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COMPOSITIONS OF THE HYDROTHERMAL SYSTEM  
IN TWIN FALLS AND JEROME COUNTIES, IDAHO**

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CHEMICAL, ISOTOPIC, AND DISSOLVED GAS COMPOSITIONS OF THE  
HYDROTHERMAL SYSTEM IN TWIN FALLS AND JEROME COUNTIES, IDAHO

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Abstract

The chemical, isotopic, and gas compositions of the hydrothermal system in Twin Falls and Jerome counties, Idaho, change systematically as the water moves northward from the Idaho-Nevada boundary toward the Snake River. Sodium, chloride, fluoride, alkalinity, dissolved helium, and carbon-13 increase as calcium and carbon-14 decrease. Water-rock reactions may result in dissolution of plagioclase or volcanic glass and calcite, followed by precipitation of zeolites and clays. On the basis of carbon-14 age dating, apparent water ages range from 2,000 to more than 26,000 years; most apparent ages range from about 4,000 to 10,000 years. The older waters, north of the Snake River, are isotopically depleted in deuterium and are enriched in chloride relative to waters to the south. Thermal waters flowing northward beneath the Snake River may join a westward flow of older thermal water slightly north of the river. The direction of flow in the hydrothermal system seems to parallel the surface drainage.

Introduction

Thermal fluids occur along virtually the entire length of the Snake River Plain in southern Idaho (Mitchell and others, 1980). However, the distribution of known thermal fluids within the plain is usually asymmetrical. In the eastern third of the plain, the presence of thermal fluids is known only along the southern edge. In the central third of the state, thermal fluids occur south of the plain, as well as along the southern edge. In the western third of the plain, thermal fluids occur beneath most of the plain although they are still more common along the southern edge. We have previously studied the Boise system in the western third of the plain (Mariner and others, 1989). To begin our study of the hydrothermal systems of the central third of the Snake River Plain, we selected an area including Twin Falls. The study area in south-central Idaho, is about 30 miles wide (east-west) and 35 miles long (north-south). It extends from approximately the Snake River on the north to the Idaho-Nevada boundary on the south (figure 1). The area is a broad, undulating plain with a few volcanic buttes. Several perennial streams cross the area in deeply incised canyons. The plain slopes gently upward from the Snake River southward to the Jarbidge and Granite Mountains in northern Nevada.

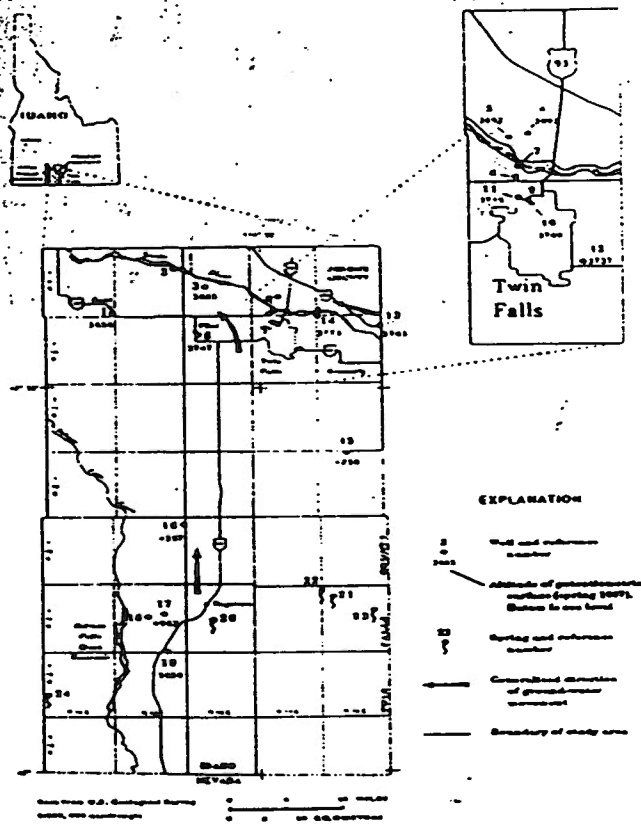


Figure 1.--Locations of and potentiometric data for sampled wells and springs.

Quaternary and Tertiary volcanics and Paleozoic marine sediments underlie the plain (Lewis and Young, 1989). Quaternary basalts are exposed in the northern part of the study area. Thicknesses of these basalts are variable, but individual flows probably do not exceed 50 feet (Lewis and Young, 1989). Quaternary-Tertiary basalts of the Glenns Ferry Formation (lower Pleistocene and upper Pliocene) are also exposed in the northern part of the area. These basalt flows generally form sheetlike layers within the detrital deposits of the Glenns Ferry Formation. Thickness of this unit in the study area probably does not exceed 500 feet (Lewis and Young, 1989). Malde and Powers (1962) stated that the Tertiary volcanics consist chiefly of Banbury Basalt (Miocene) and silicic welded tuffs and basalt flows of the Idavada

Volcanics (Miocene and Pliocene). Thickness of the Banbury Basalt is variable; northwest of the study area this unit is more than 980 feet thick (Malde and others, 1963). Total thickness of the Idavada Volcanics in the area is unknown but exceeds 2,000 feet northwest of Buhl (Malde and Powers, 1972). The Idavada Volcanics are the major aquifer for thermal water in the area (Lewis and Young, 1989).

Thickness of the Paleozoic rocks beneath the plain is unknown. As much as 4,900 feet of Paleozoic rocks have been reported in the Jarbidge Mountains to the south (Schroeder, 1912).

The hydrothermal system in Twin Falls and Jerome counties was not utilized until the mid-1970's when wells were drilled in the western part of the study area to provide thermal water for space heating and aquaculture. Water temperatures in most of the wells are between 25 and 50 °C. Utilization of the resource for space heating, greenhouse operations, irrigation, and aquaculture has increased dramatically in recent years. The resource has been developed primarily near the Snake River at the northern edge of the study area. Well depths range from 350 to 2,220 feet (Lewis and Young, 1989). As a result

of the increased utilization of the resource, well-head pressures have declined as much as 15 pounds per square inch, and several previously artesian wells must now be pumped (Lewis and Young, 1989).

The purpose of this paper is twofold: first, to describe the distribution of °C and dissolved helium in the waters of the geothermal system, and second, to estimate circulation times from the °C data. In examining the water chemistry, we will look at the chemical and isotopic constituents of the water that indicate increased water-rock reaction. Finally we will compare these chemical and isotopic values with the °C activities and dissolved helium concentrations.

Major previous studies of the hydrology include those of Wood and Low (1986a and 1986b) and Lewis and Young (1989). Wood and Low (1989b) investigated the diagenetic reactions that control aqueous geochemistry in the eastern part of the Snake River Plain regional aquifer system. Their study area covered 11,000 square miles of the Snake River Plain. This study covers a smaller area (1,500 square miles) near Twin Falls, of which only 390 square miles is within the Snake River Plain. Lewis and Young (1989) studied essentially the

Table 1.—Chemical composition of selected thermal-water wells and cold-water springs

[Concentrations in milligrams per liter, except where noted; —, no data]

Refer- ence No.	Local number	Collec- tion date	Temper- ature (°C)	pH	Ca	Mg	Na	K	Li (µg/L)	Cl	F	SO <sub>4</sub>	Alkalinity (as CaCO <sub>3</sub> )	SiO <sub>2</sub>	Total dis- solved solids
<b>Thermal waters</b>															
1	9S-14E-36DAC1	3-14-79	29.0	7.9	36.0	5.4	61	10	70	31	1.9	61.0	139	66	363
2	15E-12OCA1	4-12-88	50.0	9.2	1.1	.10	100	1.3	30	12	20	16	148	84	372
3	16E-20ADD1	9- 6-84	30.5	9.1	2.0	.05	82	2.9	21	11	12	20	123	67	291
4	17E-28BDA1	3-18-81	27.0	9.0	1.9	.10	110	3.5	20	10	22	18	156	82	368
5	29ACD1	12- 7-77	42.0	8.8	2.5	.01	110	1.9	4	16	16	15	151	74	350
6	32DDA1	4- 8-81	39.5	9.2	1.9	<.10	99	1.9	6	15	14	25	129	66	301
7	33BBC1	7-24-85	39.0	9.3	1.6	.06	96	2.8	—	15	11	20	119	67	331
8	10S-16E- 8CAB1	7-14-87	27.0	8.6	5.1	.17	61	4.3	—	11	3.6	16	110	77	253
9	17E- 4CAC1	4-22-81	38.0	8.8	3.3	.20	78	2.5	10	14	9.7	21	99	59	259
10	4CDA1	4-13-88	37.5	8.7	4.5	.25	77	3.2	9	18	11	29	106	58	274
11	5DAA1	7-24-85	30.5	8.6	8.6	.40	74	6.3	—	21	11	26	99	55	267
12	14CCD1	4- 8-81	30.5	7.8	37	6.8	31	4.9	30	31	1.0	51	82	50	266
13	18E- 1DDD1	7- 2-86	42.0	9.0	1.7	.08	130	2.5	—	36	26	28	160	60	408
14	6BBB1	1-13-87	41.5	9.2	1.5	<.01	120	1.9	—	17	14	32	170	66	—
15	12S-18E- 4ABD1	9-22-81	34.0	7.6	17	1.7	17	7.4	18	7.7	.6	6.0	75	70	176
16	13S-15E- 1DAD1	7-30-86	35.5	7.9	9.4	0.42	82	3.5	—	7.6	4.8	28	160	54	288
17	14S-15E- 1CBD1	8- 4-82	32.0	7.8	21	2.0	18	6.9	34	6.8	.7	10	—	58	185
18	16DDC1	3-18-81	26.0	7.5	22	2.6	19	5.8	20	6.4	.6	12	90	60	185
19	35CDD1	7-25-85	32.0	7.6	18	2.3	18	4.7	—	6.5	.8	8.8	84	65	176
<b>Cold springs</b>															
20	14S-16E-21BAB1S	2-10-81	7.5	7.6	34	5.4	19	3.6	0	16	3	17	98	52	214
21	18E- 50CC1S	5-18-82	6.5	6.2	3.2	.87	4.0	3.3	<10	1.8	.1	7.0	—	47	82
22	6BCC1S	8-25-82	9.0	6.8	5.1	1.2	6.1	5.8	14	2.3	.1	<5.0	—	58	—
23	14ABD1S	5-13-81	4.5	6.0	2.6	.70	.14	2.6	4	1.3	.1	3.4	16	38	63
24	15S-14E-19CDD1S	5-23-89	7.0	5.9	1.5	.25	2.5	3.9	<4	20	.1	<1.0	13	48	—

same area considered in this report. They described the general geologic setting, major and minor element chemistry of the thermal waters, chemical geothermometry, and results of several electrical resistivity studies, and proposed a conceptual model for the system. Their model consisted of a single 2,000-foot-thick aquifer in the Idavada Volcanics, which is recharged near the Idaho-Nevada boundary and is heated by deep circulation.

#### Water Composition

Temperatures of thermal waters near and south of Twin Falls range from 25 to 50 °C (table 1). The waters are dilute, 175 to 400 mg/L dissolved solids, contain sodium and calcium as the major cations, and bicarbonate as the major anion. Concentrations of sodium and calcium are approximately equal in the waters at the southern end of the study area near the Idaho-Nevada boundary. Concentrations of sodium and chloride, alkalinity, water temperature, and pH increase northward. Fluoride concentrations are high (as much as 26 mg/L) in the hotter waters. Plots of chloride versus sodium show little correlation (figure 2). Thermodynamic calculations at measured discharge temperatures show (table 2) that the thermal waters are generally saturated with respect to aragonite, calcite, dolomite, and fluorite.

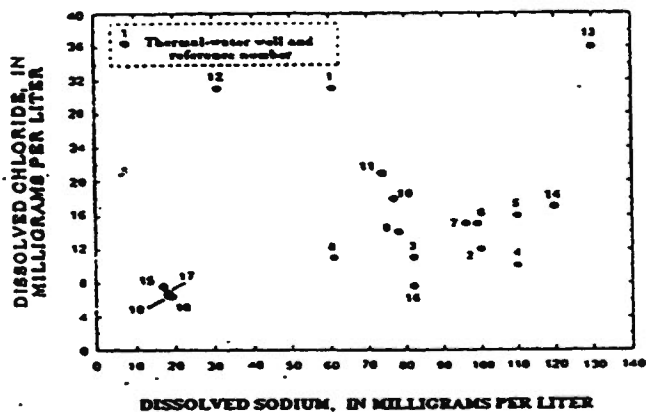


Figure 2.—Relation between dissolved chloride and sodium.

#### Stable Isotopes

The  $\delta D$  and  $\delta^{18}O$  values (table 3) of the thermal waters plot on or slightly to the right of the local meteoric water line (figure 3) determined for the western Snake River Plain by Wood and Low (1989b). Sample 20, a cold spring, is chemically and isotopically unusual. It may have a thermal component ( $Cl = 16$  mg/L) and apparently has been concentrated by evaporation.

Arenally,  $\delta D$  values of the thermal waters are lower toward the north near the Snake River. Cold springs near the southern boundary of the study area are not depleted enough in  $\delta D$  to be the source of recharge for the thermal water near the Snake River. Recharge must have occurred when the climate was colder than it is today or the water must have recharged farther

Table 2.—Thermodynamic calculations for thermal waters

[Saturation states in kilocalories per mole<sup>1</sup>]

Reference number	Temperature (°C)	Aragonite	Calcite	Dolomite	Fluorite
2	50	-0.12	0.05	0.96	-0.23
3	30.5	-0.16	0.03	-0.32	0.02
4	27	-0.17	0.02	0.13	0.64
5	42	-0.01	0.18	0.95	0.22
7	39	-0.01	0.17	0.43	-0.52
13	42	-0.04	0.14	0.52	0.60
18	26	-0.86	-0.67	-0.79	-1.85

<sup>1</sup> Free energies of formation ( $\Delta G$ ) calculated with the model SOLMINEQ.88 (Kharaka and others, 1988).

Table 3.—Isotope analyses of water from selected thermal-water wells and cold-water springs

[Values are in permil, except as noted; —, not analyzed]

Refer- ence No.	Temper- ature (°C)	$\delta D$ (SMOW)	$\delta^{18}O$ (SMOW)	$\delta^{13}C$ (PDB)	Percent modern carbon	Water age (years)	
					Raw	Corrected	
<b>Thermal waters</b>							
1	29.0	-130	-16.8	-10.0	36.4	66.7	2,000
2	50.0	-134	-17.2	-9.9	13.1	24.4	10,000
3	30.5	-131	-16.9	-9.8	17.2	31.7	8,200
4	27.0	-137	-17.7	-7.1	2.9	10.3	17,000
5	42.0	-135	-16.9	-7.5	15.3	48.1	4,700
6	39.5	-132	-17.0	—	—	—	—
7	39.0	-138	-17.0	-8.2	19.4	50.8	4,300
8	27.0	-127	-17.1	-10.1	18.1	32.6	7,900
9	38.0	-131	-17.4	—	—	—	—
10	37.5	-131	-17.4	-9.1	22.0	47.5	4,800
11	30.5	-132	-17.1	—	—	—	—
12	30.5	-127	-16.4	-13.4	—	—	—
13	42.0	-139	-17.5	-5.2	< 4	< 3.7	> 26,000
14	41.5	-136	-17.6	-6.7	12.4	50.5	4,300
15	34.0	-132	-16.8	-13.5	46.9	54.3	3,700
16	35.5	-134	-17.1	-6.5	9.5	41.8	5,900
17	32.0	-130	-16.9	-11.2	55.6	85	0
18	26.0	-131	-16.7	—	—	—	—
19	32.0	-132	-16.8	-12.0	—	—	—
<b>Cold springs</b>							
20	7.5	-120	-14.6	—	—	—	—
21	6.5	-123	-16.2	-19.9	—	—	—
22	9.0	-121	-16.0	-17.9	—	—	—
23	4.5	-123	-16.2	—	—	—	—

east where precipitation is more depleted. Mixing of thermal waters should be apparent on  $\delta D$ -Cl plots (figure 4). However, no convincing trends are discernible, although  $\delta D$  tends to become more depleted as chloride concentrations increase.

Carbon-13 ( $\delta^{13}C$ ) values range from -13.5 to -5.2 permil in the thermal waters and from -17.9 to -19.9 permil in the cold waters (table 3). In the thermal waters,  $\delta^{13}C$  values correlate

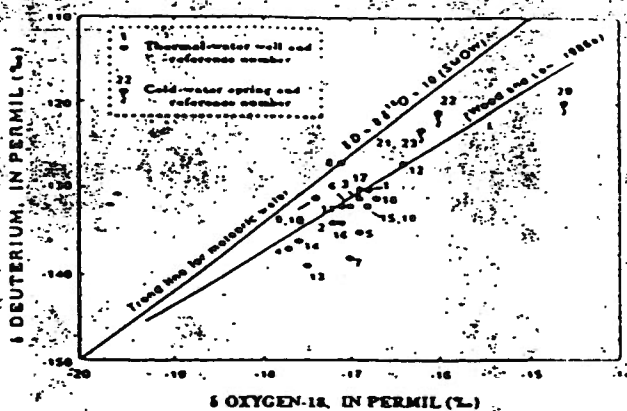


Figure 3.—Relation between deuterium and oxygen-18.

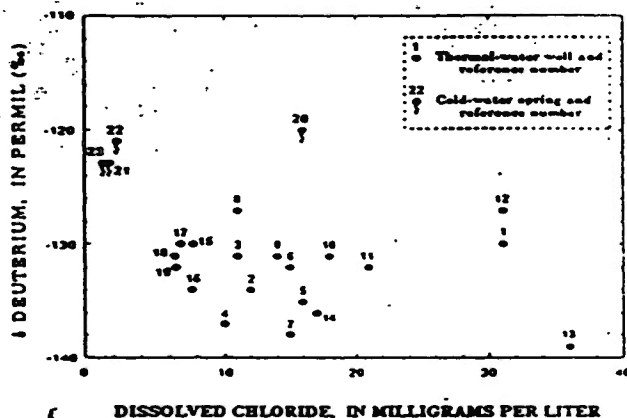


Figure 4.—Relation between deuterium and dissolved chloride.

with total alkalinity (figure 5). As alkalinity increases, the dissolved carbon becomes more enriched in <sup>13</sup>C. Possible sources of carbon include dolomite (δ<sup>13</sup>C = 0 permil) and caliche in the Idavada Volcanics. Caliche in southern Idaho is about -4 permil in δ<sup>13</sup>C (Wood and Low, 1986b). Dissolution

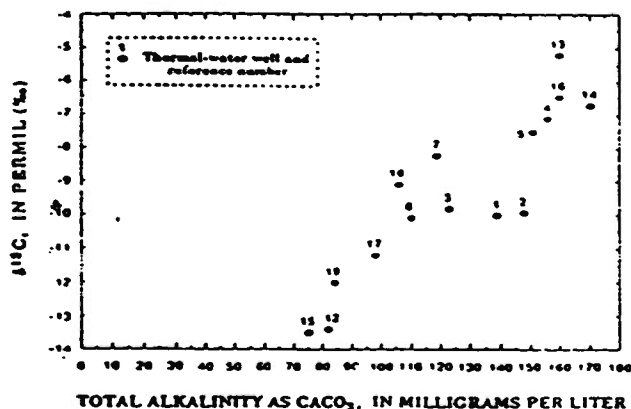


Figure 5.—Relation between δ<sup>13</sup>C and total alkalinity

of plagioclase or volcanic glass in the Idavada Volcanics may have resulted in precipitation of calcium-bearing aluminosilicates. In weakly alkaline waters such as these, calcium-bearing zeolites are probable alteration products. Removal of calcium from solution would permit additional calcium carbonate or calcium magnesium carbonates to dissolve, thus increasing alkalinity and enriching the water in <sup>13</sup>C.

The carbon isotopic composition of the recharge water can be estimated from the relation between total dissolved carbon and <sup>13</sup>C. Cold waters in the area have total dissolved carbon of about 14.8 mg/L (total carbon as C). Fitting a least-squares line to the δ<sup>13</sup>C and total dissolved carbon data for the thermal waters and extrapolating to the probable recharge carbon concentration gives a δ<sup>13</sup>C value for the probable recharge water of -15 permil.

#### Carbon-14 Data

Uncorrected <sup>14</sup>C values for the thermal waters range from less than 0.4 percent modern to 55.6 percent modern (table 3). These <sup>14</sup>C activities correlate with δ<sup>13</sup>C values (figure 6). Part of the change in <sup>14</sup>C activity is due to dilution with isotopically dead carbon from the rock. Ingerson and Pearson (1964) used the equation

$$T = -8270 \{ \ln(^{14}\text{C}/^{12}\text{C}_0) - \ln[(\delta^{13}\text{C}_f - \delta^{13}\text{C}_m) / (\delta^{13}\text{C}_0 - \delta^{13}\text{C}_m)] \} \quad (\text{eq. 1})$$

to correct for this isotopic dilution. The equation contains values for the measured <sup>14</sup>C activity (<sup>14</sup>C), the original <sup>14</sup>C activity of the recharge water (<sup>14</sup>C<sub>0</sub>), <sup>13</sup>C values of the recharge water (δ<sup>13</sup>C<sub>0</sub>), <sup>13</sup>C dissolved from the mineral source (δ<sup>13</sup>C<sub>m</sub>), final water <sup>13</sup>C value (δ<sup>13</sup>C<sub>f</sub>), and time (T), in years. The mineral source is assumed to be caliche in the Idavada Volcanics. Modern caliche deposits in the area are about -4 permil in δ<sup>13</sup>C (Wood and Low, 1986b). Corrected <sup>14</sup>C activities and estimated water ages calculated from equation 1 are listed in table 3. Sample 17, a 32°C water from the southern end of the study area, has a corrected <sup>14</sup>C age of 0 years. This water is obviously older than 0 years; clearly, all ages calculated from the <sup>14</sup>C data have large error bars.

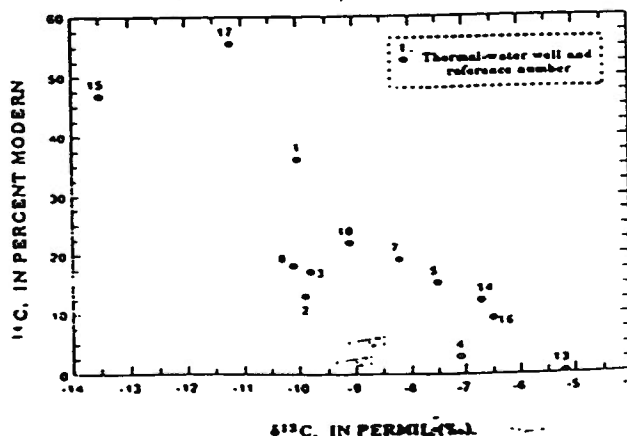


Figure 6.—Relation between <sup>14</sup>C activity and δ<sup>13</sup>C.

Dissolved Gas Composition

Dissolved gas data (table 4) show considerable variation in dissolved nitrogen, argon, and helium concentrations. The nitrogen and argon concentrations of the recharge water cannot be rigorously calculated because the nitrogen and argon concentrations do not plot along a single smooth distillation curve (figure 7). All dissolved nitrogen and argon in these waters are probably from the recharge water. Ideally, if the springs recharged in the same area, their initial nitrogen and argon concentrations would be similar, and partial degassing would produce waters plotting on a single curve on a nitrogen-argon concentration plot. Some of the scatter in the data (samples 2, 13, and 16) may be due to the way the samples were collected. To collect dissolved gas samples, a length of plastic tubing was attached from the sample port on the well to a 1,000-cc glass vessel with gas-tight stopcocks at each end. The flow rate through the glass vessel was controlled by partially closing the lower stopcock. The first water to enter the apparatus exsolved gas that adhered to the wall of the glass vessel. After the vessel was filled with water, the lower stopcock was partially closed to prevent the new water entering the vessel from exsolving gas. Ideally, water continued to flow through the vessel until the highly degassed water from the first filling was flushed from the system. Partially closing the lower stopcock increased the pressure, forcing some previously exsolved gas back into solution and, apparently, in some cases, the system was not flushed long enough to sweep this water from the vessel. The dissolved nitrogen and argon concentrations for sample 16 are larger than those in air-saturated water and the measured dissolved helium is probably higher than in the thermal-aquifer at depth because we did not get all of the redissolved gas swept out of the collection system. However, dissolved nitrogen and argon concentrations are near probable recharge concentrations for the other samples, so measured helium concentrations (sample 16 excepted) approximate the dissolved helium concentrations in the thermal aquifer. Dissolved helium concentrations increase from south to north and correlate with dissolved chloride (figure 8) and  $\delta^{13}C$  (figure 9). Thus, higher chloride concentrations and lower  $^{13}C$  values occur in the older waters.

Table 4.—Dissolved gas data for selected thermal-water wells

[cc-gas/cc-water at standard temperature and pressure;  
— no data; ASW, air-saturated water]

Reference No	Nitrogen $N_2 \times 10^{-2}$	Argon $Ar \times 10^{-4}$	Helium $He \times 10^{-6}$	Oxygen $O_2 \times 10^{-3}$
1	1.03	2.80	0.2	2.95
2	1.34	3.25	4.6	.0058
3	1.38	—	2.7	.009
4	1.20	3.23	7.8	.0058
5	1.40	—	9.4	.067
7	1.41	—	5.2	1.75
8	1.27	3.54	1.7	2.11
10	1.41	—	4.3	2.11
12	1.43	3.94	.2	4.43
13	1.41	3.41	16.0	.0045
15	1.35	—	.9	3.7
16	2.15	4.52	.6	.004
17	1.24	—	.9	3.25
ASW (5 °C) at 5,000 feet	1.36	3.60	.040	7.44

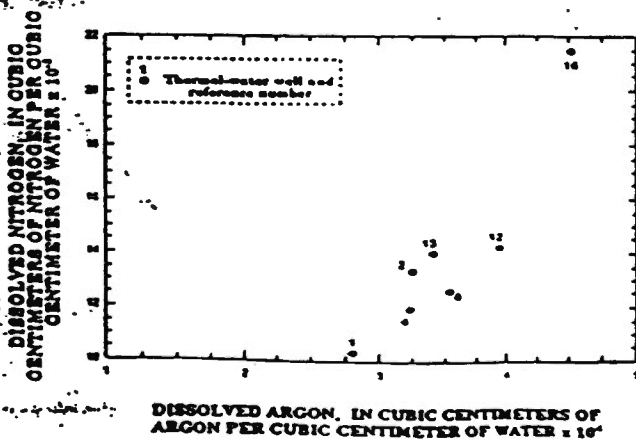


Figure 7.—Relation between dissolved nitrogen and argon.

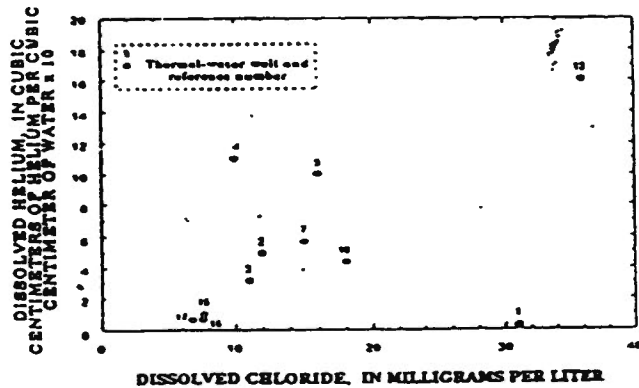


Figure 8.—Relation between dissolved helium and chloride.

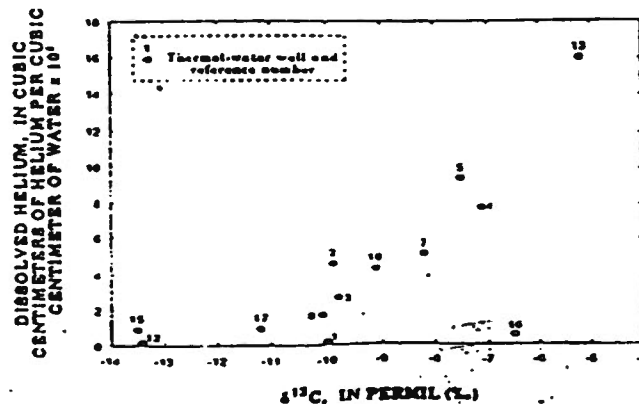


Figure 9.—Relation between dissolved helium and  $\delta^{13}C$ .



Dissolved helium concentrations increase from sample 10 to sample 7 on the south side of the Snake River and from sample 4 to sample 5 on the north side of the river (figure 10), paralleling the direction of water movement inferred from the potentiometric data. The discrepancy in  $^{14}\text{C}$  age and dissolved helium concentrations for sample 5 may indicate that the  $^{14}\text{C}$  value is questionable. Carbon-14 and dissolved helium for sample 5 were collected several years apart from a well that was reworked between the times when the dissolved helium and Carbon-14 samples were collected. Several shallow aquifers were sealed off when the well was reworked, and water from these aquifers probably contained more modern carbon than water from the deeper aquifers.

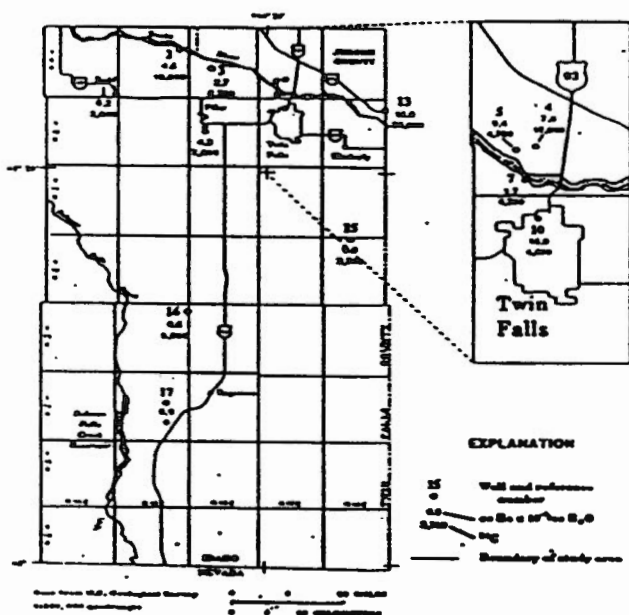


Figure 10.—Dissolved helium concentrations and carbon-14 ages of thermal waters.

Water ages calculated from the  $^{14}\text{C}$  data and supported semiquantitatively by the dissolved helium data indicate a sharp increase in water age north of the Snake River. Sudden increases in water age in a porous aquifer are difficult to explain unless the older waters originated in a different aquifer system. The potentiometric data (figure 1) show that the oldest water (more than 26,000 years) represented by sample 13 may have originated to the east. Waters recharged in the uplands near the Idaho-Nevada boundary may move northward at depth in the Idaho Nevada Volcanics until they encounter another flow of thermal water from the east. Other thermal waters recharged near the Idaho-Nevada boundary, but east or west of the study area, may follow parallel paths, joining the "west-flowing stream" of thermal water beneath or slightly north of the current position of the Snake River. Thus, thermal water in wells drilled along the north side of the Snake River may have a component from farther east.

### Conclusions

The chemical, isotopic, and dissolved gas compositions of the hydrothermal system change as the water moves northward from the Idaho-Nevada boundary toward the Snake River. Sodium, chloride, fluoride, total alkalinity, dissolved helium, and  $^{14}\text{C}$  values increase as calcium concentrations and  $^{14}\text{C}$  activity decrease. Probably, plagioclase or volcanic glass dissolves and zeolites are precipitated. Calcium concentrations may be kept low by precipitation of calcium zeolites. The potentiometric surface shows that the thermal waters flow northward toward the Snake River where they join the general westward flow of older thermal water beneath the plain. Carbon-14 decreases because of radioactive decay and dilution with radioactively dead carbon dissolved from a mineral source. Dissolved helium concentrations increase owing to decay of thorium and uranium in the aquifer rock. Corrected water ages ( $^{14}\text{C}$ ) range from about 4,000 to 10,000 years, although one sample (13) has an apparent age of more than 26,000 years. Dissolved helium concentrations change much more systematically along probable flowpaths than do apparent  $^{14}\text{C}$  ages. Carbon-14 ages have major discrepancies relative to dissolved helium and flow directions at sites represented by samples 17 and 16 near Rogerson. No increase in  $^{14}\text{C}$  age is apparent over sites north of Twin Falls represented by samples 10, 7, and 5, even though dissolved helium concentrations increase more than twofold.

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