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CHEMICAL, ISOTOPIC, AND DISSOLVED GAS COMPOSITIONS OF THE HOT SPRINGS OF THE OWYHEE UPLANDS, MALHEUR COUNTY, OREGON

R.H. Mariner[1], H.W. Young[2], and W.C. Evans[1]

1. U.S. Geological Survey, Menlo Park, California

2. U.S. Geological Survey, Boise, Idaho

ABSTRACT

Hot springs along the Owyhee River in southeastern Oregon between Three Forks and Lake Owyhee could be part of a north flowing regional system or a series of small separate geothermal systems. Heat for the waters could be from the very young (Holocene) volcanic activity (basalt flows) of the Owyhee Uplands or the regional heat flow. The springs discharge warm to hot, dilute, slightly alkaline, sodium-bicarbonate waters. Chemically they are similar to the dilute thermal waters at Bruneau-Grand View and Twin Falls, Idaho. Maximum aquifer temperatures in the Owyhee Uplands, estimated from chemical geothermometry, are about 100 °C. Dissolved helium concentrations, carbon-14 activity, and chemical and isotope data are examined for systematic trends which would indicate a geothermal system of regional extent.

INTRODUCTION

Geothermal systems of regional extent occur in the Late Tertiary and Quaternary volcanic rocks along the south side of the Snake River Plain in southern Idaho at Twin Falls (Mariner et al., 1991) and Bruneau-Grand View (Young and Lewis, 1982). Although the Snake River Plain turns northward near the Idaho-Oregon boundary, similar late Tertiary and Quaternary volcanic rocks occur in the Owyhee Uplands of southeastern Oregon. The regional geothermal systems, which occur along the south side of the Snake River Plain in southern Idaho recharge near the Idaho-Nevada boundary, and flow northward in Tertiary volcanic rock (and possibly Paleozoic limestones) to the margin of the Snake River Plain, where some of the fluid discharges as hot springs, some is captured by wells, and some joins a westward flowing thermal-aquifer in Tertiary volcanic rock beneath the Snake River Plain.

A similar "regional" geothermal system could occur in the Late Tertiary to Quaternary volcanics of the Owyhee Uplands of southeastern Oregon. Possible high temperature geothermal systems occur at the northern edge of the uplands at Neal Hot Springs and Vale Hot Springs (Mariner et al., 1974; 1975, and Brook, et al., 1979). Although four hot springs were known to exist in the central part of the upland prior to our study (Stearns et al., 1937, and Berry, 1980), no chemical data were available for any of the springs. Basic chemical and isotopic data had been collected near the edge of the Owyhee Uplands at Luce Hot Springs, Little Valley Hot Springs, Neal Hot Springs, and Vale Hot Springs (Mariner et al., 1974; 1975). The purpose of this study was to obtain spring temperature, chemical, stable isotope, carbon-14, and gas data for the hot springs of the Owyhee Uplands (Fig. 1) and to determine if these hot springs are associated with a northward flowing regional system or several local circulation systems.

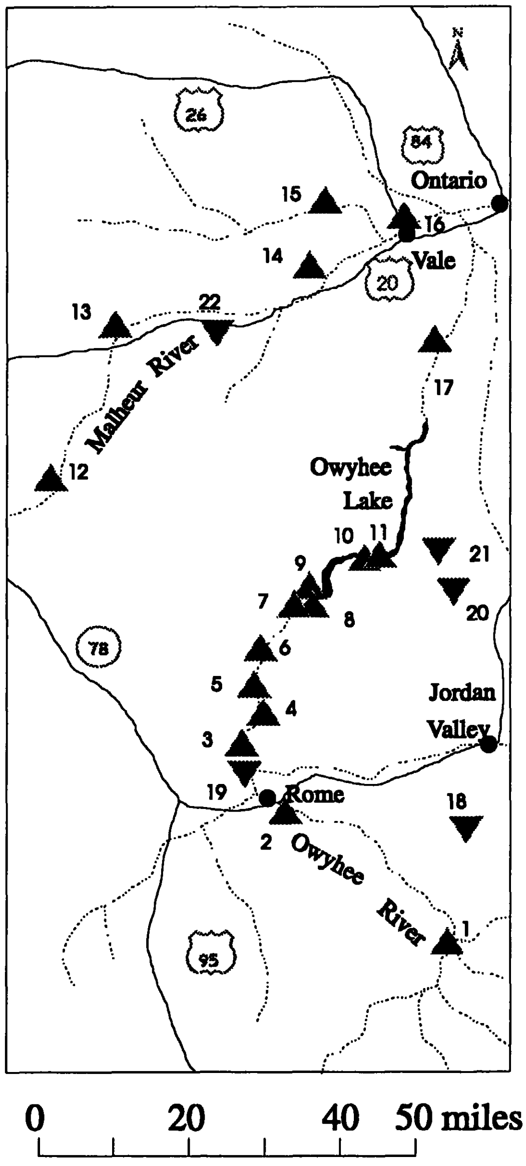

Figure 1.-- Location of sampled springs and wells. Numbers correspond to sites listed in Table 1. Normal triangles (▲) are hot springs and inverted triangles (▼) are cold springs.

GEOLOGIC SETTING

The Owyhee Uplands consist of Miocene to Holocene basalt, andesite, and rhyolite flows and pyroclastic rocks interbedded with continental sedimentary rocks (Corcoran and Walker, 1969). Total thickness of the Tertiary section is 10,000 to 12,000 ft. Mesozoic and older marine sedimentary rocks may underlie the Tertiary volcanic and sedimentary rocks, but no Mesozoic or older rock crop out in the uplands. Late Cretaceous-Tertiary granite associated with the Idaho batholith occurs along the eastern side of the uplands in Idaho. Jordan Craters, located 20 mi. west of Jordan Valley, Oregon, consist of 1,000 to 10,000 year old basalt flows, shields, and cones deposited on more extensive basalt flows of Pleistocene to Pliocene Age (Leudke and Smith, 1982). Southwest of Jordan Craters, major faults trend northwesterly, parallel to The Brothers Fault Zone, but north of Jordan Craters, most faults trend northerly (Walker, 1977). The Owyhee River, the only major stream to cross the uplands, flows through a steep walled canyon 1,000 to 2,000 ft. below the topographic surface of the uplands. Hot springs, which occur in the Owyhee River canyon, usually discharge from permeable horizons a few feet above the river. No mineral deposits occur at any of the hot springs.

WATER COMPOSITION

Temperatures of thermal springs in Owyhee Canyon between Rome and Lake Owyhee range from 20° to 67 °C (Table 1). The waters are dilute (specific conductance ranges from 322 to 848 µS/cm), slightly alkaline (pH 7.9 to 9.6), and contain principally sodium and bicarbonate (Table 1). Fluoride concentrations are high (up to 29 mg/L) and, in the lower part of the canyon, often exceed chloride concentrations. In the upper part of the canyon, Lambert and Rye Grass hot springs are chemically very similar, as are the waters from Weeping Wall and Squeeze warm springs. The waters are near saturation with respect to calcite at the measured discharge temperatures (Table 2) although no calcite is or has recently been deposited at any of the springs. The thermal springs at Three Forks, upstream from Rome, are cooler (34 °C) and slightly less concentrated (less saline), but are chemically similar to the thermal water from Squeeze and Weeping Wall warm springs. The thermal waters in the Malheur Basin to the north are more variable in composition: Luce Hot Springs, Juntura Hot Spring, and the Owyhee Energy well discharge sodium sulfate waters; Neal Hot Springs and Little Valley Hot Springs discharge sodium bicarbonate waters; and Vale Hot Springs discharges a sodium chloride water.

If the waters have similar conservative constituent ratios (Cl/Br) then they may be associated with the same rock type (and aquifer) at depth. With the exception of Rye Grass and Lambert hot springs, chloride concentrations and Cl/Br values are very similar for the waters which discharge along the Owyhee River from Three Forks to Lake Owyhee (Fig. 2). The Owyhee Energy well, Luce Hot Springs, and Neal Hot Springs also have Cl/Br values similar to the hot springs along the Owyhee River. Mariner et al. (1991) found a generally consistent increase in chloride down gradient in the large scale geothermal system at Twin Falls, Idaho. The absence of any trends in chloride concentrations in the thermal waters of the Owyhee Uplands is an indication that a large scale (regional) system does not exist in the area.

GEOTHERMOMETRY

The thermal waters of the Owyhee Uplands have moderate to cool aquifer-temperatures based on chemical geothermometers (Table 3). Maximum aquifer temperatures of 100 to 120 °C are estimated for the thermal springs discharging along the Owyhee River; higher temperatures are estimated for springs in the Malheur Basin at Neal Hot Springs and Vale Hot Springs (155 to 180 °C for Na-K-Ca and quartz geothermometers, and 200 to 215 °C for the sulfate-water isotope geothermometer). The temperature estimated from the silica geothermometer at Luce Hot Springs (143 °C) may be too high due to dissolution of glass in the Tertiary volcanic rocks near the spring site. The Na-K-Ca, Mg-Li, and K-Mg geothermometer all indicate temperatures near 100°C for the water at Luce Hot Springs.

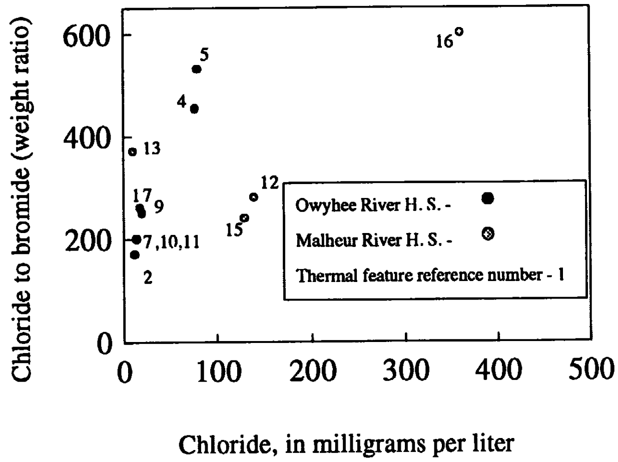

Figure 2.-- Relation between Cl/Br values (weight ratio) and chloride.

STABLE ISOTOPES

Cold spring δD values in the Owyhee Uplands and Malheur Basin range from -109 to -124‰ (Table 4; Fig. 3) and $\delta^{18}O$ values show an oxygen shift of about 1‰ relative to the Global Meteoric Water Line of Craig (1961). Thermal springs of the uplands are more depleted in deuterium (-126 to -138 ‰ δD) than the cold springs but show a similar oxygen shift. A least squares line fitted through all of the data (cold and hot) for the Owyhee Uplands produces the equation "$\delta D = 7.6\delta^{18}O - 6.8$" and has a correlation coefficient of $r = 0.95$. The apparent oxygen shift of both cold and thermal waters may be caused by precipitation evaporating as it falls through dry air. The isotopically enriched (heavy) nature of the cold spring waters relative to the hot spring waters, could also be a function of several years of drought; or the cold spring data may be biased toward values for summer precipitation; and/or the hot springs may have recharged during a time of isotopically more depleted (lighter) precipitation (colder climate). Hot springs in the Great Basin to the south are typically more depleted in deuterium than modern precipitation, and may have recharged during the Pleistocene (Mariner et al., 1983). As discharge rates for most of the hot springs of the Owyhee Uplands are relatively low, a few 10's to perhaps 100 gal/min., circulation times of more than 10,000 years are possible. The highest mountains bounding the Owyhee River basin are the Santa Rosa Range, north of Winnemucca, Nevada and the Independence Mountains, north of Elko, Nevada. Delta D values from cold springs in these mountains range from -120‰ to -127‰

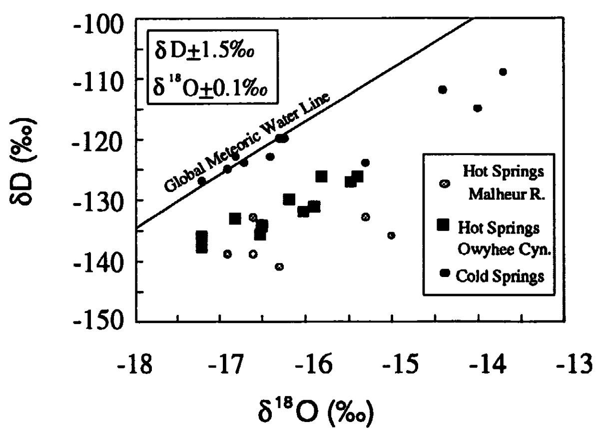

Figure 3.-- Relation between deuterium and oxygen-18

Table 1. -- Chemical composition of thermal springs, hot wells, and cold springs

[Concentrations in milligrams per liter, -, no data]

Map #	Local number	Collection date	T °C	pH	SiO_2	Ca	Mg	Na	K	Li	Cl	F	Br	SO_4	HCO_3*	Specific conductance (µS/cm)
	Thermal waters															
1	35S45E3CDC1s	7 - - 73	34	8.1	40	10.5	.7	61	1.4	0.40	18	4.2	0.07	34	110	338
2	32S42E6CBC1s	6-16-92	20	9.0	65	2.3	.26	110	3.3	.021	19	14	.10	39	177	488
3	29S41E31ADB1s	6-10-93	20	7.9	62	14	5.6	49	8.3	-	9.6	.9	-	22	149	322
4	29S41E16BAD1s	6-10-93	50	8.4	53	2.0	.2	180	2.0	.021	77	26	.17	57	231	848
5	29S41E4DDC1s	6-16-92	50	8.9	58	2.0	.08	180	2.3	.36	80	30	.15	65	217	820
6	28S41E14ACD1s	6-11-93	28½	8.0	53	21	8.7	79	7.1	-	16	2.2	-	83	189	503
7	27S42E23DBD1s	4-21-92	55	9.4	61	.73	<.01	110	1.4	.097	14	9.1	.07	49	189	522
8	27S43E18BDC1s	10-24-91	63	9.5	72	.93	.01	150	2.2	.11	18	22	-	89	182	647
9	27S43E7CDC1s	10-24-91	67	9.4	69	.90	.02	150	2.0	.12	20	23	.08	97	178	663
10	26S44E18ADB1s	4-23-92	50	9.6	64	.72	<.01	130	1.1	.04	14	29	.07	50	200	532
11	26S44E16BCB1s	4-24-92	47½	9.5	60	.95	.05	110	.9	.063	12	16	.07	60	177	503
12	24S37E20CAC1s	8-29-72	62	7.4	110	34	.5	240	9.7	.27	140	4.8	.5	290	160	1330
13	21S38E3CAC1s	6-18-92	49	9.0	69	1.3	<.01	59	.4	.007	11	.9	.03	24	117	279
14	19S43E30BBD1s	7-28-73	70	8.7	115	3.2	<.05	160	3.2	.11	74	6.8	-	110	174	740
15	18S43E9BAC1s	8-26-72	87	7.3	180	8.8	.2	190	3.2	.30	120	9.4	.5	120	243	1010
16	18S45E20DCD1s	8-14-74	73	7.5	130	19	.8	310	16	.28	360	6.1	.6	100	178	1530
17	21S45E13CDD1	6-18-92	66	8.6	120	4.8	.06	110	2.3	.035	24	13	.10	120	85	559
	Cold springs															
18	32S45E13DA1s	6-17-92	14	6.5	38	9.1	2.7	7.4	3.4	-	2.9	<.1	-	4.6	51	104
19	30S41E21BAB1s	6-10-93	18½	8.2	47	25	6.8	31	4.8	-	12	.7	-	42	116	321
20	27S46E5CDC1s	6-17-92	12	7.6	68	38	9.6	32	7.9	-	17	.5	-	28	201	371
21	26S45E2CCA1s	6-19-92	14	7.2	49	13	2.8	15	4.1	-	7.5	.2	-	11	62	164
22	21S40E1DCC1s	6-19-92	11	7.5	45	13	1.8	13	3.9	-	3.5	-	-	11	59	150

* total alkalinity as HCO_3

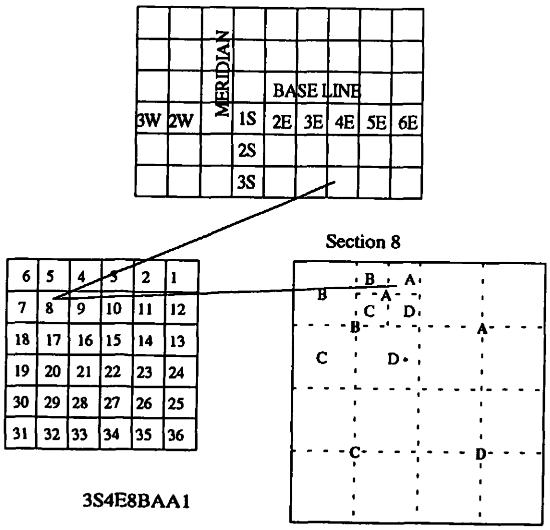

Diagram showing the well and spring numbering system

Map #, feature name, and source of data

1 - Three Forks Warm Springs; Mariner et al., 1974; 1975
2 - Owyhee Springs; new data
3 - Weeping Wall Springs, new data
4 - Lambert Hot Spring, new data
5 - Rye Grass Hot Springs; new data
6 - Squeeze Warm Springs, new data
7 - Greeley Bar Hot Springs; new data
8 - Upper Birch Creek Hot Springs; new data
9 - Lower Birch Creek Hot Springs; new data
10 - Upper Lake Owyhee Hot Springs; new data
11 - Lower Lake Owyhee Hot Springs; new data
12 - Luce Hot Springs; Mariner et al., 1974; 1975
13 - Juntura Hot Springs, new data
14 - Little Valley Hot Springs; Mariner et al., 1974 , 1975
15 - Neal Hot Springs; Mariner et al., 1974; 1975
16 - Vale Hot Springs; Mariner et al., 1974; 1975
17 - Owyhee Energy well; new data
18 - Castro Spring; new data
19 - Unnamed cold spring; new data
20 - Unnamed cold spring; new data
21 - Unnamed cold spring; new data
22 - Unnamed cold spring; new data

Table 2. -- Saturation state with respect to calcite at the spring temperature

[Values in kilocalories/mole]

Name	Saturation state
Three Forks W.S.	-0.2
Owyhee Sprs.	0
Weeping Wall Sprs.	0.4
Lambert H.S.	-0.3
Rye Grass H.S.	0.3
Squeeze Sprs.	0.2
Greeley Bar H.S.	-0.1
Upper Birch Cr. H.S.	0
Lower Birch Cr. H.S.	0
Upper Lake Owyhee H.S.	0.1
Lower Lake Owyhee H.S.	0

Table 3. -- Chemical geothermometry

[Temperatures in °C]

Name and map number	$t_{Na\text{-}K\text{-}Ca}$	$t_{Mg\text{-}Li}$	$t_{K\text{-}Mg}$	t_{Quartz}	$t_{Chalcedony}$	t_{Spring}
1 Three Forks W.S.	46	51	53	98	79	34
2 Owyhee Sprs.	132	48	85	114*	96*	20
3 Weeping Wall Sprs.	55	-	70	115*	91*	20
4 Lambert H.S.	100	50	76	105*	81*	50
5 Rye Grass H.S.	106	93	90	106*	76*	50
6 Squeeze W.S.	53	-	61	109*	84*	28½
7 Greeley Bar H.S	106	128	105	91*	59*	55
8 U. Birch Cr. H.S.	114	132	118	86*	53*	63
9 L. Birch Cr. H.S.	110	124	105	88*	50*	67
10 U. Lake Owyhee H.S.	88	92	73	87*	56*	50
11 L. Lake Owyhee H.S.	93	102	98	91*	63*	47½
12 Luce H.S.	96	101	10[illegible]	143*	116*	62
13 Juntura H.S.	50	98	73	141*	109*	49
14 Little Valley H.S.	69	108	75	145	119	70
15 Neal H.S.	86	117	87	173	151	87
16 Vale H.S.	157	95	112	152	127	73
17 Owyhee Energy well	133	48	85	115	88	66

* Corrected for dissociation of dissolved silica due to high pH

δD (Table 4); too enriched in deuterium to be the recharge waters for the hot springs of the Owyhee Uplands or the Malheur River Basin. The cold waters of the Santa Rosa and Independence mountains plot on the "global" meteoric water line, unlike the cold springs of the Owyhee Uplands which have about a +1‰ shift in $\delta^{18}O$ relative to the "global" meteoric water line. The cold waters from the mountains are unusual in that δD and $\delta^{18}O$ values increase with increasing altitude; exactly opposite to the expected trend. This "reverse" trend may be a function of precipitation from warm summer thundershowers, which are more common at higher altitudes, or the lack of vegetation at higher altitudes may permit more snow to evaporate in the windier environment. Three Forks and Squeeze warm springs are isotopically more similar to modern precipitation in the region than the hot springs and could be a mixture of "old" thermal water and "young" meteoric water. However, the "young" component must be at least 50 years old as all thermal waters analyzed for tritium (Table 4) are tritium dead (<2 TU).

Most thermal springs which discharge along the Owyhee River occur in a section of the river which trends northeastward. Therefore, the decrease in deuterium downstream could be a "distance effect", wherein precipitation becomes more depleted as the distance from the source of the moisture (Pacific Ocean) increases. Augmenting the distance effect may be an increase in the proportion of old (Pleistocene) water, and/or recharge at a higher elevation.

Luce, Lambert, and Rye Grass hot springs are chemically similar, and Luce Hot Springs water could be diluted with an equal amount of shallow ground water of composition, -131 ‰ δD, -16.7‰ $\delta^{18}O$, to produce the water discharged at Rye Grass Hot Springs. The diluting water would be only slightly more depleted in deuterium and oxygen-18 than the 20°C water from Owyhee Springs (-130‰ δD, -16.2‰ $\delta^{18}O$).

Values of $\delta^{13}C$ for most of the thermal waters from the central part of the uplands are between -9.1 and -9.6 ‰ $\delta^{13}C$. Rye Grass and Lambert hot springs are the exceptions ($\delta^{13}C$ = -6.1 to -6.8‰); they are much more like Luce Hot Springs (-7.4 ‰), Vale Hot Springs (-8.0 ‰), and Neal Hot Springs (-7.4 ‰) outside of the uplands. Dilution of Luce Hot Springs water to produce Rye Grass-Lambert hot springs water, permitted based on δD and $\delta^{18}O$ data, does not appear likely because Rye Grass and Lambert waters are more enriched in ^{13}C than either Luce Hot Springs or any of the cold springs. Cold spring $\delta^{13}C$ values in the uplands range from -8.1 to -18.0 ‰ $\delta^{13}C$. $\delta^{13}C$ data for the hot springs generally show enrichment in ^{13}C as total alkalinity increases (Fig. 4). Dissolution of ^{13}C rich caliche is the probable source of the heavier carbon. The large range in $\delta^{13}C$ values (-18 to -8 ‰) of the cold springs probably indicates that different plant communities in the respective recharge areas have greatly different ^{13}C values. It appears (Fig. 4) that the recharge water for most thermal springs in the Owyhee Uplands has a $\delta^{13}C$ of -12 ‰; reaction of this water with a mineral containing isotopically heavier carbon produces the range in $\delta^{13}C$ observed in the hot springs. Lambert and Rye Grass hot springs, again, do not plot on the same trend as the other hot springs of the uplands.

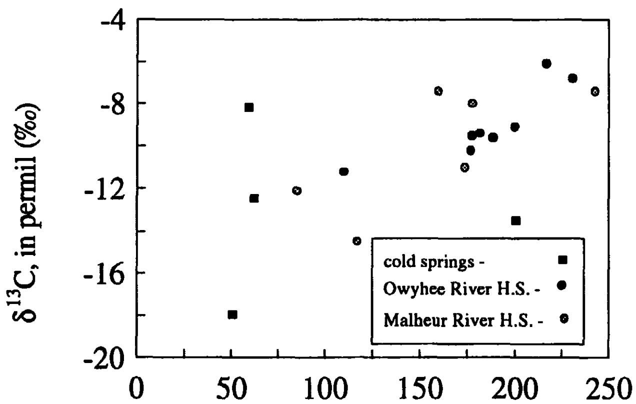

Figure 4.-- Relation between $\delta^{13}C$ and total alkalinity

Table 4. -- Isotope analyses of water and carbon from thermal springs, hot-water well, and cold springs

[Values in permil, except as noted; -, not sampled]

Name and/or sample #	Temperature (°C)	δD (SMOW)	$\delta^{18}O$ (SMOW)	$\delta^{13}C$ (PDB)	% modern carbon	Tritium (T.U.)	Collection date
Thermal waters							
1 Three Forks Warm Sprs.	34	-126	-15.8	-11.2	27.6	<2	8-22-91
2 Owyhee Sprs.	20	-130	-16.2	-10.2	-	-	6-16-92
3 Weeping Wall Sprs.	20	-126	-15.4	-	-	-	6-10-93
4 Lambert Hot Spr.	50	-131	-15.9	-6.8	-	<2	6-10-93
5 Rye Grass Hot Sprs.	50	-132	-16.0	-6.1	2.1	-	6-16-92
6 Squeeze Warm Sprs.	28½	-127	-15.5	-	-	<2	6-11-93
7 Greeley Bar Hot Sprs.	55	-133	-16.8	-9.6	1.9	<2	4-21-92
8 U. Birch Cr. Hot Sprs.	63	-134	-16.5	-9.4	-	-	10-24-91
9 L. Birch Cr. Hot Sprs.	67	-135	-16.6	-9.5	.7	<2	10-24-91
10 U. Lake Owyhee Hot Sprs.	50	-136	-17.2	-9.1	1.5	<2	4-23-92
11 L. Lake Owyhee Hot Sprs.	47½	-138	-17.2	-	-	<2	4-24-92
12 Luce Hot Sprs.	62	-133	-15.3	-7.4	10.4	-	8-21-91
13 Juntura Hot Sprs.	49	-133	-16.6	-14.5	20.5	<2	6-18-92
14 Little Valley Hot Sprs.	70	-141	-16.3	-11.0	1.6	-	8-21-91
15 Neal Hot Sprs.	93	-139	-16.6	-7.4	-	-	8-20-91
16 Vale hot well	108	-136	-15.0	-8.0	0.6	-	10-23-91
17 Owyhee E. well	66	-139	-16.9	-12.1	61.3	<2	6-18-92
Cold springs							
Owyhee Uplands					elevation (ft.)		
18 Castro	14	-115	-14.0	-18.0	4800	-	6-17-92
19 unnamed	18½	-124	-15.7	-	3275	-	6-10-93
20 unnamed	12	-124	-15.3	-13.5	4654	-	6-17-92
21 unnamed	14	-112	-14.4	-12.5	4805	-	6-19-92
Malheur Basin							
22 unnamed	11	-109	-13.7	-8.1	2758	-	6-19-92
Santa Rosa Range, Nevada (north of Winnemucca)							
23 unnamed	-	-123	-16.8	-	8130	-	6/16/93
24 unnamed	-	-120	-16.3	-	8440	-	6/16/93
25 unnamed	-	-127	-17.2	-	8250	-	6/16/93
26 unnamed	-	-125	-16.9	-	7850	-	6/16/93
Independence Mountains, Nevada (north of Elko)							
27 unnamed	14	-124	-16.7	-	6250	-	8/6/93
28 unnamed	15	-123	-16.4	-	7035	-	8/6/93
29 unnamed	9½	-120	-16.3	-	8040	-	8/6/93

Location data for cold springs #23-29: 23:41°41.1' 117°34.6' 24:41°40.8' 117°35.1' 25:41°41.0' 117°34.7' 26:41°41.0' 117°32.8' 27:41°20.7' 116°02.9' 28:41°25.8' 115°57.5' 29:41°18.7' 116°01.2'

GAS DATA

Dissolved and exsolved gases in the hot springs are principally nitrogen and argon (Tables 5 and 6). The small range in dissolved nitrogen and argon concentrations and the lack of a free gas phase in most of the hot springs of the Owyhee Uplands indicates that relatively little degassing has occurred. Air saturated water of about 13°C at 5000 ft. would have the same dissolved nitrogen and argon concentrations as the hot springs of the uplands (Fig. 5); most cold springs without a thermal component in the uplands had discharge temperatures of 12° to 14°C (Table 1).

The range in dissolved helium concentrations in the hot springs of the Owyhee Uplands is similar to the range in the system at Twin Falls (Mariner et al., 1991), but, unlike the Twin Falls system, no consistent trend exists in the dissolved helium concentrations. The largest dissolved helium concentration occurs at Rye Grass Hot Springs (1.18×10^{-5} $ccHe/ccH_2O$). Other hot springs in the central part of the upland contain less dissolved helium (typically about 5×10^{-6} $ccHe/ccH_2O$). Upper Lake Owyhee Hot Spring, farther down the Owyhee River Canyon, contains less helium (3×10^{-6} $ccHe/ccH_2O$). If the thermal system beneath the uplands flows generally from south to north and the same rocks are present beneath the entire area, then an increase in dissolved helium should occur

Table 5. -- Dissolved gas data

[Values in cc-gas/cc-water at STP; ASW, air-saturated water]

Name and Map number	Nitrogen N_2 x10^{-2}	Argon Ar x10^{-4}	Helium He x10^{-6}	Oxygen O_2 x10^{-3}	Methane CH_4 x10^{-4}
1 Three Forks W.S.	1.09*	2.9	0.76	3.2	<.5
4 Lambert H.S.	1.07	-	6.41	.0016	.85
5 Rye Grass H.S.	1.20	3.0	11.8	.0022	1.02
7 Greeley Bar H.S.	1.14	3.0	4.5	.02	.25
9 L. Birch Cr. H.S.	.86	2.2	3.65	.002	.39
10 U. Lake Owyhee H.S.	1.09	2.7	2.80	<.002	.27
12 Luce H.S.	.90	2.5	9.3	.3	.1
13 Juntura H.S.	.95	2.6	.45	2.5	<.005
15 Neal H.S.	.27	.6	.11	.3	.27
17 Owyhee E. well	1.30	2.7	4.08	.02	1.0
ASW(5°C) at 5,000 feet	1.36	3.6	.040	7.4	<.005

Sample numbers and collection dates:

1 - 6-17-92	7 - 4-21-92	12 - 8-21-91	17 - 6-18-92
4 - 6-10-93	9 - 4-24-92	13 - 6-18-92	
5 - 6-16-92	10 - 4-23-92	15 - 8-20-91	

* 0.0109 cc-N_2 / cc-H_2O or 1.09 cc-N_2/100 cc-H_2O

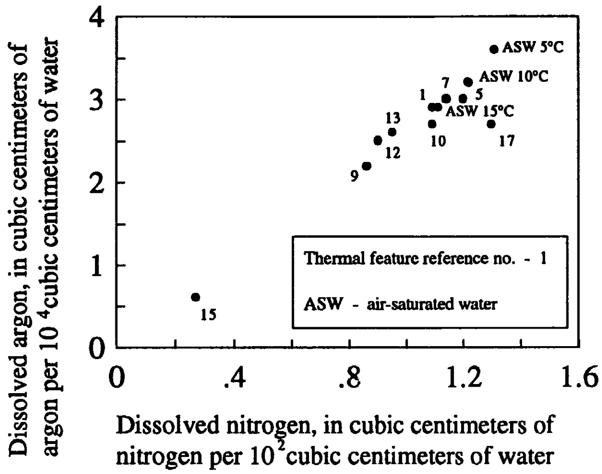

Figure 5. -- Relation between dissolved nitrogen and argon.

Table 6. -- Chemical composition of gas bubbles in selected hot springs

[Values in volume percent]

Chemical constituent	Lambert H.S.	Greeley Bar H.S.	Upper Lake Owyhee H.S.	Lower Lake Owyhee H.S.	Juntura H.S.	Neal H.S.
Helium	0.130	0.0568	0.0454	0.0285	0.0227	0.0115
Hydrogen	<.0002	<.0002	.0575	.0002	.0004	.0549
Argon	1.34	1.39	1.29	1.36	1.33	.538
Oxygen	.574	.054	<.001	.468	.288	.0275
Nitrogen	96.7	98.1	96.9	97.1	99.3	14.5
Methane	.502	.105	.146	.089	.0259	2.85
Carbon Dioxide	.052	.014	.071	.0088	<.0002	82.92
Hydrogen Sulfide	<.0005	<.0002	<.0005	.010	<.0005	.0705
Total	99.30	99.7	98.5	99.1	101.	101.

northward across the region. However, the highest dissolved helium concentration in the springs of the upland occurs at Rye Grass Hot Springs, the most southerly spring of the central group.

Rye Grass and Lambert hot springs are in a region of northwest-southeast faulting, and may be structurally isolated from the other hot springs of the uplands. After correcting for gas loss, Luce Hot Springs and Rye Grass Hot Springs, have basically identical dissolved helium concentrations. The similarity in dissolved helium concentrations at Rye Grass and Luce, after correcting for gas loss, make a mixing relation between them less likely. The large dissolved helium concentrations at Rye Grass, Lambert, and Luce hot springs must result from more uranium and thorium in the rock, or the water must be much older. A uranium and thorium rich horizon or formation seems to be the more likely possibility.

CARBON-14 DATA

Carbon-14 (^{14}C) values in the thermal waters (Table 4) range from 61.3 to 0.6 percent modern. ^{14}C values are consistently low along the Owyhee River in the central part of the Owyhee Uplands (2.1 to 0.7 % modern). The large ^{14}C activity in the Owyhee Energy well may be caused by mixing of thermal and fresh water at shallow depths near the well. ^{14}C activity can decrease by dissolution of ^{14}C dead carbon from aquifer minerals or by decay of ^{14}C over time. If dissolution of mineral carbon is important in controlling ^{14}C activity and $\delta^{13}C$ values, then ^{14}C activity should decrease as $\delta^{13}C$ becomes more positive. However, no clear correlation exists between ^{14}C activity and $\delta^{13}C$ (Fig. 6); Three Forks Warm Springs, Luce Hot Springs, and possibly Rye Grass Hot Springs may be

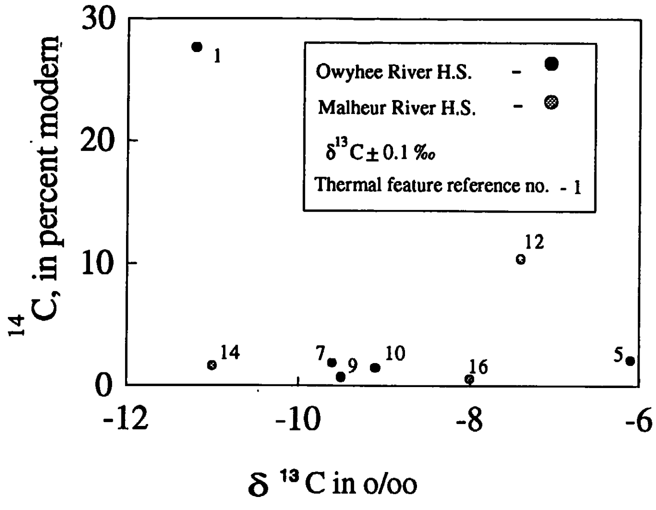

Figure 6.-- Relation between ^{14}C activity and δ^{13}C.

exceptions. Conversely, if radioactive decay of ^{14}C is controlling ^{14}C activity, then ^{14}C activity should decrease as dissolved helium concentrations increase. ^{14}C activity is generally not related to dissolved helium concentration (Fig. 7). All that can be determined with confidence is that Three Forks Warm Springs discharges the youngest thermal water in the Owyhee Uplands. The slight decrease in ^{14}C from Rye Grass Hot Springs downstream to Upper Lake Owyhee Hot Spring may indicate progressively older water downstream, but the data are not conclusive.

The disparity between the ^{14}C and dissolved helium data may be a function of the dissolved helium concentration being controlled by different rock types (different uranium and thorium concentrations) in, or beneath, the thermal aquifer. Cl/Br values indicate at least two distinct units. Mixing of an old ^{14}C-dead water from a deep thermal aquifer with a modern shallow groundwater is not a viable alternative because the thermal spring waters are tritium dead.

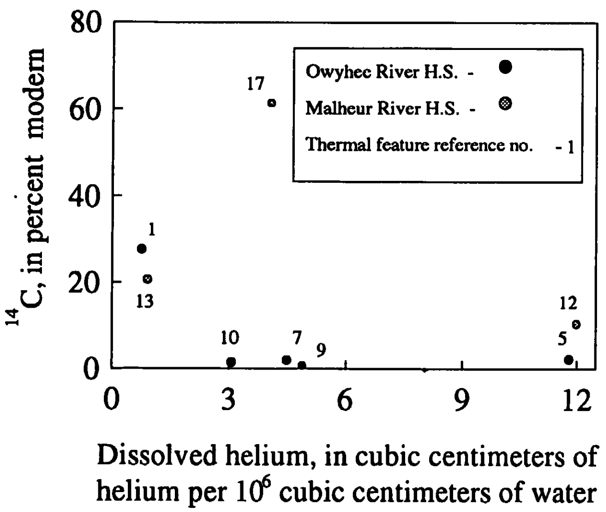

Figure 7.-- Relation between ^{14}C and dissolved helium.

TYPE OF GEOTHERMAL SYSTEM

At Twin Falls, Idaho, the presence of a large scale geothermal system which recharged near the Idaho-Nevada boundary was demonstrated by Mariner et al. (1991). The potentiometric surface for this system slopes to the north; near the Snake River these northward flowing thermal waters join westward flowing thermal waters beneath the Snake River Plain. Deuterium concentrations in the thermal waters of this system were constant within a very narrow range (-130 to -132 ‰) from the Idaho-Nevada boundary to the Snake River, a distance of about 50 mi. (80 km.). In the Twin Falls System, ^{14}C activity decreased northward as chloride and helium concentrations increased. Data from the hot springs of the Owyhee Uplands are very different. Deuterium concentrations show a much wider range, and decrease from -126 to -138‰ δD over a distance of 50 mi. (80 km.). In addition, no distinct trends exist in the chloride concentrations, ^{14}C data, or dissolved helium concentrations. The hot springs of the Owyhee Uplands do not appear to be part of a regional scale system; instead, they may represent separate systems isolated from each other by north or northwest trending faults. The absence of a demonstrable link between the hot springs of the Owyhee Uplands and the hotter systems to the north along the Malheur River, make it likely that the hotter systems in the Malheur River are similar to those in much of Nevada. That is, although high temperatures (>150°C) are present, relatively little fluid is available to support the requirements of a geothermal power plant.

SUMMARY

Thermal springs in the Owyhee Uplands range from warm (20 °C) to hot (67 °C), are relatively dilute (specific conductance of 340 to 820 µS/cm), slightly alkaline (pH 8 to 9½) waters in which sodium and bicarbonate predominate. Chloride concentrations are generally low (typically 10 to 20 mg/L) and fluoride concentrations are in some cases higher than those of chloride. Maximum aquifer-temperatures based on chemical geothermometry are about 100 °C. Cold springs in possible recharge areas are too enriched in deuterium to have recharged the current thermal waters. The warm springs at Three Forks may be the exception; their large flow rate suggests that the waters may have a short travel time, and waters recharged during the Pleistocene would have been discharged long ago. Thermal waters currently being discharged by the other thermal springs of the Owyhee Uplands must have recharged during times of colder climate, that is, during the Pleistocene. Attempts to use dissolved helium and ^{14}C to establish relative water ages were not successful in the hot springs of the Owyhee Uplands. Generally, ^{14}C activities and dissolved helium concentrations do not indicate the same relative water ages, perhaps because helium is being added to the aquifer-fluid at different rates depending on the composition of the confining or underlying rock. Among the seven thermal springs sampled in Owyhee Canyon, Rye Grass and Lambert hot springs stand out because of the large chloride concentrations, large dissolved helium concentrations, and the ^{13}C enrichment. Rye Grass, Lambert, and Luce hot springs are within a region of northwest trending faults that may be associated with The Brothers Fault Zone. The similar chemical character of the waters from Three Forks Warm Springs, Rye Grass, Lambert, and Luce hot springs indicate that they circulate through rock of similar composition but ^{14}C, ^{13}C, and dissolved helium data show that only Lambert and Rye Grass hot springs can be part of the same geothermal system. The available chemical data indicate that the hot springs of the Owyhee Uplands are not part of a regional scale geothermal system, nor is there a demonstrable link between these hot springs and the high temperature systems associated with Vale or other hot springs discharging along the Malheur River.

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