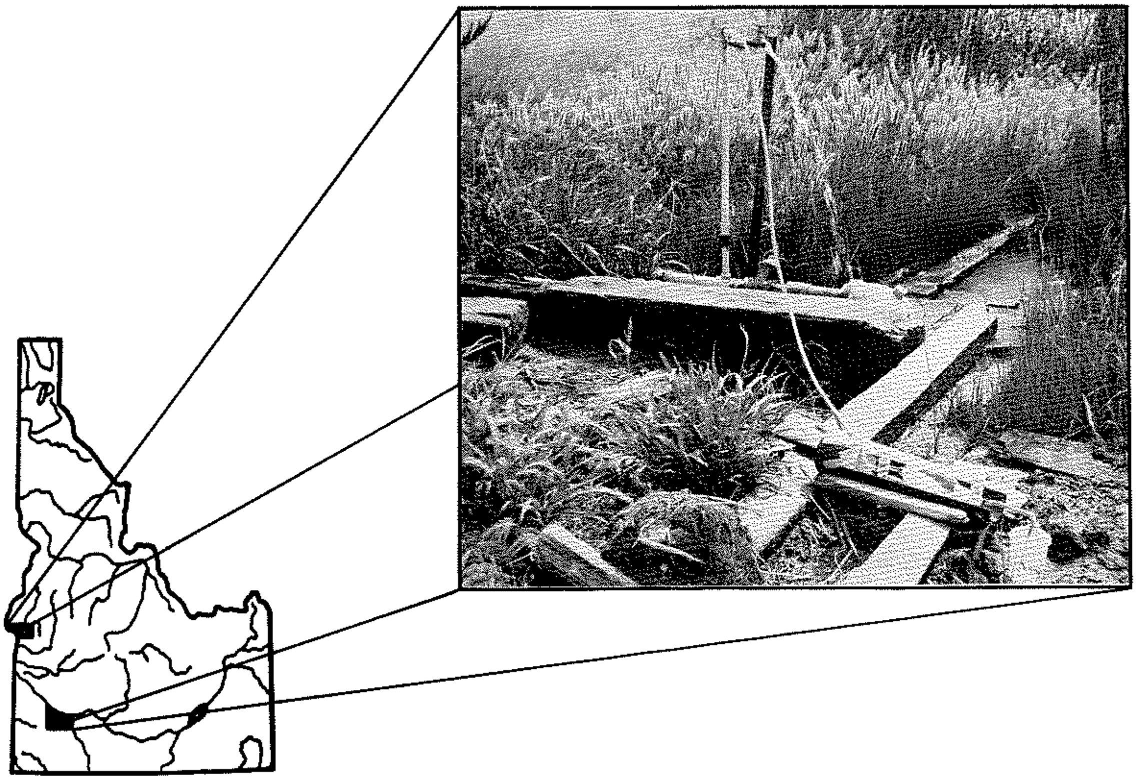
GEOTHERMAL INVESTIGATIONS IN IDAHO

PART 4

ISOTOPIC AND GEOCHEMICAL ANALYSIS OF WATER FROM THE BRUNEAU-GRAND VIEW AND WEISER AREAS, SOUTHWEST IDAHO



IDAHO DEPARTMENT OF WATER RESOURCES
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GEOTHERMAL INVESTIGATIONS IN IDAHO

Part 4

Isotopic and Geochemical Analyses of Water from the Bruneau-Grand View and Weiser Areas, Southwest Idaho

by

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Prepared by the U. S. Geological Survey
in cooperation with
the Idaho Department of Water Resources
Statehouse
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ABSTRACT

Variations of deuterium and oxygen-18 concentrations in thermal ground waters and local nonthermal springs have been used to aid in describing the source of recharge in the Bruneau-Grand View and Weiser areas, southwest Idaho.

Isotope and geochemical data for the Bruneau-Grand View area suggest that recharge to the area may not be entirely from sources within the local surface-drainage area, but possibly from the areas of higher altitude of the Bruneau River drainage to the southeast; or that the hot water that wells and springs are discharging is water that was recharged at a time when the regional climate was much colder than the present climate. Recharge to the Weiser area is probably from areas of higher altitude to the north and northeast of the local drainage area. However, "local" precipitation does influence both the chemical and isotopic compositions of the waters in each area.

INTRODUCTION

The Bruneau-Grand View and Weiser areas (fig. 1) were recommended for geothermal investigation by Young and Mitchell (1973). Subsequently, studies of the geothermal potential of those areas were made by the U. S. Geological Survey in cooperation with the Idaho Department of Water Resources (Young and Whitehead, 1975 and 1975b).

In conjunction with the above studies, water samples were collected for analyses of D (deuterium) and ^{18}O (oxygen-18), which, it was believed, could aid in understanding the hydrology of the two areas. Isotope analyses were incomplete at the time of publication of the above reports. This report contains the isotope and related chemical data for the Bruneau-Grand View and Weiser areas and summarizes the analyses of those data.

The isotope data presented in this report are sparse and do not represent the entire ground-water flow system of each area, and, therefore, must be considered to be of a reconnaissance level. Additional isotope samples might provide further clues to help in describing the ground-water flow system of each area.

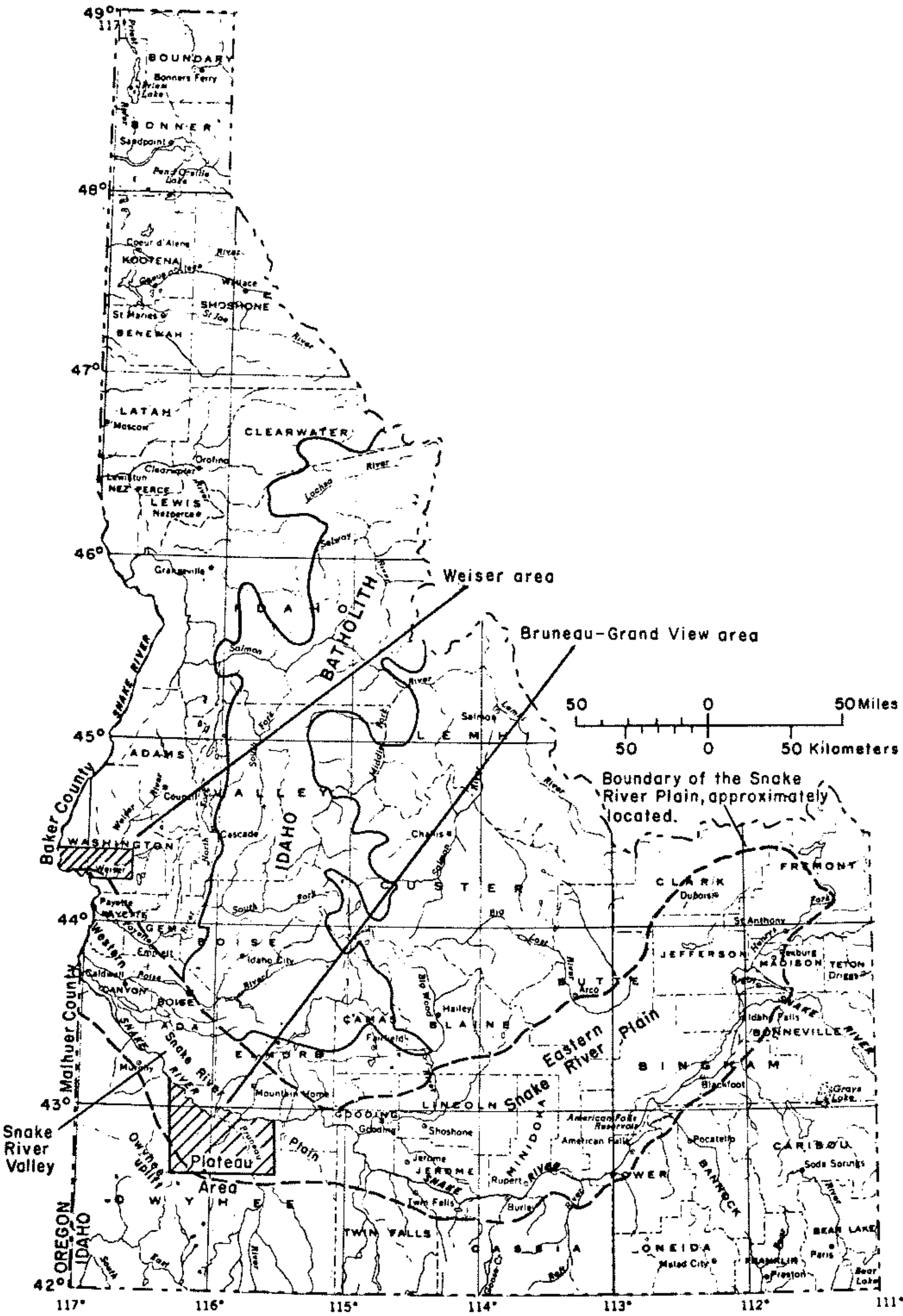

FIGURE 1. Index map showing location of the Bruneau-Grand View and Weiser geothermal areas.

Conversion Factors

The International System of Units (SI) is being adopted for use in reports prepared by the U. S. Geological Survey. To assist readers of this report in understanding and adapting to the new system, feet and inches are given in both units. To convert feet to metres, multiply ft (feet) by 0.3048 to obtain m (metres); and multiply in (inches) by 25.4 to obtain mm (millimetres). To convert acres to square kilometres, multiply acres by 4.047×10^{-3} to obtain km^2 (square kilometres). Chemical data for concentrations are given only in mg/l (milligrams per litre) or μg/l (micrograms per litre) because these values (within the range of values presented) are numerically equal to equivalent values expressed in parts per million, or parts per billion, respectively. The following table shows the relation between °C (Celsius) and °F (Fahrenheit).

TEMPERATURE–CONVERSION TABLE

°C	°F	°C	°F	°C	°F	°C	°F
7.0	44.6	17	62.6	27	80.6	50	122
8.0	46.4	18	64.4	28	82.4	55	131
9.0	48.2	19	66.2	29	84.2	60	140
10	50.0	20	68.0	30	86.0	65	149
11	51.8	21	69.8	32	89.6	70	158
12	53.6	22	71.6	34	93.2	75	167
13	55.4	23	73.4	36	96.8	80	176
14	57.2	24	75.2	38	100	85	185
15	59.0	25	77.0	40	104	90	194
16	60.8	26	78.8	45	113	95	203

Well- and Spring-Numbering System

The numbering system used by the Geological Survey in Idaho indicates the location of wells or springs within the official rectangular subdivision of the public lands, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and a numeral, which indicate the quarter section, the 40-acre (0.16 km^2) tract, the 10-acre (0.04 km^2) tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from the northeast quarter of each section (fig. 2). Within the quarter sections, 40-acre (0.16 km^2) and 10-acre (0.04 km^2) tracts are lettered in the same manner. Well 6S-3E-2ccc1 is in the SW¼SW¼SW¼, sec. 2, T. 6 S., R. 3 E., and was the first well inventoried in that tract. Springs are designated by the letter "S" following the last numeral, as in 8S-6E-3bdd1S.

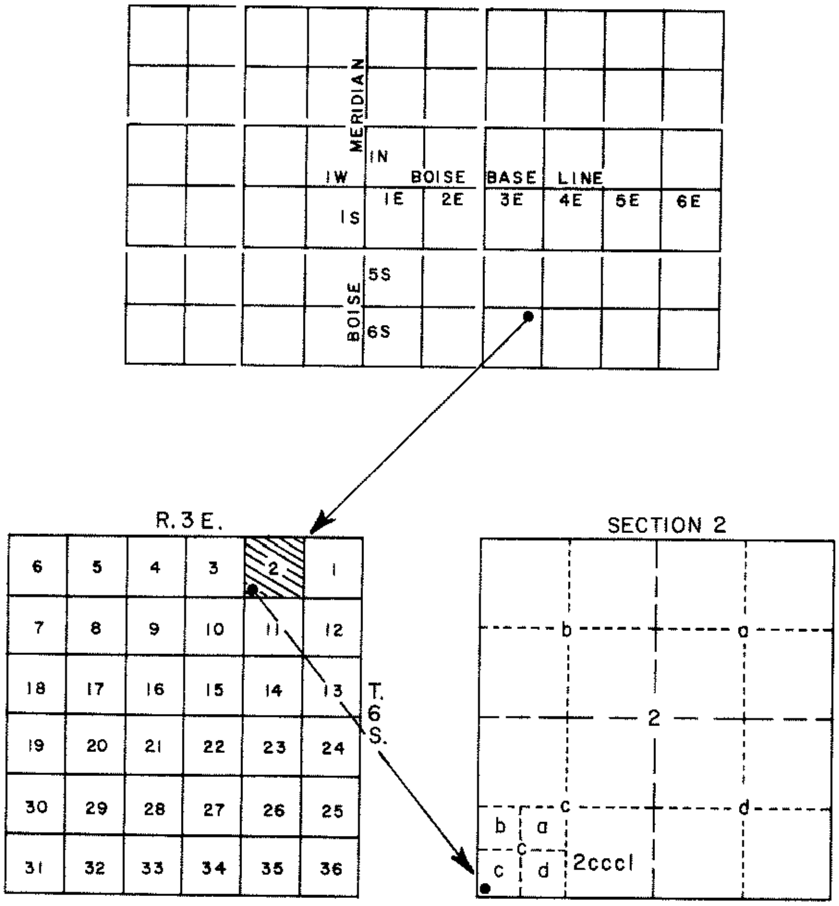

FIGURE 2. Diagram showing the well- and spring-numbering system. (Using well 6S-3E-2ccc1)

ISOTOPE ANALYSES

Isotope analysis of ground water can yield valuable information about its source, age, and environment. Isotopes, which are atomic species of the same chemical element, can be classified as stable or unstable (radioactive). Stable isotopes are those which do not undergo radioactive decay, whereas unstable isotopes are radioactive and decay by known sequences to stable isotopes of elements of lower atomic mass.

Hydrogen and oxygen each have naturally occurring stable isotopes. Stable hydrogen exists as hydrogen, ^{1}H, and deuterium, D or ^{2}H. Oxygen exists as three stable isotopes, ^{16}O, ^{17}O, and ^{18}O. A water molecule may be composed of any combination of these stable isotopes plus tritium, ^{3}H, which is a short half-life, (about 12.5 years) radioactive hydrogen isotope. SMOW (Standard Mean Ocean Water) is composed of 99.726 percent $H_2{}^{16}O$, 0.200 percent $H_2{}^{18}O$, 0.042 percent $H_2{}^{17}O$, and 0.031 percent $HD^{16}O$. All the other possible isotope combinations compose the remaining 0.001 percent (Craig, 1961a).

Stable isotopic variations are usually expressed in delta units (δ) defined as

$$\delta = \left[\frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}}\right] \times 1{,}000$$

where,

δ = reporting unit in $^{0}/oo$ (parts per mil),

R_{sample} = ratio of isotopic concentration ($^{18}O/^{16}O$, D/H, for example) of the sample, and

R_{standard} = ratio of isotopic concentration of the standard (in this report, SMOW).

Reported values of D and ^{18}O are considered accurate within ranges of $\pm 1.5\ ^{0}/oo$ and $\pm 0.1\ ^{0}/oo$, respectively.

As water evaporates from the ocean, moves through the atmosphere, and condenses to form precipitation, the percentage of each isotopic species (molecule) changes due to fractionation (a process similar to that employed in refining petroleum). Because of slightly different physical properties, each species evaporates, condenses, or freezes at a different rate for a given temperature and pressure. The result of this differential evaporation, condensation, or freezing is that isotopic composition of precipitation differs from that of the water body from which it originated. In addition to the simple processes of evaporation, condensation, and freezing, such factors as number of times reevaporation occurs (related to distance from source), temperature and pressure at which the various processes occur (related to altitude and latitude of source), intensity of the storm in which precipitation falls, and amount of particulate matter in the air can also affect the resultant isotopic composition of the precipitation. Despite all the various factors involved, the mean isotopic composition of precipitation in a given area will have an identifiable character representative of the environmental conditions of that area, and hence, serves as an identifier for the local meteoric water.

Worldwide analyses of precipitation have established that a relation exists between δD and $\delta^{18}O$. When δD is plotted against $\delta^{18}O$, almost all analyses of precipitation cluster about a line (the meteoric line) defined by $\delta D = 8\,\delta^{18}O + 10$ ‰ (Craig, 1961b). See figure 6 for plot of meteoric line. While the slope of eight is usually consistent for meteoric waters, the intercept may vary significantly, depending on "local" precipitation conditions.

Exceptions to this relation are generally due to such factors as precipitation originating from sources other than the ocean. In closed basins, for example, precipitation originating from lakes or inland seas that have different isotopic composition than ocean water may not plot on the meteoric line.

After entering the ground-water system, water usually conserves its original meteoric isotopic composition. However, several factors that can cause the δD or $\delta^{18}O$ concentrations of ground waters to differ from "local" meteoric water include: (1) recharge to the aquifer from areas of a differing altitude and latitude; (2) recharge from a body of surface water that has been partially evaporated; (3) recharge that occurred at an earlier time when local or worldwide climate was different; (4) mixing with other sources of water, such as brines or magmatic water; and (5) interaction with aquifer materials.

These factors all have a definite, predictable effect on a δD-$\delta^{18}O$ plot. If only one of these factors affects the isotopic composition of the ground water, the reason for variation may be evident. However, it is probable that several factors contribute to the total isotopic composition of a ground-water sample. When possible, chemical and hydrologic data should be combined with isotopic data to permit the most complete interpretation of the system of interest.

A brief description of how each of the above factors could affect the D and ^{18}O content may be helpful: (1) if recharge occurs from a nonlocal source, the D and ^{18}O values for ground water will plot on or near the meteoric line but will be displaced upslope or downslope from the local meteoric water; (2) ground water recharged from a water body where evaporation has occurred may be enriched in D and ^{18}O and will plot to the right of the meteoric line; (3) ground water that was recharged at some earlier time (the Pleistocene ice ages, for example) will have δD and $\delta^{18}O$ values quite different from present-day meteoric water, for known examples of paleowater or fossil water often are depleted in both D and ^{18}O (Gat, 1971); (4) mixing with other sources of water might be expected if plots of ground-water samples have a definite trend toward some point off the meteoric line. By comparing the chemistry of the ground water and the body of water with which it is suspected to be mixing, a clue to the degree of mixing may be found; (5) interaction with the aquifer material may result in enrichment of ^{18}O with little change occurring in the D content. The degree of interaction (and, therefore, the degree of ^{18}O enrichment) is dependent on the isotope difference between the recharge water and the rock materials, the ratio of the amount of water to the amount of rock, and the length of time the water is in contact with the rock. Porosity of the aquifer directly affects the interaction. This process is greatly increased at high temperatures and is frequently observed in geothermal areas (Craig, 1963).

A plot of δD against $\delta^{18}O$ for ground-water samples can thus yield valuable information about the ground-water system. If the data do not plot near data from known local meteoric sources, such as shallow wells or nonthermal springs, one or more of the above factors may have caused the discrepancy. Analysis of the variation together with other data may reveal the source, suggest the age, or aid in explaining the history of movement of the sample.

Deuterium and ^{18}O compositions have been used to study components of the hydrologic cycle by Friedman and others (1964), Dansgaard (1964), Friedman and Smith (1970), and others. Gat (1971) discussed the application of stable isotope techniques to studies of regional ground-water systems. Deuterium has been used as a tracer in determining regional ground-water flow in southern Nevada by Winograd and Friedman (1972).

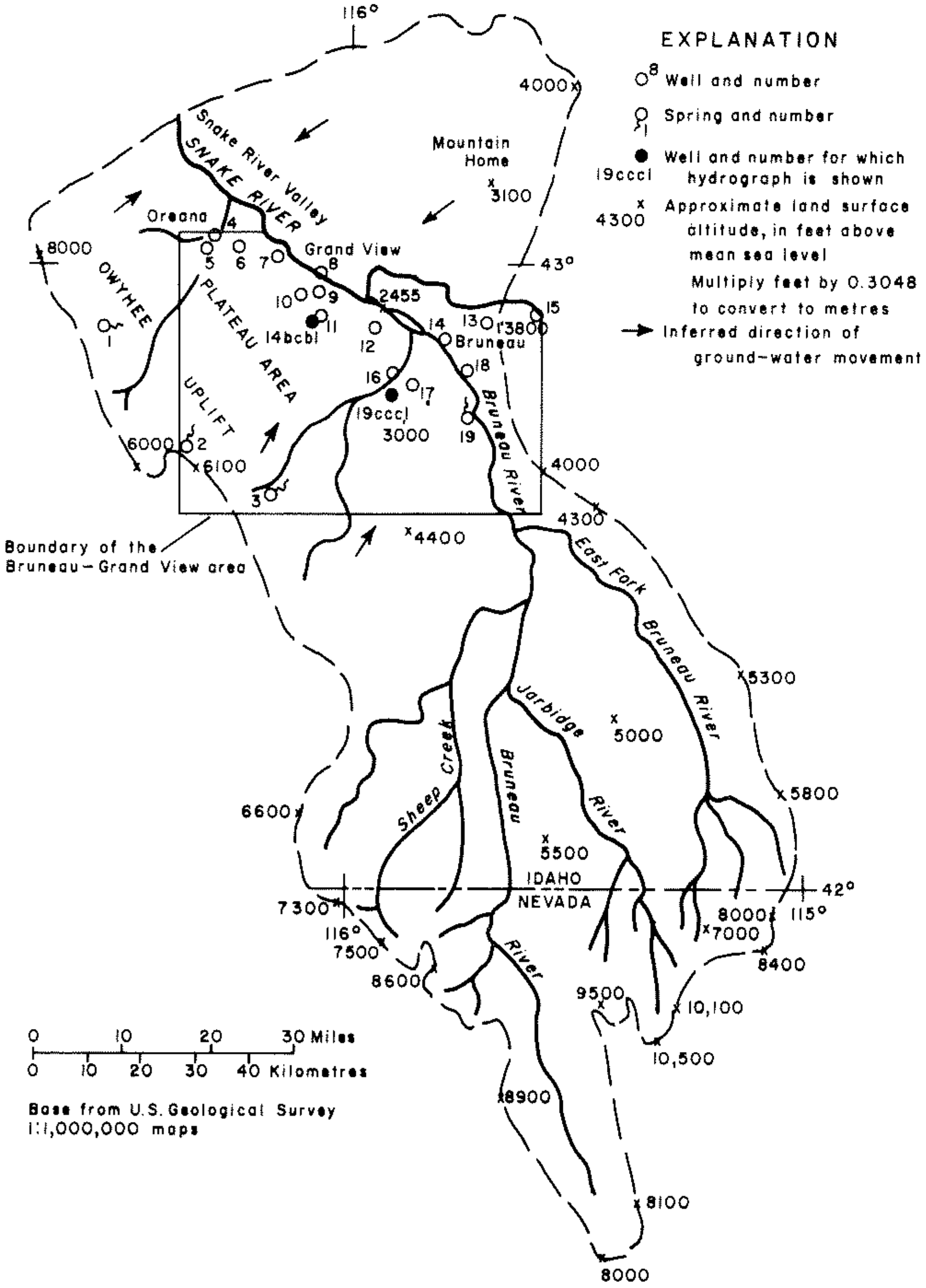

FIGURE 3. Map showing the generalized topographic drainage basin and location of wells and springs for the Bruneau-Grand View area.

BRUNEAU–GRAND VIEW AREA

The Bruneau-Grand View area is in the western Snake River Plain of southwestern Idaho. Figure 3 shows the three principal physical subdivisions of the area: (1) the Snake River valley, ranging in altitude from about 2,300 to 3,000 ft (700 to 900 m); (2) the plateau area, ranging in altitude from about 3,000 to 7,000 ft (900 to 2,130 m); and (3) part of the Owyhee uplift, in which altitudes range from about 3,000 to 8,400 ft (900 to 2,560 m).

The general lithology of this area (fig. 4) is as follows: granitic rocks of Cretaceous age, rhyolitic rocks of Miocene(?) age, Idavada Volcanics (silicic volcanic rocks of Pliocene age), and the Idaho Group of Pliocene and Pleistocene age. The Idaho Group contains chiefly sedimentary rocks of lacustrine and fluvial origin, but also includes some interbedded basaltic volcanic rocks, one of which is the Banbury Basalt. Deposits of alluvium of Pleistocene and Holocene age cover the older rocks at many places in the lowlands and valleys.

The aquifers have been classified into two groups by Young and Whitehead (1975a): (1) the volcanic-rock aquifers, which include the older rhyolites, Idavada Volcanics, and the Banbury Basalt; and (2) the sedimentary-rock aquifers, composed primarily of the sedimentary rocks of the Idaho Group. (Refer to table 1 for a description of each unit.)

The climate of the area is semiarid, with precipitation averaging less than 10 in (254 mm) per year in the Snake River valley. Some areas to the south and southwest receive precipitation of up to 30 in (760 mm) per year. Comparison of this area with areas to the north, also in the Snake River surface-water drainage basin, where annual precipitation is commonly above 30 in (760 mm), shows the potential recharge on the southern side of the valley to be minor (Mundorff, Crosthwaite, and Kilburn, 1964).

Recharge to the two principal aquifer systems in the Bruneau-Grand View area is believed to be from the same source, but by different means. Precipitation, chiefly in the form of snow, on the higher altitudes to the south and southwest provides recharge to both aquifers. However, recharge to the sedimentary-rock aquifers is chiefly from vertical movements of water from the underlying volcanic-rock aquifers.

The Snake River Plain is generally believed to be a faulted graben in which many faults and fractures permit waters to migrate across stratigraphic boundaries (fig. 4). In addition to natural mixing of waters, many wells are open to both the volcanic- and sedimentary-rock aquifers, making sampling of any one particular aquifer extremely difficult and the interpretation of the data derived from such wells questionable.

FIGURE 4. Idealized hydrogeologic section showing general relation of geologic units, "local" recharge, and inferred pattern of ground-water movement in the Bruneau-Grand View area.

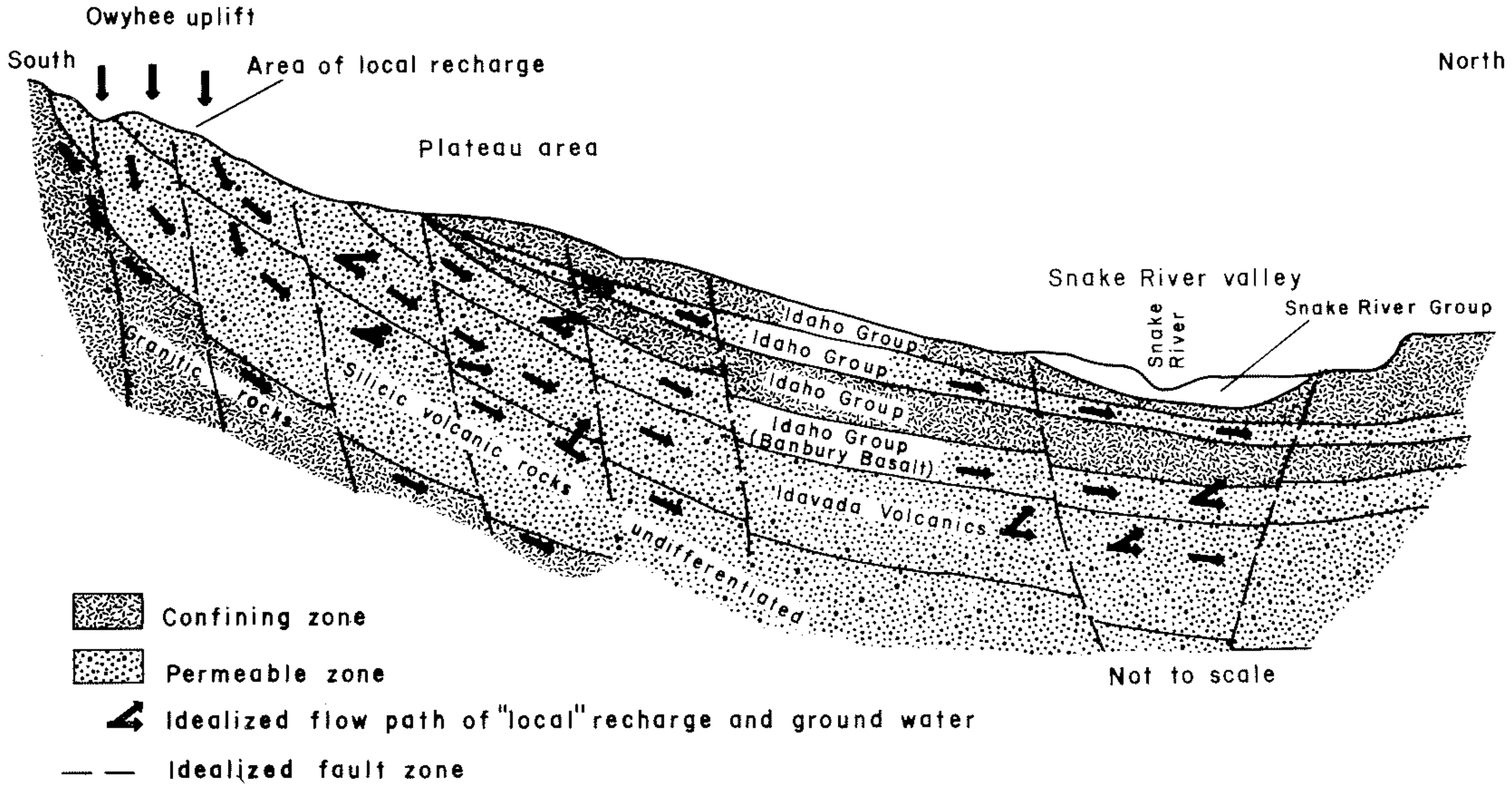

TABLE 1

DESCRIPTION AND WATER–BEARING CHARACTERISTICS OF GEOLOGIC UNITS IN THE BRUNEAU–GRAND VIEW AREA[1]

ERA	PERIOD	EPOCH	ROCK UNIT	DESCRIPTION[2]	WATER–BEARING CHARACTERISTICS[3]
Cenozoic	Quaternary	Holocene	Alluvium and dune sand	Includes clay, silt, sand, and gravel. Chiefly fluvial and eolian deposits of Holocene age. The deposits form hills, mounds, and crescent-shaped dunes.	Surficial deposits that are not permanently saturated. Too limited in extent to be important as aquifers.
Cenozoic	Quaternary and Tertiary	Pleistocene and Pliocene	Idaho Group, undifferentiated	Poorly to well-stratified fluvial and lacustrine deposits of unconsolidated to consolidated gravel, sand, silt, and clay with layers of ash and intercalated basaltic lava flows. In places exceeds 3,000 feet in thickness.	Yields to wells vary from very poor to good depending upon unit penetrated. Important as an aquifer. See descriptions for individual units below.
Cenozoic	Tertiary	Pliocene	Banbury Basalt of the Idaho Group	Lava flows of olivine basalt interbedded locally with minor amounts of stream and lake deposits. Flows mostly vesicular and less than 15 feet thick. Includes some basaltic pyroclastic material in vent areas. Maximum thickness is about 1,000 feet.	Yields to wells range from very poor to excellent depending upon degree of alteration present in area penetrated by the well. A highly altered zone of this basaltic unit tends to be a poor aquifer, whereas the unaltered unit is a good aquifer.
Cenozoic	Tertiary	Pliocene and Miocene	Silicic volcanic rocks	Silicic volcanic rocks, undifferentiated. Includes Idavada Volcanics and rhyolitic rocks.	Remarks for Idavada Volcanics and rhyolitic rocks apply to this unit.
Cenozoic	Tertiary	Pliocene	Idavada Volcanics	Silicic latite; chiefly thick layers of devitrified welded tuff, but includes some vitric tuff and lava flows. Rhyolitic rocks occur in minor amounts. Predominantly porphyritic with phenocrysts of andesine, clinopyroxene, hyperstene, and magnetite, but with no quartz, sanidine, hornblende, or biotite. Overlies older rhyolitic and related rocks, locally exceeds 3,000 feet in thickness.	The highly jointed and fractured character of these rocks make them a good aquifer in the study area and large well yields are obtained. It is believed that these rocks serve to transmit recharge-water to the area thence upward to overlying units.
Cenozoic	Tertiary	Miocene(?)	Rhyolitic rocks	Fine- to coarse-grained extrusive rocks rich in quartz and biotite. Locally cut by mineralized fault zones. Several thousand feet are exposed in the Owyhee uplift.	Unknown; may be an important aquifer.
Mesozoic	Cretaceous		Intrusive rocks	Intrusive granitic rocks of comparable age and composition to the Idaho batholith. Exposed in the southwestern part of the study area. Believed to form the basement complex.	Unknown; may be an aquifer.

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[1] Modified from Young and Whitehead, 1975a.

[2] Modified chiefly from Malde, Powers, and Marshall (1963); and in part from Littleton and Crosthwaite (1957).

[3] Modified from Littleton and Crosthwaite (1957) and Ralston and Chapman (1969).

TABLE 2

CHEMICAL ANALYSES OF WATER FROM SELECTED WELLS AND SPRINGS IN THE BRUNEAU–GRAND VIEW AREA

(Chemical constituents in milligrams per litre except where noted.)

Well or spring location number	Reported well depth below land surface (feet)	Major aquifer	Minor aquifer	Date of collection	Discharge (cubic feet per second)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite plus nitrate (NO_2+NO_3)	Phosphorus (P)	Dissolved solids (calculated)	Dissolved solids (tons per ac-ft)	Hardness		Percent sodium	Sodium adsorption ratio	Specific conductance (field)	pH (field)	Water temperature (ºC)	Chemical constituents in micrograms per litre				Reference number
																					as $CaCO_3$	Noncarbonate						Arsenic (As)	Boron (B)	Lithium (Li)	Mercury (Hg)	
														NONTHERMAL																		
6S-2N-14cba1S		Alluvium near Idavada Volcanics		73/7/3	0.06	30	5.6	1.4	8.2	2.0	28	0	23	8.5	6.3	0.1	2.3	0.06	86	0.12	20	0	44	0.8	91	7.1	11.0	1	30	0	0.2	1
8S-1E-20cca1S		Idavada Volcanics		73/7/2	.01	22	11	2.8	6.0	.7	62	0	51	3.2	2.0	.2	.62	.07	81	.11	39	0	25	.4	100	7.1	9.5	2	20	0	.1	2
9S-2E-13cbc1S		Idavada Volcanics		73/7/2	.01	39	14	2.9	11	2.1	71	0	58	9.5	6.3	.3	.04	.08	120	.16	47	0	33	.7	130	7.2	11.0	0	40	0	.3	3
														THERMAL																		
4S-1E-26abc1	1,700	Sedimentary rocks of Idaho Group		73/6/8	0.01	96	13	2.8	250	29	763	0	626	3.6	13	0.6	0.01	0.16	786	1.07	44	0	87	16	1,160	7.3	27.0	14	730	740	0.6	4
34bad1	2,960	Idavada Volcanics	Banbury Basalt(?)	73/7/9	--	91	1.0	0	99	.8	72	46	136	40	13	13	0	0	339	.46	3	0	98	27	453	9.2	75.5	29	150	10	0	5
4S-2E-32bcc1	2,704	Sedimentary rocks of Idaho Group	Banbury Basalt(?) Idavada Volcanics(?)	73/7/9	.05	110	5.8	.7	150	8.5	383	0	314	5.2	17	8.7	.70	.07	499	.68	17	0	92	16	699	8.8	43.0	5	1,000	260	.3	6
5S-2E-1bbc1	1,800	Banbury Basalt(?)		73/7/9	.06	77	1.7	0	86	.6	46	59	136	7.1	16	15	.36	0	288	.39	4	0	86	18	423	9.8	49.5	1	1,100	10	0	7
5S-3E-14cbb1	2,300	Idavada Volcanics(?)	Banbury Basalt(?)	73/7/23	.14	81	2.4	0	91	.8	66	42	124	10	18	23	0	.05	302	.41	6	0	97	16	419	9.6	58.5	2	1,100	10	0	8
26bcb1	2,970	Idavada Volcanics	Banbury Basalt	73/6/7	--	110	2.1	0	110	1.7	22	64	125	62	15	15	.01	.02	391	.53	5	0	97	21	530	9.3	83.0	4	570	40	.3	9
28bcc1	2,540	Idavada Volcanics	Banbury Basalt	73/5/31	--	98	.8	0	97	1.3	27	67	134	9.8	15	21	0	.02	324	.44	2	0	98	30	437	9.4	65.0	5	620	20	.1	10
6S-3E-2ccc1	1,940	Banbury Basalt	Sedimentary rocks of Idaho Group	73/7/6	1.6	100	1.2	.1	110	4.0	120	37	160	27	18	17	.03	.01	374	.51	3	0	97	26	504	9.2	53.0	3	760	40	.1	11
6S-4E-14abc1	1,906	Idavada Volcanics	Banbury Basalt	73/5/30	3.3	140	5.0	.1	110	4.7	20	74	140	65	19	24	.02	.06	452	.61	13	0	93	13	583	9.4	54.0	30	540	0	.4	12
6S-6E-12ccd1	990	Sedimentary rocks of Idaho Group		73/7/6	–	120	10	.6	180	15	493	0	404	3.6	19	5.9	3.0	.07	612	.83	27	0	89	15	843	8.2	37.0	1	1,100	220	.3	13
19ccd1	913	Banbury Basalt	Sedimentary rocks of Idaho Group	73/5/22	.01	88	3.0	0	93	3.1	94	19	109	38	10	26	.01	.01	327	.44	8	0	95	15	457	9.0	38.0	15	340	0	.2	14
6S-7E-2cdd1	1,350	Sedimentary rocks of Idaho Group	Banbury Basalt(?)	73/6/25	.01	75	5.8	.5	210	7.6	524	0	431	2.8	56	7.6	.30	.01	628	.85	17	0	94	22	951	8.0	34.5	1	1,700	20	0	15
7S-5E-7abb1	1,625	Idavada Volcanics	Banbury Basalt	73/7/6	7.8	91	8.5	.2	51	7.4	96	0	79	17	9.8	9.7	.95	.04	246	.33	22	0	78	4.7	279	8.5	39.0	21	90	0	.6	16
15acd1	1,515	Idavada Volcanics	Banbury Basalt	73/5/30	--	90	6.7	.1	53	6.5	101	0	87	20	9.8	16	.26	.02	259	.35	17	0	83	5.9	278	8.7	39.5	17	90	10	.3	17
7S-6E-9bad1	910	Banbury Basalt(?)		73/7/5	--	100	1.6	.3	100	2.8	59	43	120	27	10	24	.06	.04	338	.46	5	0	96	19	461	9.4	50.5	78	210	10	.1	18
8S-6E-3bdd1S		Banbury Basalt Tuff Idaho Group		73/7/5	1.0	87	6.5	.6	53	6.7	113	5	101	15	9.1	6.0	.66	.06	248	.34	19	0	81	5.3	300	8.3	39.0	18	80	10	0	19

Analyses by: U. S. Geological Survey
Conversion factor: multiply ft (feet) by 0.3048 to get m (metres).

Geochemistry of the Bruneau-Grand View Area Ground Waters

A total of 19 springs and wells were sampled in the Bruneau-Grand View area (fig. 3) in an attempt to determine the isotopic and geochemical relations of the waters. Three nonthermal springs were sampled near the topographic drainage boundary of the study area to determine the isotopic composition of local meteoric water. The isotopic composition of the nonthermal springs is assumed to be representative of the precipitation in the assumed principal recharge area.

The 19 wells and springs were sampled for isotopic analysis at the same time that a larger sampling was conducted (Young and Whitehead, 1975a). The chemical analyses for these wells and springs are shown in table 2.

The data, plotted on a trilinear diagram (fig. 5), show that water from two of the three nonthermal springs is calcium bicarbonate type water. The third nonthermal spring discharges a calcium sodium bicarbonate water. The remainder of the water samples are sodium bicarbonate type water. Two distinct groupings of the sodium bicarbonate water are shown in figure 5. Samples 4, 6, 13, and 15 are clustered in the extreme sodium bicarbonate region, whereas the remainder of the samples contain higher percentages of chloride and sulfate. Available lithologic information suggests that samples 4, 6, 13, and 15 were obtained principally from sedimentary-rock aquifers. The bicarbonate concentrations in these samples are higher, and the surface temperatures are lower than those in the remaining samples.

Isotopic Geochemistry of the Bruneau-Grand View Area Ground Waters

Comparison of the isotopic composition of the Bruneau-Grand View water and other major geothermal systems of the world is shown in figure 6. As illustrated in figure 6, waters of these known major geothermal systems are dominantly meteoric in origin, with δD values similar to those of the "local" recharge water but with ^{18}O values significantly enriched relative to the local recharge water. This enrichment probably results from isotope-exchange reactions with aquifer materials. However, the thermal water in the Bruneau-Grand View area apparently differs significantly from nonthermal waters in both the δD and δ^{18}O values. The Bruneau-Grand View area is relatively large, compared to other geothermal systems, which might account for the variation. However, the significant depletion of δD and the apparent depletion in δ^{18}O is not consistent with isotope exchange and suggests that other factors may be involved.

The range of δD values for the Bruneau-Grand View thermal waters is from -135 to -156 ^{o}/oo (table 3 and fig. 7). The range of δ^{18}O values with one exception, (sample 15, $\delta^{18}O = -15.0$), is from -17.0 to -18.2 ^{o}/oo. The majority of the samples cluster in a region bounded by δD values between -142 and -146 ^{o}/oo, and δ^{18}O values between -17.0 and -18.2 ^{o}/oo. Samples 11, 14, and 19, which, on the basis of well construction, hydrology, and geologic data, appear to have derived water from the Banbury Basalt, are the samples most depleted in D, with δD ranging from -150 to -156 ^{o}/oo.

The majority of the Bruneau-Grand View waters fall near or slightly to the right of the nonthermal samples, which are themselves slightly to the right of the worldwide meteoric line (fig. 7). A line with a slope of 8 through the average of the nonthermal springs has an intercept of 3 ^{o}/oo. This deviation from the worldwide precipitation line for the nonthermal samples indicates the possibility of slight evaporation prior to recharge, which may be

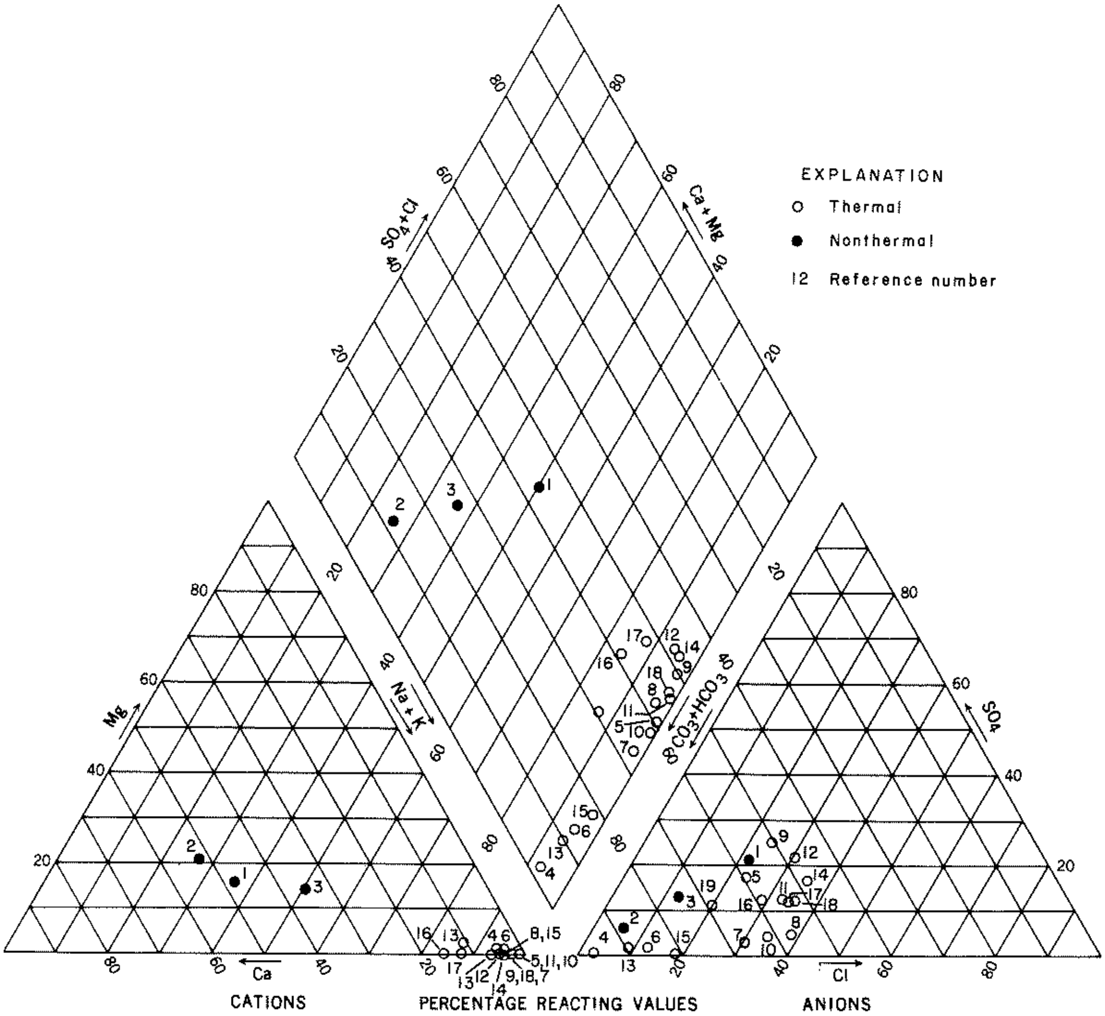


FIGURE 5. Variation of chemical constituents in water from selected wells and springs in the Bruneau-Grand View area.

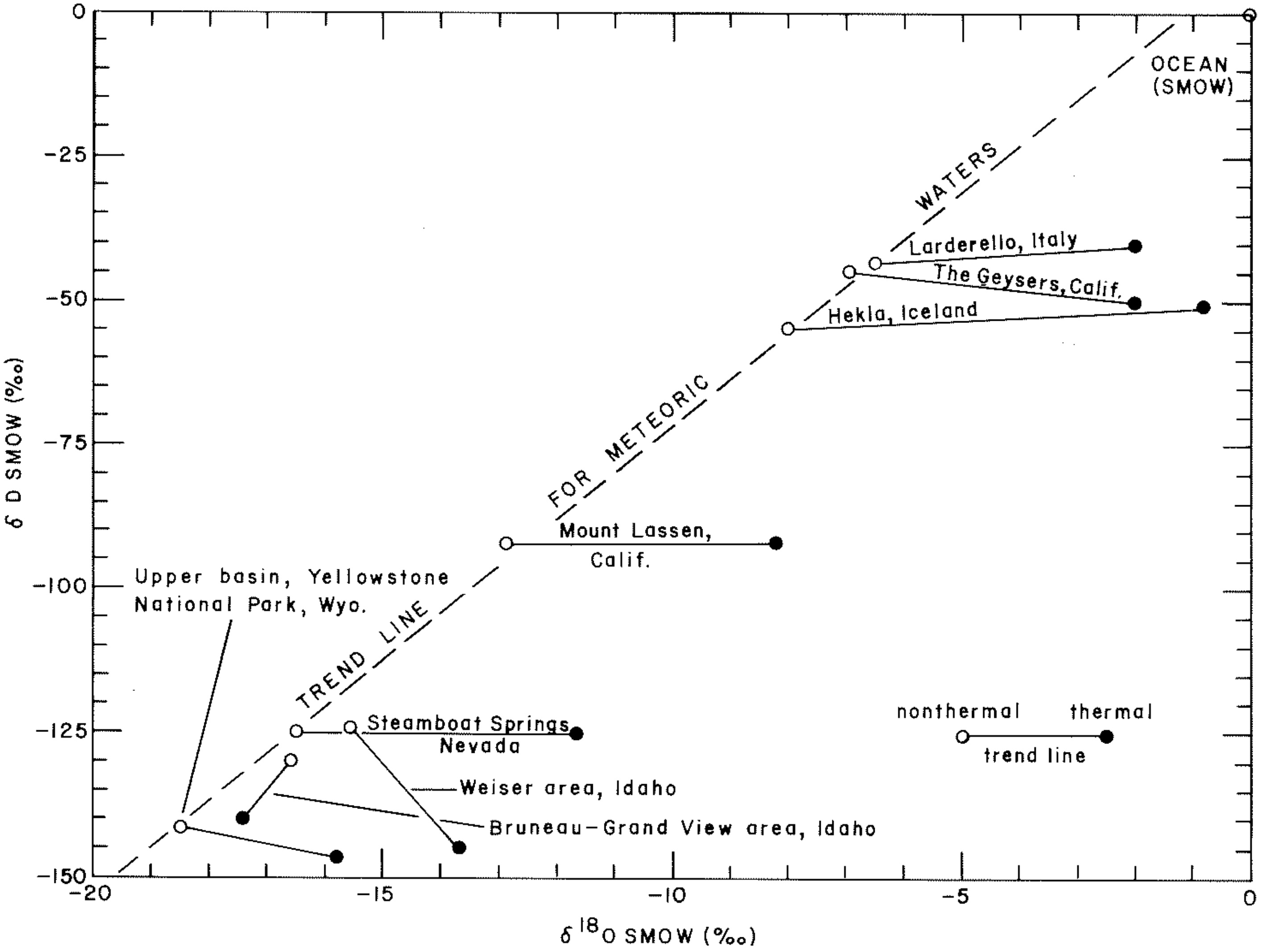


FIGURE 6. Comparison of isotopic composition of the nonthermal and thermal waters, Bruneau-Grand View and Weiser areas, Idaho, and of nonthermal and thermal waters elsewhere (after White, Barnes, and O'Neill, 1973, fig. 1).

TABLE 3

ISOTOPE ANALYSES OF WATER FROM SELECTED WELLS AND SPRINGS IN THE BRUNEAU—GRAND VIEW AREA

Well or spring location number	δD SMOW	$\delta^{18}O$ SMOW	$\Delta^{18}O$	Reference number
NONTHERMAL				
6S-2W-14cba1S	-133	-16.4	+1.45	1
8S-1E-20cca1S	-128	-17.1	+0.20	2
9S-2E-13cbc1S	-129	-16.5	+0.90	3
THERMAL				
4S-1E-26abc1	-144	-18.2	+0.95	4
34bad1	-145	-17.5	+1.80	5
4S-2E-32bcc1	-146	-17.4	+2.05	6
5S-2E-1bbc1	-144	-17.0	+2.25	7
5S-3E-14cbb1	-142	-17.6	+2.00	8
26bcb1	-146	-17.5	+2.00	9
28bcc1	-142	-17.6	+0.90	10
6S-3E-2ccc1	-154	-17.6	+2.80	11
6S-4E-14abc1	-144	-17.6	+1.65	12
6S-6E-12ccd1	-144	-18.1	+1.10	13
19ccd1	-156	-18.1	+2.55	14
6S-7E-2cdd1	-135	-15.0	+3.25	15
7S-5E-7abb1	-135	-17.6	+0.55	16
16acd1	-135	-17.1	+1.00	17
7S-6E-9bad1	-142	-18.2	+0.80	18
8S-6E-3bdd1S	-150	-17.1	+2.95	19

Analyses by: U. S. Geological Survey

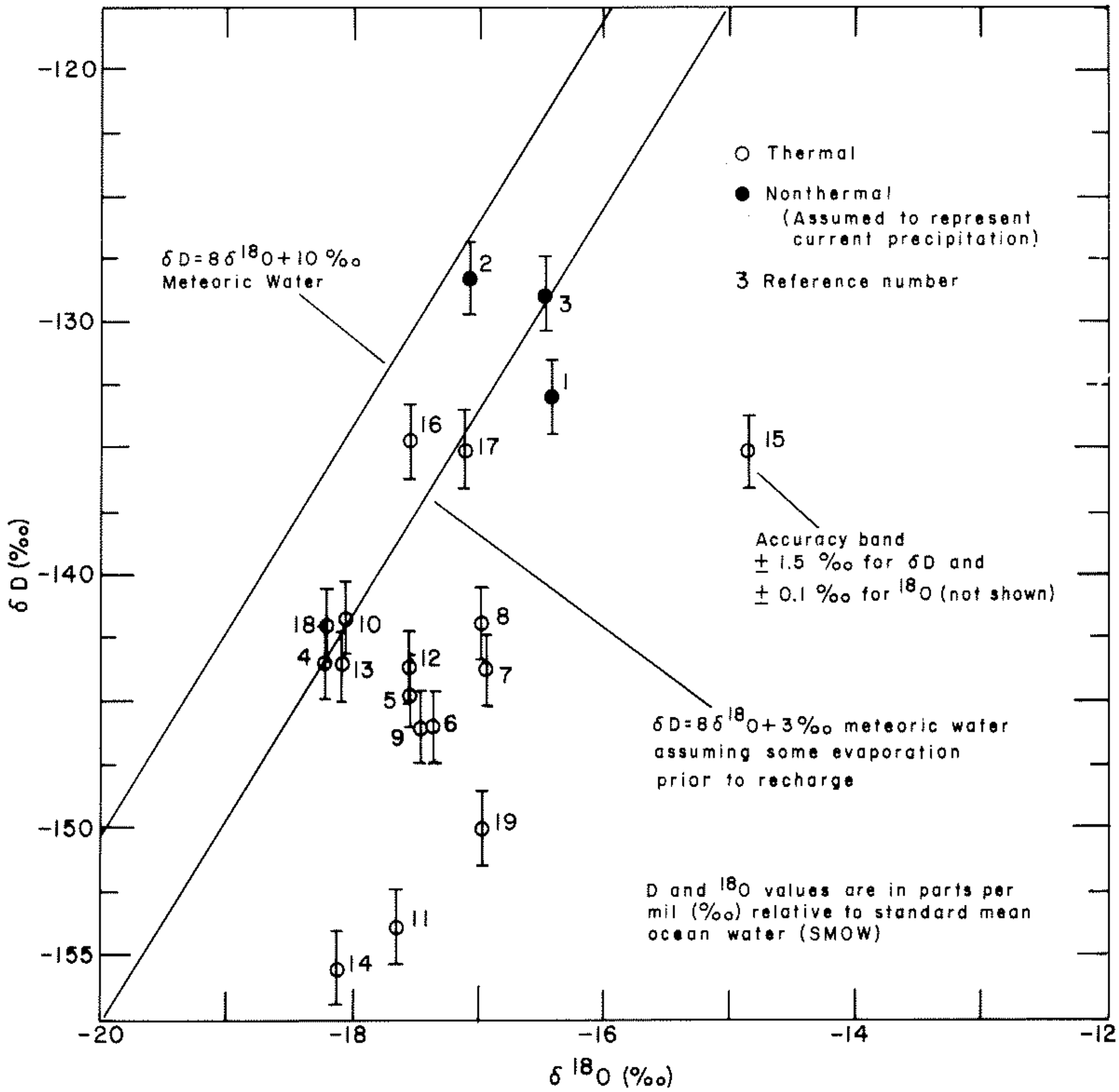
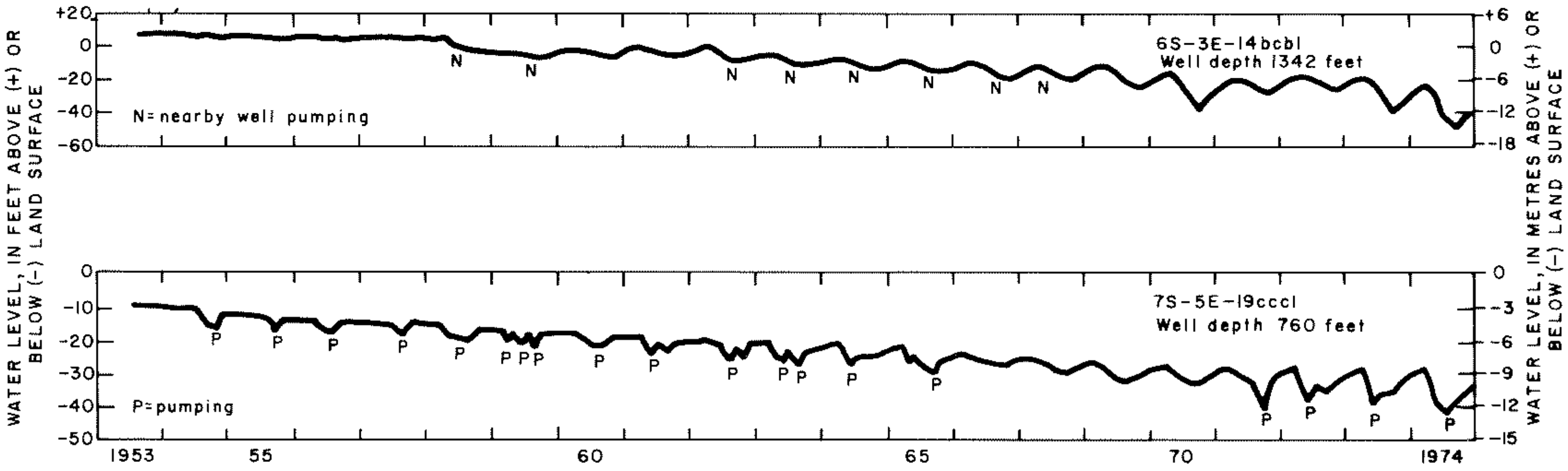


FIGURE 7. Isotope variations in water from selected wells and springs in the Bruneau-Grand View area and relation to meteoric water.

FIGURE 8. Hydrographs for wells 6S-3E-14bcb1 and 7S-5E-19ccc1 in the Bruneau-Grand View area.



Modifed from Sisco, 1974

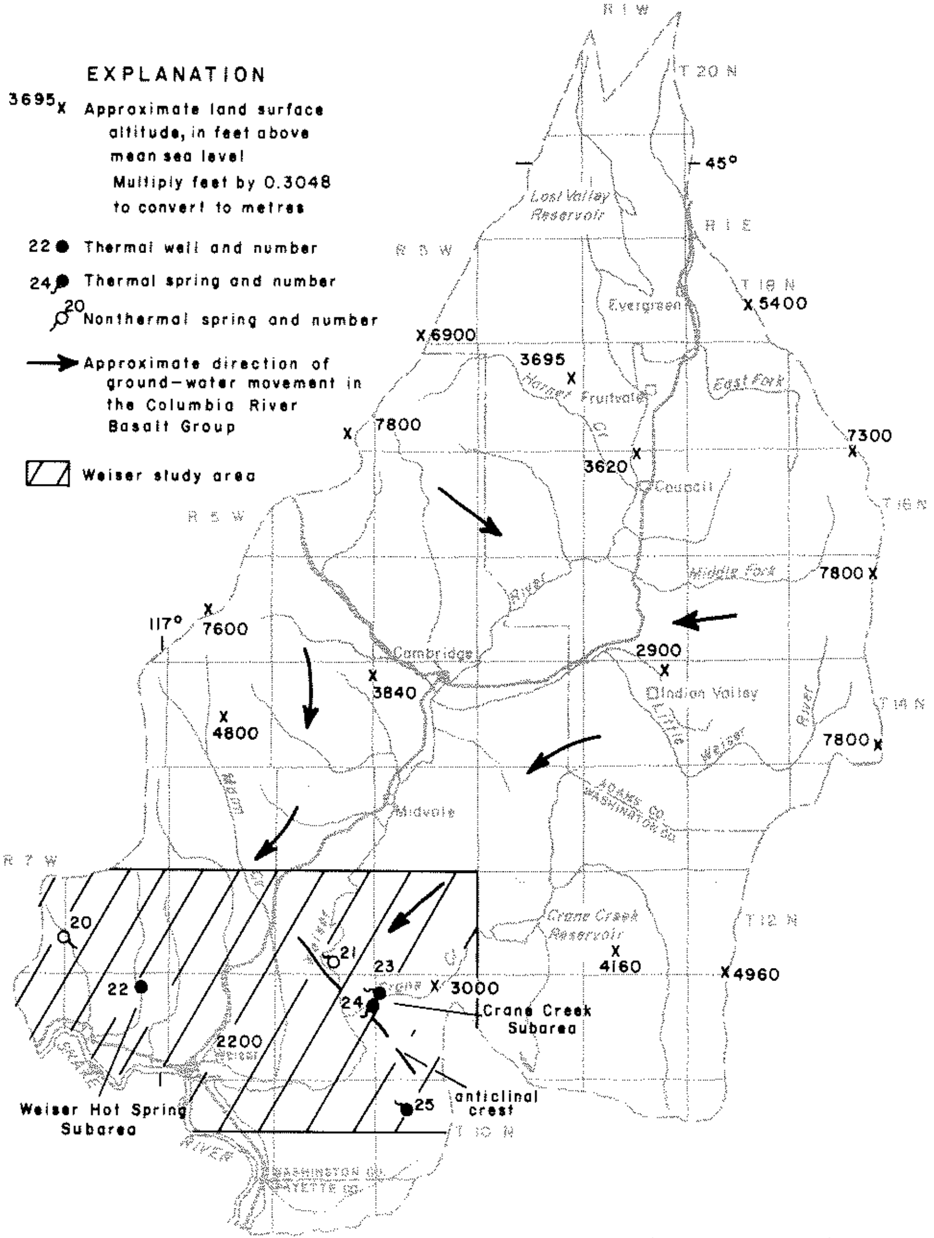
Location of wells shown in fig. 3

expected in arid or semiarid regions such as this. Examination of figure 7 shows possible oxygen-isotope exchange in the thermal water due to elevated temperatures. The $\delta^{18}O$ shifts range from -0.40 (sample 16) to +2.25 $^{o}/oo$ (sample 15) from the "local" precipitation line with the equation $D = 8\ \delta^{18}O + 3\ ^{o}/oo$. Assuming that the waters have been exposed to the same aquifer materials, oxygen-isotope shifts suggest that samples 11, 14, 15, and 19 have been exposed to the highest subsurface temperatures. The $\delta^{18}O$ deviation of those samples from the meteoric waterline ranges from 1.60 to 2.5 $^{o}/oo$.

The position of the "local" precipitation samples in relation to the majority of the thermal ground-water samples as shown on figure 7 suggest that the thermal ground water was not wholly derived from current "local" precipitation within the local topographic drainage of the study area from which the samples were collected (fig. 3). The isotopic values of most of the sampled thermal water exhibit significant depletion in D and an apparent depletion in ^{18}O relative to recent "local" precipitation indicating that the water fell as precipitation in an environment that was different from the current local one. This different environment could represent recharge from the higher altitude of the Bruneau River drainage area southeast of the study area, or at some previous time when the climate was significantly colder than the present-day climate.

Regardless of the recharge source, hydrologic data shown in figure 8 indicate that in parts of the area, water levels in some wells show a steady decline since 1953. The downward trend probably results from pumping ground water for irrigation at a faster rate than it can be replaced. Seasonal fluctuations in the hydrographs (fig. 8) representing local recharge do occur. These seasonal fluctuations indicate that local surface-water drainage does contribute some water to the aquifers in the Bruneau-Grand View area.

The declining water levels and the "nonlocal" nature of water samples collected suggests that current recharge is not sufficient to replace ground water extracted by wells in the areas affected by the declining water levels. Together with the isotope data, the declining water levels strongly suggest that recharge to the system may have occurred over a considerable timespan. Present-day extractions may be water that accumulated over a long period of time.



Base from U. S. Geological Survey, Idaho 1968

FIGURE 9. Map showing the generalized topographic drainage basin for the Weiser area.

WEISER AREA

The Weiser area is in the extreme northwestern part of the Snake River Plain in southwestern Idaho (fig. 9). It is at the southern end of a system of northwest-trending eroded anticlines. The system of anticlines dips towards the Plain and terminates abruptly at the northern margin of the Plain at an altitude of about 2,200 ft (670 m).

Two separate areas were studied in the Weiser area: the Weiser Hot Springs subarea to the west and the Crane Creek subarea to the east (fig. 9). The Weiser Hot Springs subarea is along the northern margin of the Snake River Plain, and the Crane Creek subarea is along the crest of an anticline.

In succession, the lithology of the Weiser area consists of volcanic and interbedded sedimentary rocks of Permian and Triassic age and granitic rocks of Cretaceous age, which underlie volcanic rocks of the Columbia River Basalt Group of Miocene and Pliocene age. The Columbia River Basalt Group occurs both below and above sedimentary rocks of the Payette Formation. Sedimentary rocks of the Idaho Group of Pliocene and Pleistocene age overlie the Columbia River Basalt Group and Payette Formation. Alluvium and colluvium of Pleistocene and Holocene age generally overlie the older rocks in the lowlands and valleys. Refer to table 4 for a description of each water-bearing unit.

Precipitation in the mountainous regions to the north and northeast of the area (fig. 9) is believed to furnish recharge to the area's aquifers. The Columbia River Basalt Group is believed to transmit water from the catchment areas to the lowlands.

Geochemistry of the Weiser Area Ground Waters

Five springs and one well were selected for isotopic analyses in the Weiser area (fig. 9) to determine the isotopic and chemical relations of the ground waters. The chemical analyses of these springs and the well are given in table 5.

Two nonthermal springs were sampled (samples 20 and 21) as in the Bruneau-Grand View area, to provide background information for precipitation in the local area. The temperature of these springs was 13.5 and 15.0°C, respectively. The dissolved solids for both springs is approximately 200 mg/l, with silica concentrations of approximately 50 mg/l.

A trilinear diagram (fig. 10) illustrates the chemistry of the thermal and nonthermal waters. The nonthermal water in the Weiser Hot Springs subarea (sample 20) is calcium sodium bicarbonate water, and sample 21 from the Crane Creek subarea is calcium bicarbonate water. The thermal waters from both subareas are grouped in the sodium sulfate

TABLE 4

DESCRIPTION AND WATER–BEARING CHARACTERISTICS OF GEOLOGIC UNITS IN THE WEISER AREA, IDAHO[1]

ERA	PERIOD	EPOCH	ROCK UNIT	DESCRIPTION	WATER–BEARING CHARACTERISTICS
Cenozoic	Quaternary	Holocene and Pleistocene	Alluvium and Colluvium	Clay, silt, sand, and gravel; chiefly fluviatile deposits. Includes some landslide materials. Thickness is variable.	Yields adequate supplies of water to domestic and stock wells. Important locally as an aquifer.
Cenozoic	Quaternary and Tertiary	Pleistocene and Pliocene	Idaho Group, undifferentiated	Fluviatile and lake deposits of clay, silt, sand, and gravel, compacted to poorly consolidated, poorly to well stratified. Contains beds of ash and intercalated basaltic lava flows. Exceeds 1,500 feet in thickness in the Weiser River Valley near Weiser. Exceeds 4,000 feet near Ontario, Oregon about 16 miles south of Weiser (Kirkham, 1931a).	Hydraulic conductivity highly variable. Generally contains confined water, yields to wells range from few gallons per minute to several hundred gallons per minute. Important as an aquifer.
Cenozoic	Tertiary	Pliocene and Miocene	Columbia River Basalt Group	Flood-type basalt, light- to dark-gray, dense; crude columnar jointing at places; folded and faulted; may include some andesitic and rhyolitic rock types. The Payette Formation is sandwiched between units of this basalt at places, which is a characteristic feature distinguishing the Payette Formation from sediments of the Idaho Group. Thickness of the upper basalt unit exceeds 1,000 feet in the canyon of Crane Creek just east of the study area, other measured thicknesses range from 445 to 680 feet at places in and near the study area (Kirkham, 1931a).	Unknown in Weiser area; but generally yields are highly variable in areas where wells are producing from this aquifer.
Cenozoic	Tertiary	Pliocene(?) and Miocene	Payette Formation	Compacted beds of clay, silt, sand, and volcanic ash, intercalated in the Columbia River Basalt Group. Thickness of this unit is about 1,000 feet (Anderson, 1941).	Unknown, but possibly could be an aquifer in places.
Mesozoic and Paleozoic	Pre-Tertiary		Pre-Tertiary Rocks undifferentiated	Permian and younger igneous rocks, includes some well indurated sedimentary rocks of the Seven Devils Volcanics that have been faulted and folded, and includes some granitic rocks of the Idaho batholith. Total thickness of the volcanic rocks is not known, but it exceeds 10,000 feet (Kirkham, 1931b). Thickness of the granitic rocks is unknown.	Generally very low in hydraulic conductivity. Not important as an aquifer in this area.

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[1] Modified from Young and Whitehead, 1975b.

TABLE 5

CHEMICAL ANALYSES OF WATER FROM SELECTED SPRINGS AND A WELL IN THE WEISER AREA

(Chemical constituents in milligrams per litre except where noted.)

Spring or well location number	Reported well depth below land surface (feet)	Date of collection	Discharge (cubic feet per second)	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity as $CaCO_3$	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite plus nitrate (NO_2+NO_3)	Phosphorus (P)	Dissolved solids (calculated)	Dissolved solids (ton per ac-ft)	Hardness		Percent sodium	Sodium adsorption ratio	Specific conductance (field)	pH (field)	Water temperature (°C)	Chemical constituents in micrograms per litre				Reference number
																			as $CaCO_3$	Noncarbonate						Arsenic (As)	Boron (B)	Lithium (Li)	Mercury (Hg)	
NONTHERMAL																														
12N-7W-24aad1S		73/8/6	0.01	47	20	3.6	24	7.5	129	0	106	22	3.3	0.4	0.04	0.02	192	0.26	65	0	41	1.3	273	7.9	15.0	18	0	40	0	20
12N-4W-34abb1S		73/8/7	.01	54	30	11	13	3.9	167	0	137	13	3.5	.7	1.0	.19	216	.29	120	0	18	.5	264	7.4	13.5	41	0	20	0	21
THERMAL																														
11N-6W-10cca1	400	73/8/2	.01	140	2.9	0	140	5.0	35	38	92	150	56	3.3	1.0	.06	573	.78	7	0	96	23	726	9.3	70.5	0	2,200	40	0	22
11N-3W-7bdb1S		73/8/2	.01	180	29	.5	280	18	201	0	165	250	200	3.2	.01	.19	1,070	1.46	74	0	86	14	1,630	7.8	92.0	41	10,000	620	.3	23
7cbb1S		73/10/1	.10	180	26	.3	290	18	197	0	162	240	200	3.8	1.4	.03	1,070	1.46	66	0	88	16	1,500	7.1	77.0	42	11,000	660	0	24
10N-3W-9cc1S		73/8/9	.01	130	20	.2	320	22	107	0	88	270	310	4.7	0	.12	1,140	1.55	51	0	90	20	1,940	7.4	74.0	510	7,800	560	.3	25

Conversion factor: multiply ft (feet) by 0.3048 to get m (metres).
Analyses by: U. S. Geological Survey

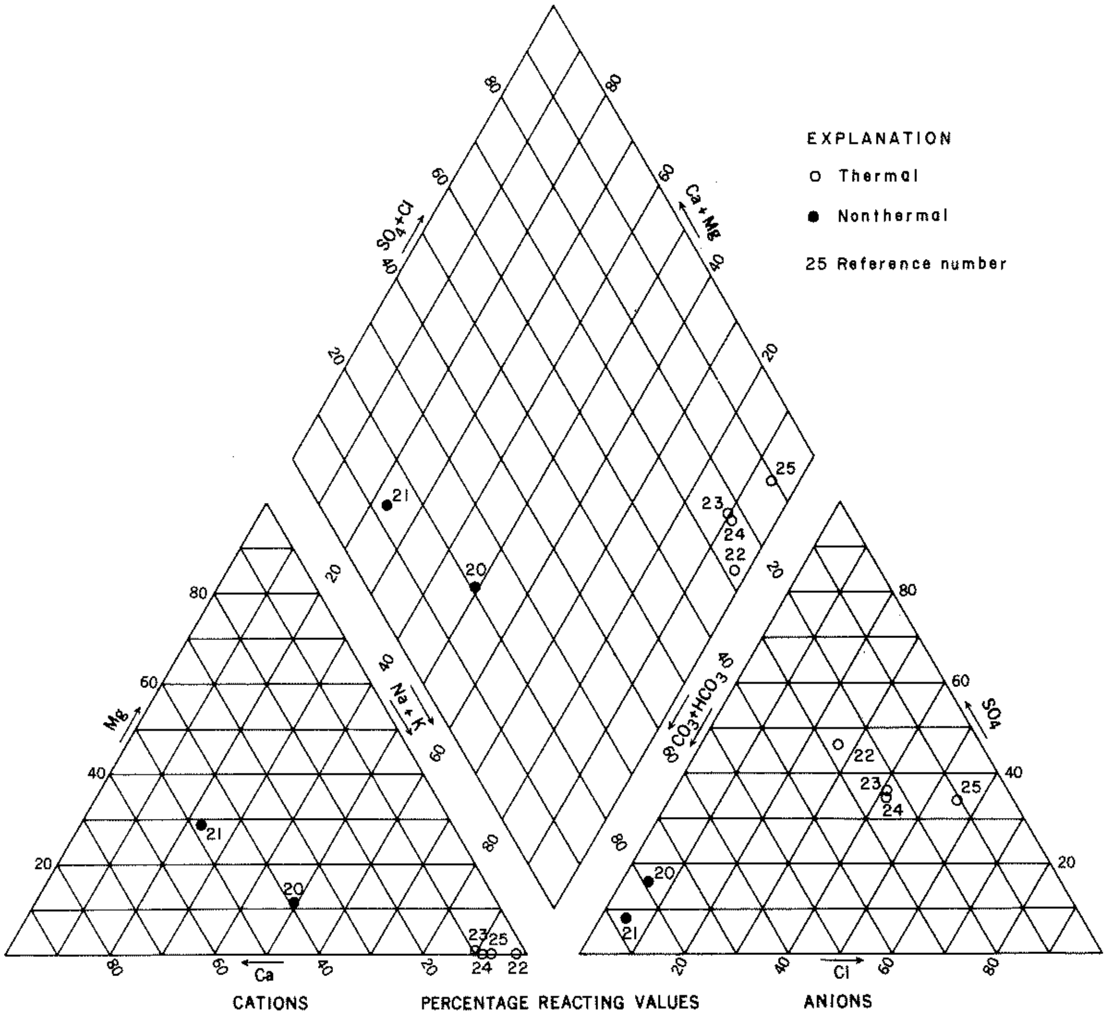

FIGURE 10. Variation of chemical constituents in water from selected sites in the Weiser area.

chloride region of the diagram. However, the dissolved solids of the Crane Creek samples (23, 24, and 25) are double that of the Weiser Hot Springs sample (22). The silica concentration in the thermal waters ranges from 130 to 180 mg/l.

Samples were collected from two vents of the Crane Creek hot springs complex. The surface temperature at the time of sampling for these two samples differed by 15°C (77°C for sample 24 and 92°C for sample 23). For all practical purposes, the remainder of the chemistry, with the exception of pH, nitrite and nitrate, and phosphorus, is identical.

Isotopic Geochemistry of the Weiser Area Ground Waters

The isotopic composition of the thermal water in the Weiser area (fig. 11) is significantly different from the "local" precipitation (nonthermal springs). The $\delta^{18}O$ ranges from -12.3 (sample 25) to -14.6 $^{o}/oo$ (sample 24, table 6). The δD for these springs and well ranges from -138 (sample 25) to -150 $^{o}/oo$ (sample 23). The "local" precipitation (samples 21 and 20) have $\delta^{18}O$ values of -15.1 and -16.1 $^{o}/oo$ and δD values of -120 and -128 $^{o}/oo$, respectively. Figure 11 shows a line through samples 20 and 21 which has a slope of 8 and an intercept of +0.8: $D = 8\,\delta^{18}O + 0.8\ ^{o}/oo$. Such a trend could be expected for recharging waters in a semiarid region. The thermal waters are depleted in D by more than 10 $^{o}/oo$, but enriched in ^{18}O as much as +2.85 $^{o}/oo$ relative to nonthermal waters in the area.

The oxygen shift can be accounted for by isotope exchange between water and the aquifer material at elevated temperatures, but the depletion of D must be explained by another method. Since, in most natural aquifer systems, it is difficult to find a source of hydrogen to exchange with the hydrogen in the water, it must be assumed that the deuterium content of the samples is approximately equal to that of the recharging water.

TABLE 6

ISOTOPE ANALYSES OF WATER FROM SELECTED SPRINGS AND WELLS IN THE WEISER AREA

Spring or well location number	δD SMOW	$\delta^{18}O$ SMOW	$\Delta^{18}O$	Reference number
		NONTHERMAL		
12N-7W-24aad1S	-128	-16.1	+1.15	20
12N-4W-34abb1S	-120	-15.1	+1.15	21
		THERMAL		
11N-6W-10cca1	-149	-13.4	+6.50	22
11N-3W-7bdb1S	-150	-14.4	+5.65	23
7cbb1S	-142	-14.6	+4.35	24
10N-3W-9ccc1S	-138	-12.3	+6.25	25

Analyses by: U. S. Geological Survey

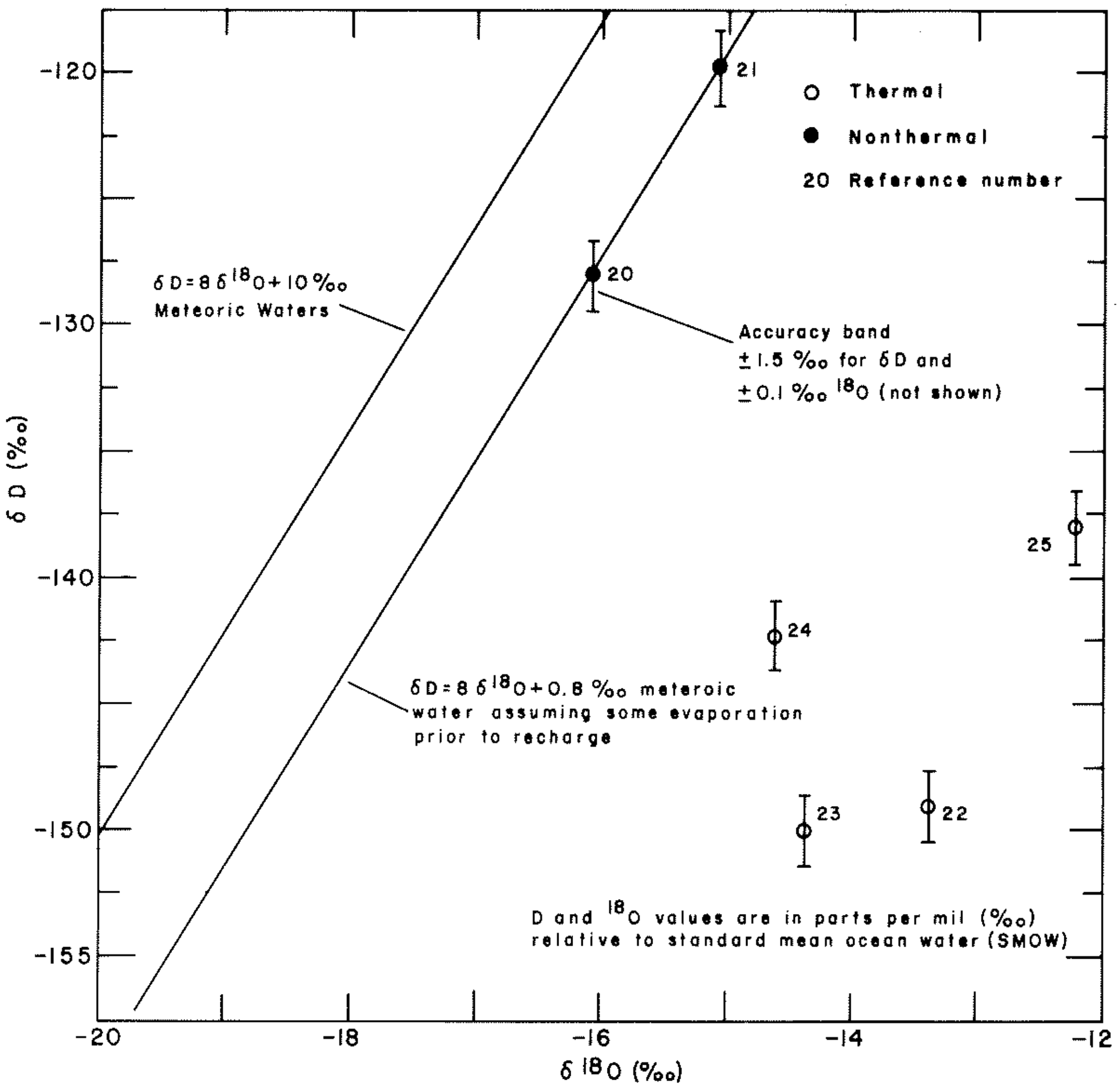

FIGURE 11. Isotope variations in water from selected springs and a well in the Weiser area, and relation to meteoric water.

Therefore, the deuterium depletion relative to "local" precipitation indicates either a nonlocal source of recharge--from higher altitude and/or colder climate, or recharge at some time in the past under a colder regional climate.

Assuming that the waters have been exposed to the same aquifer material, we can postulate on the basis of the oxygen-isotope data, that sample 22 has been exposed to the highest temperatures, followed closely by sample 25. Samples 23 and 24 show a much less pronounced shift. It is impossible to attempt quantitative determinations on the basis of the oxygen shifts, as the hydrology, and, therefore, the aquifer material, are at present poorly known.

SUMMARY AND COMPARISON OF ISOTOPIC GEOCHEMISTRY OF BRUNEAU–GRAND VIEW AND WEISER AREA GROUND WATERS

Comparison of the high-altitude nonthermal spring samples from the mountains surrounding the Bruneau-Grand View area with the ground waters beneath the Snake River Plain in this region show that the deep ground waters are more depleted in deuterium than the nonthermal high-altitude springs. This indicates that the recharge water had a colder source from either (1) an area of higher altitude southeast of the local region in the Bruneau River drainage, or (2) the prevalence of a colder regional climate at some time in the not-too-distant past. A similar comparison involving the waters in the Weiser area yields the same conclusions. Recharge to the Weiser area hot springs system is possibly from areas of higher altitude and colder temperatures to the north and northeast of the study area.

As the deuterium contents of the waters from the two areas are within the same range, it seems that the systems were recharged with similar waters. If the rock type and the effective porosity (surface area) of the aquifers for the two areas are similar, then it appears on the basis of the oxygen shift, that the Weiser area waters have attained much higher subsurface temperatures than the waters of the Bruneau-Grand View area.

On the basis of the isotopic analyses conducted on these waters, current precipitation on the adjacent uplands is not the only contributor to the thermal ground waters in either area. There is, however, evidence that current precipitation does influence both the chemical and isotopic composition of these waters.

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