULATIONS(C)
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Numbers in parentheses are calculated from silicic acid (H_4SiO_4) concentration calculated at the spring temperature;
Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate-water.
HARNEY COUNTY											
22	MICKEY SPRINGS	86.0	138	198	312		185	172	164	61	
22	MICKEY SPRINGS	86.0	136	196	309	195	185	172	164	61	
22	MICKEY SPRINGS		138	205	349		180	168	159	56	
23	ALVORD HOT SPRINGS	82.2	145	193	252	182	155	147	130	33	
23	ALVORD HOT SPRINGS	76.0	153	198	254	164	148	141	122	26	231
23	ALVORD HOT SPRINGS	78.5	146	194	253	160	152	145	127	30	
23	ALVORD HOT SPRINGS	78.5	144	192	252	157	151	145	126	30	
24	HOT BORAX LAKE	29.4	127	161	163		174	164	152	51	
24	HOT BORAX LAKE	31.1	133	168	174	167	178	166	156	54	
24	HOT BORAX LAKE	36.0	143	176	181		176	165	155	53	336
27	UNNAMED HOT SPRING NEAR TROUT CREEK		181	191	152	174	124	122	96	6	
27	UNNAMED HOT SPRING NEAR TROUT CREEK	52.0	118	143	118	141	140	135	114	19	235
39	GOODMAN SPRING (HOTCHKISS)	22.0	169	156	69		98	99	68	-17	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73.9	144	175	173		147	141	122	26	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	79.4	147	179	182		170	160	148	47	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	87.0	149	183	193		165	156	142	42	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	96.0	144	176	178		165	156	142	42	231
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	91.0	145	176	178		176	165	154	53	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	97.0	136	169	172		169	159	146	46	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	90.5	141	172	171		163	154	139	40	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	86.0	139	172	174		164	155	141	41	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	97.0	138	171	174		166	157	143	44	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	84.0	138	172	177		167	157	144	44	
44	HOTCHKISS WELL	27.0	160	146	56		103	103	73	-13	
44	HOTCHKISS WELL	27.0	171	155	64		98	99	68	-17	
45	HINES LUMBER CO. WELL	25.0	190	167	70		106	106	77	-10	
46	CITY OF HINES WELL	17.0	230	192	81	46	111	110	81	-7	
JACKSON COUNTY											
01	JACKSON HOT SPRING	35.0	64	95	72	42	114(89)	113	86(58)	-3	
KLAMATH COUNTY											
	ALFRED JACOBSEN	30.0	250	221	131	78	114	113	86	-3	
	BILL HILL	20.0	284	217	83	cold	74	78	42	-38	
	CLAUDE SHUCK	24.0	252	203	84	46	108	108	79	-9	
	CLYDE DEHILINGER	24.0	213	189	95	53	120	118	91	1	
	FALCON HEIGHTS SCHOOL	37.0	192	181	104	33	125	122	97	6	

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Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate-water
KLAMATH COUNTY											
	GEORGE CARTER	22.0	160	156	83	126	93	95	62	-22	
	GEORGE STACY CO.	25.0	231	183	61		85	88	54	-29	
	JACK O'CONNER	38.0	90	116	83		114	113	86	-3	
	LEN DOBRY	21.0	201	180	88	95	114	113	86	-3	
	LESTER BROOKSHIRE	25.0	213	173	57		86	89	55	-28	
	MELVIN MCCOLLUM	25.0	231	178	50		104	104	74	-12	
	MONTE DEHILINGER	26.0	273	207	73	22	105	106	76	-11	
	O'CONNER LIVESTOCK CO.	30.0	108	123	72	102	125	122	97	6	
	OREGON WATER CORP.(4)	26.0					113	112	84	-4	
	POPE'S MEAT CO.	22.0	180	161	67		72(69)	77	40(38)	-39	
	RAY BIXLER	22.0	234	182	55		101	102	71	-15	
	ROBERT LANGLEY	23.0	252	200	78	25	102	103	72	-14	
	TOWN OF MERRILL	21.0	165	155	71	41	89	92	59	-25	
	U.S. AIR FORCE(1)	31.0	227	209	129	100	105	105	75	-12	
	U.S. AIR FORCE(2)	30.0	220	201	117	65	103	103	73	-13	
	WEYERHAUSER WELL NO. 4	22.0	178	159	65		55	62	23	-53	
01	EAGLE POINT SPRING	35.0	169	190	170		89	92	59	-25	
02	J. E. FRIESEN	73.0	83	109	75		130(111)	126	102(82)	10	
02	LOIS MERRUYS	71.0	80	106	73		127(115)	124	99(86)	8	
02	MEDO-BELL DAIRY	81.0	83	109	75		126(102)	123	98(72)	7	
02	MEDO-BELL DAIRY	81.0									185
02	MILLS SCHOOL	89.0	47	83	67		124	121	96	5	
02	MOYINA WATER CO.	50.0	196	177	86	64	114	113	85	-4	
02	O.I.T. NO. 5	89.0	57	91	72		120(104)	118	92(74)	2	
02	O.I.T. NO. 6	88.0	83	108	71		81	84	49	-32	
02	O.I.T. NO. 6	79.0					131	128	104	12	185
02	OREGON WATER CORP.(1)	21.0					98	99	68	-17	
02	OREGON WATER CORP.(2)	21.0					70	75	39	-40	
02	OREGON WATER CORP.(3)	20.0					72	77	40	-39	
03	HOWARD HOLLIDAY	25.0	181	157	56		75	79	44	-36	
04	MAZAMA SCHOOL	61.0	93	129	126	96	133	129	105	13	
06	ABE BOEHM	25.0	114	132	87	57	137	133	110	17	
06	ABE BOEHM	25.0									58
06	DAN O'CONNER	24.0	254	207	91	34	94	96	63	-21	
06	JACK LISKEY	93.0	83	111	82		131(106)	128	104(76)	12	138
06	JACK LISKEY	22.0	85	121	115	38	137	133	110	17	
06	JACK LISKEY	25.0									93
06	O. H. OSBORN	90.0	87	113	83		131(65)	128	104(33)	12	135
07	OLENE GAP HOT SPRINGS	73.9	72	101	72		124	122	96	6	
07	OLENE GAP HOT SPRINGS	74.0	115	130	80	122	136	132	109	16	
07	OLENE GAP HOT SPRINGS	87.0									196
08	ROENICKE HOT SPRING	65.0	90	112	72	85	100	101	70	-16	
16	MELVIN FEIGI	31.0	71	103	80		143(132)	137	116(105)	22	
22	RAY SMITH WELL	25.0	145	143	68		102	103	72	-14	
23	KLAMATH ICE CO.	51.7					118(99)	117	90(69)		
24	J. K. O'NEIL		249	203	87	20	97	99	67	-18	
24	J. K. O'NEIL	23.0	230	194	88	cold	102	103	72	-14	

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Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate-water
LAKE COUNTY											
05	ANA RIVER SPRING	18.9	162	157	80	27	88	91	57	-26	
14	SUMMER LAKE HOT SPRING (WOODWARD)	46.7	76	130	182	113	135(123)	131	108(95)	15	
14	SUMMER LAKE HOT SPRING (WOODWARD)	43.0	61	112	149		134(127)	130	107(99)	14	189
23	HUNTERS HOT SPRINGS (LAKEVIEW)	98.0	125	148	120		159	151	135	37	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	86.0	128	154	134	74	157	149	133	35	158
23	HUNTERS HOT SPRINGS (LAKEVIEW)	96.0	119	143	114		157	149	133	35	
24	LEITHEAD HOT SPRINGS (JOYLAND PLUNGE, LEO	69.4	69	96	61		115	114	86	-2	
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	85.0	107	140	130	102	157	149	133	35	
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	88.0	106	139	131		152	145	127	31	
28	ANTELOPE HOT SPRINGS	40.0	149	168	138	87	168	159	146	45	
32	FISHER HOT SPRINGS	68.0	165	169	112	123	123	121	95	4	
33	CRUMP SPRING	40.0	130	147	104	112	150	143	125	29	
33	CRUMP SPRING	78.0	117	144	122		173	162	151	50	202
33	CRUMP WELL (1)	99.0	118	150	141	144	169	159	146	46	
33	CRUMP WELL (2)	88.0	112								
LANE COUNTY											
01	BELKNAP HOT SPRINGS	86.7	226	202	110	183	126	123	98	7	
01	BELKNAP HOT SPRINGS	71.0	87	113	82	34	135	131	108	15	148
02	FOLEY SPRINGS	80.6	91	106	52		111	110	82	-6	
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44.0	74	95	48		102	103	72	-14	
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	42.0	86	103	51		99	100	69	-16	
04	WALL CREEK WARM SPRINGS	41.0	110	125	73		113	112	84	-5	
05	MCCREDIE SPRINGS	73.0	88	114	81	74	124	122	96	6	
05	MCCREDIE SPRINGS	71.0	104	125	86	84	115	114	86	-3	
06	KITSON SPRINGS	44.4	82	110	83		99	100	69	-16	
06	KITSON SPRINGS	43.0	77	107	81	71	97	98	67	-18	
08	BIGELOW HOT SPRINGS	61.0	104	125	85	120	117	116	89	-1	
MALHEUR COUNTY											
03	NEAL HOT SPRINGS	87.0	163	181	151		173	162	151	50	210
04	BEULAH HOT SPRINGS	60.0	103	124	85		169	159	146	46	
05	VALE HOT SPRINGS	73.0	132	157	135	150	152	145	127	31	201
05	VALE HOT SPRINGS	90.0									161
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	70.0	83	118	109		145(126)	139	119(98)	24	215
08	MITCHELL BUTTE HOT SPRINGS	62.0	70	99	72		134(118)	130	107(90)	14	
18	UNNAMED HOT SPRING AT THREE FORKS	35.0					96	97	66	-19	

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Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate-water
MALHEUR COUNTY											
18	UNNAMED HOT SPRING AT THREE FORKS	34.0	83	98	42		92	94	61	-23	
19	UNNAMED HOT SPRING NEAR MCDERMITT	53.5	66	107	109		131(101)	128	104(71)	12	
19	UNNAMED HOT SPRING NEAR MCDERMITT	52.0	45	90	104		120(106)	118	91(76)	1	
23	LUCE HOT SPRINGS	63.0	119	137	96		143	137	116	22	
24	JONESBORO WARM SPRING	44.5	53	89	73		118(70)	117	90(39)		
25	JUNTURA WARM SPRING #1	25.0	285	205	59		106(84)	106	77(53)	-10	
26	JUNTURA WARM SPRING #2	35.0	56	92	78		124(76)	122	96(44)	6	
27	ARTESIAN WELL	46.0	39	78	71		96(57)	97	65(24)	-19	
28	ALKALI FLAT GRADIENT WELL	24.0	68	108	109		82	85	51	-31	
29	NORTH HARPER BLM WELL	36.0	75	109	94	95	91	93	61	-23	
30	UNNAMED WARM SPRING NEAR BULLY CREEK	37.0	266	148	-24		137	132	110	16	
MARION COUNTY											
01	BREITENBUSH HOT SPRINGS	92.0	122	149	128		127	124	99	8	179
01	BREITENBUSH HOT SPRINGS -WELL	110.0	130	155	134		174(157)	163	152(133)	50	176
MULTNOMAH COUNTY											
01	CORBETT WARM SPRING	18.0	178	170	92	158	96	98	66	-19	
02	YMCA CAMP COLLINS	23.3	430	283	103	260	111(104)	110	81(75)	-7	
UMATILLA COUNTY											
01	BINGHAM SPRINGS	34.4	138	151	102	70	117(110)	115	88(81)	-1	
03	LEHMAN SPRINGS	61.0	66	97	72		96	97	66	-19	
UNION COUNTY											
01	COVE WARM SPRING	29.4	75	95	46		78(40)	82	47(7)	-34	
01	WELL	27.0	224	194	92	168	128	125	100	8	
01	WELL	25.0	215	190	94	81	120	118	91	1	
01	WELL	27.0	258	200	73	195	119	117	90	1	
02	HOT LAKE	80.0	85	114	89		100(62)	101	70(30)	-16	63
05	WAGNER WELL	29.0	203	183	93	94					
07	MEDICAL HOT SPRINGS	60.0	78	97	48		135	131	109	15	
07	MEDICAL HOT SPRINGS	60.0	114	125	66		125	122	97	6	
WALLOWA COUNTY											
01	COOK CREEK WARM SPRING	36.0	119	118	40		98	99	68	-17	
WASCO COUNTY											
01	KAHNEETAH HOT SPRINGS	52.0	56	102	120		139	135	113	19	
02	MILTON MARTIN WELL	22.2	220	188	84	89	128(124)	125	100(96)	8	
03	J. SANDOZ WELL	27.8	221	196	103	69	134	130	107	14	

to calcium ratios have long been considered a qualitative indicator of low reservoir temperature (Ellis, 1970; White, 1970). The recently developed Na-K-Ca-Mg geothermometer (Fournier and Potter, 1979) quantifies this observation and results in generally better agreement between the silica and cation geothermometers, particularly in the lower (<150°C) temperature range. The magnesium-corrected Na-K-Ca geothermometer was not calculated for samples with Na-K-Ca temperatures of less than 70°C.

To apply the magnesium correction, the ratio (R), defined by Fournier and Potter (1978) to be:

$$R = \frac{\text{millequivalents Mg} \times 100}{\text{millequivalents Mg} + \text{milliequivalents Ca} + \text{milliequivalents K}} \quad (4)$$

was determined for all samples with magnesium, calcium, and potassium concentrations larger than the detection limits. If R was greater than 50, the sample was designated "cold" and no quantitative temperature was calculated. A magnesium-corrected temperature was calculated for all remaining samples, but was printed only if the corrected temperature was less than the uncorrected Na-K-1/3Ca temperature. The Na-K temperatures are based on the revised equation of Fournier (1979).

The sulfate-water isotope geothermometer (McKenzie and Truesdell, 1977) is based on the temperature-dependent fractionation of the isotopes of oxygen (O^{16}/O^{18}) between water and dissolved sulfate. McKenzie and Truesdell (1977) describe three end-member models for calculating reservoir temperatures with the sulfate-water isotope geothermometer: (1) conductive heat loss, (2) one-step steam loss, and (3) continuous steam loss. Samples from isolated springs with low flows and/or no steam loss, and condensed total-flow samples from wells, are assumed to have cooled conductively without any change in isotopic composition. One-step steam loss occurs in geysers and steam wells having two-phase flow from which only the water is collected. Continuous steam loss may occur in springs issuing in areas having fumaroles and steaming ground. If dilution occurs but is not detected, temperatures less than the actual reservoir temperature will be estimated. Generally, the continuous-steam-loss model is best for boiling springs and the conductive-heat-loss model for all other samples. Erroneous temperature estimates will be produced if nonthermal equilibrated sulfate is added by processes such as solution of gypsum, oxidation of sulfide to sulfate, or mixing with sulfate bearing brines.

Besides these quantitative indicators of subsurface temperature, the presence of travertine or siliceous sinter is generally a good qualitative indicator of temperature. Travertine indicates low temperatures, while siliceous sinter indicates temperatures of 180°C or more (White, 1970). Only Hot Lake and Mickey Springs in southern Harney County, and Neal Hot Springs in northern Malheur County, have large sinter deposits.

The following procedure is recommended to determine which estimated subsurface temperature (table 4) is best:

1. Examine the Mg-corrected Na-K-Ca and the Na-K-4/3Ca temperatures and select the lower temperature as the better estimate. If neither is less than 100°C, then select the Na-K-1/3Ca temperature as the best cation-based estimate of the last temperature of water-rock equilibrium.

2. If the spring is boiling, select the quartz adiabatic temperature as the best silica-based temperature indicator. Otherwise, selection of the best silica-based temperature depends on having some knowledge of the principal rock type in the area of the individual hot spring. In alkaline waters discharging from granite, quartz solubility seems to limit silica concentrations at temperatures as low as 75°C. In waters of neutral pH, quartz solubility limits silica concentrations at temperatures of more than 180°C in basalts, and 90°C in granite.

3. Consider the temperatures estimated from the sulfate-water geothermometer to be speculative. Although tantalizing, these temperatures must be substantiated by additional information.

After careful application of the geothermometers, some samples may remain which give inconsistent or otherwise doubtful results. For example, dissolution of glass from vitric or lapilli tuffs releases large quantities of silica which renders the silica geothermometer useless. The high silica concentration at Beulah Hot Springs in Malheur County and at the warm springs near Venator in Harney County may be meaningless since both springs issue from vitric tuffs. The low temperatures estimated from the Na-K-Ca geothermometers indicate that the springs are not an important geothermal resource.

The chemical composition of the thermal waters issuing along the shores of East Lake and Paulina Lake are also difficult to interpret. These springs have negligible flow rates, high silica concentrations (up to 200 mg/L), and issue from lapilli tuffs. Solution of glass from the lapilli tuffs could account for the large silica and relatively large magnesium concentrations. Since the temperatures of the springs increases as gas discharge increases, the "springs" are probably drowned gas vents. The concentrations of silica, sodium, potassium, and calcium in these thermal waters may be functions of the length of time that the heated lake water has been in contact with the tuff and may have no relationship to the temperature at depth. The relatively large magnesium concentration also favors a low-temperature system.

The sulfate-water isotope geothermometer produces considerably higher estimated temperatures of water-rock equilibrium than the chemical geothermometers in most systems. The high temperatures estimated from the sulfate-water isotope geothermometer may indicate that the systems have a deep reservoir in which isotopic equilibrium is being established, and a shallower, cooler reservoir in which chemical equilibrium is being established. This is possible because the rate of sulfate-water isotopic equilibrium is relatively slow. Times to achieve equilibrium depend on both temperature and pH (Lloyd, 1968). To achieve 99-percent equilibration at neutral pH's, 330 years would be required at 100°C, 52 years at 150°C, and 12 years at 200°C. However, it is possible that the sulfate is added to the system slowly as the fluids circulate, thus requiring longer times to achieve 99-percent equilibration. An alternate explanation for the high temperatures estimated in the Cascades is that the sulfate represents fossil sulfate associated with the mineralization which is common in the Western Cascades. However, until additional data are available, it will not be possible to determine if the high apparent temperatures of sulfate-water isotopic equilibrium are real or the result of solution of "fossil" sulfate, mixing of thermal and nonthermal waters, reduction of sulfate, membrane filtration, different rates of isotopic exchange between sulfate, water, and rock, or other nonthermal effects.

SUMMARY

Most of the thermal springs in the central and northern parts of the Cascades in Oregon contain appreciable connate marine water similar to cold connate marine waters discharged from mineral springs and deep wells in the Willamette Valley and the Coast Range. Thermal springs in the southern part of the Cascades discharge similar waters to which a significant amount of CO_2 has been added. Numerous cold CO_2-charged springs also issue in this area. Dilute, alkaline thermal waters issue from springs associated with granitic rocks, principally in northeastern Oregon. These waters are sufficiently alkaline to require that the silica geothermometer be corrected for the dissociation of silicic acid. Near-surface water-rock reactions have rendered the chemical composition of thermal water at Newberry Caldera useless for geothermal calculations. Based on the geothermometers, the following areas have the greatest geothermal potential: Alvord Area (including Mickey Springs, Alvord Hot Springs, and Hot Borax Lake), Vale Hot Springs, Neal Hot Springs, Crump Spring, Lakeview, and Breitenbush Hot Springs. Areas for which the geothermometers do not agree include Klamath Falls and part of the Cascades.

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