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Carl A. Ruscetta
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Editors

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WATER INFORMATION BULLETIN NO. 30

GEOTHERMAL INVESTIGATIONS IN IDAHO

PART 11

Geological, Hydrological, Geochemical and Geophysical Investigations of the Nampa-Caldwell and Adjacent Areas Southwestern Idaho

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ABSTRACT

This paper represents only part of one chapter of a detailed geological, hydrological, geochemical and geophysical investigation of thermal water occurrence, in and adjacent to the Nampa-Caldwell area of southwestern Snake River Plain, Idaho.

Geochemical studies using stable isotopes of hydrogen and oxygen show that thermal water in the Nampa-Caldwell area is depleted by 20 $^{o}/oo$ in δD and by about 2.3 $^{o}/oo$ in $\delta^{18}O$ relative to cold water and indicates the water may be rain or snow water that fell more than 11,000 years ago.

The isotope data may show the effects of considerable mixing of a thermal parent water with an isotopic composition of δD -150 $^{o}/oo$ and a $\delta^{18}O$ = -18 $^{o}/oo$ with colder waters from Lake Lowell and canal systems, Snake River water, Reynolds Creek basin or similar elevations, perhaps the Boise and Payette rivers and applied irrigation water.

The geothermal parent water in the Nampa-Caldwell area appears, from isotope data, to be identical to parent geothermal waters in the Bruneau-Grand View and Boise areas of the western Snake River Plain, or to have a similar source(s) and/or age.

STABLE ISOTOPE INVESTIGATION

by

John C. Mitchell

INTRODUCTION

Isotopes are two forms of the same element which differ only in the number of neutrons (uncharged atomic particles) in the nucleus of the atom. This means that different isotopes of the same element will differ only in their relative mass. It is this mass difference that governs their kinetic behavior and allows isotopes to fractionate during the course of certain chemical and physical processes occurring in nature.

The four stable isotopes that have proven most useful in water resource evaluation are hydrogen (^{1}H or H), deuterium (^{2}H or D), oxygen 16 (^{16}O) and oxygen 18 (^{18}O). These isotopes make up 99.9 percent of all water molecules.

Isotopic compositions are reported in "δ" notation in parts per thousand (per mil = $^{o}/oo$) relative to Standard Mean Ocean Water (SMOW) as defined by Craig (1961b), where $\delta i = [(R_i/R_{std} -1] \times 1000$. R_i equals either $^{18}O/^{16}O$ or D/H while i and std represent the sample and standard, respectively.

The result of isotopic fractionation during evaporation of ocean water and subsequent condensation of vapor in clouds is that fresh (meteoric) water is generally depleted in ^{18}O and D (enriched in ^{16}O and H) compared to seawater. The isotopic variations of water in rain, snow, glacier ice, streams, lakes, rivers, and most nonthermal groundwaters are extremely systematic; the higher the latitude or elevation, the lower (more depleted in heavy isotopes) the δD and $\delta^{18}O$ values of the waters. On the basis of a large number of analyses of meteoric waters collected at different latitudes, Craig (1961b) showed that the $\delta^{18}O$ and δD values relative to SMOW are linearly related and can be represented by the equation:

$$\delta D = 8\delta^{18}O + 10$$

which is plotted in figure 4-1. Groundwater sampled in an area whose isotopic composition plots on the trend (meteoric water line) are generally considered to be meteoric waters.

TABLE 4-1

Isotope Sample Locations, Measured Surface Temperature, δD, δ ¹⁸O, Cl and F Values from Sampled Water in the Nampa-Caldwell and Adjacent Areas of Southwest Idaho

Sample or Well No. (Location)		Measured Surface Temperature (°C)	$\delta^{18}O$ SMOW °/oo	δD SMOW °/oo	Cl mg/l	F mg/l
7N-4W-22aca	Payette R., Gem Co.	12+	-14.4	-125	-	-
7N-2E-15daa	Payette R., Boise Co.	-	-14.6	-124	-	-
6N-1W-25bbd1	Willow Cr., Gem Co.	23	-14.2	-124*	6.3	-
5N-1E-35aca1	Dry Cr., Ada Co.	40	-16.9*	-143	4.9	11
5N-1E-36bdb1	Dry Cr., Ada Co.	24	-15.4	-128	-	-
4N-4W-04dcc1		21	-17.7	-147	5.9	-
4N-4W-05dbd1		24	-17.3	-145	6.2	-
4N-3W-19adc1	Richardson #1	40	-17.2*	-142*	5.8	1.5
3N-2E-10acc1	Capitol Mall #1, Ada Co.	65	-17.0	-141	6.9	16.9
3N-3W-03bbc1		19	-15.6	-128	21.	.57
3N-3W-30ddd1		16	-16.5	-137	98.	.60
3N-2W-14ada1		22	-17.4	-138	14.	.50
3N-2W-17bcb1		24	-16.3	-136	6.1	1.00
3N-2W-23bcd1		31	-17.1	-151	4.1	1.9
3N-2W-26ddb1		18	-16.6	-135	38.	.68
3N-2W-31bbb1		15	-15.9*	-132	104.	.43
3N-2W-31dcb1		15	-16.7	-138	-	-
2N-3W-08cdd1		22	-16.8	-141	24.	.61
2N-3W-22acd1		26	-17.4	-143	26.	.69
2N-3W-22bdc1		28	-17.6	-147	16.	.50
2N-3W-25bda1		26	-16.5	-146	7.1	1.6
2N-3W-27bba1		30	-18.0	-150	11.	.85
2N-3W-35caa1		28	-17.6	-147	8.1	1.3
2N-2W-04dca1		23	-17.0	-144	20.	2.3
2N-2W-06aba1		15	-15.9	-131	-	6.3
2N-2W-16daa1		26	-17.1*	-139	16.	1.0
2N-2W-16dba	Lake Lowell Inlet	13+	-16.5	-132	21.	.4
2N-2W-18bab1		14	-16.1	-138	7.1	.55
2N-2W-34aac1		29	-16.3	-140*	28.	3.6
2N-2W-34bda1		51	-17.0	-142*	11	4.3
2N-2W-34daa1		31	-17.0	-142	11	2.4
1N-2W-03cab1		20	-16.5	-138	9.9	-
1N-2W-03cbb1		20	-16.3	-138*	-	-
1N-2W-08acb1		21	-16.7	-139	74.	.36
1N-2W-09bba1		22	-15.8	-141	24.	.34
1N-2W-09ccb1		24	-17.0	-142	38.	.75
1N-2W-17dcc1		21	-16.2	-139	165.	.38
1S-2W-17abb1		21	-17.3	-142	14.	4.7
1S-2W-17bad	Snake River near Walters Ferry Bridge	12+	-16.5	-133	21.	.4
2S-3W-36daa1	Reynolds, Owyhee Co.	8	-15.0	-123	25.x	-

* Average of two analyses or samples.
\+ Average water temperature over one year period from 12 monthly averages.
\- Data not available.
x Average chloride of 4 analyses each from six wells.

Gat (1971) reported that incongruous results in isotope hydrology studies have generally been interpreted to mean: (1) geographic displacement of groundwaters by flow, (2) recharge from partially evaporated surface waters, (3) recharge under different climatic conditions, (4) mixing with nonmeteoric water bodies--brines, sea-water, connate, metamorphic, or juvenile waters, (5) differential water movements through soils or aquifers which result in fractionation processes (membrane effects), and (6) isotopic exchange or fractionation between water and aquifer materials. Several of these processes tend to be distinctive, either in enriching or depleting the waters in heavier isotopes and can be recognized. Others tend to be similar in results; therefore, interpretations may be ambiguous.

Sampling - Sites for isotope sampling in the Nampa-Caldwell and adjacent areas were chosen on the basis of well log data on file at Idaho Department of Water Resources. Casing records, well depths, lithologies penetrated, measured surface temperature, and structural geology considerations, so far as known, were considered. Landsat images of the western Snake River Plain were studied to locate sample sites on or near lineaments passing through the Nampa-Caldwell area based on the hypotheses that the lineaments might be migration channels through which recharge waters moved into the Nampa-Caldwell area. However, sampling was restricted by lack of proper access ports from which reliable samples could be obtained. Consequently, about half the sample sites were determined by accessibility. Rivers (except the Boise, inadvertently omitted), lakes and canals in and adjacent areas outside the area of study were also sampled. Boise River water should be similar isotopically with Lake Lowell inlet waters as Lake Lowell inlet waters are derived from the Boise River. A total of 40 samples were analyzed by mass spectrometry by Krueger Enterprises, Inc., Geochron Laboratories Division, Cambridge, MA. On the basis of duplicate samples and analyses the data appear to be precise within 1 $^{o}/oo$ for δD and 0.2 $^{o}/oo$ for $\delta^{18}O$. These data are given in Table 4-1 and sample locations are shown on figure 4-2 and figure 4-3 (in pocket). The data are shown plotted as δD and $\delta^{18}O$ in per mil units on figure 4-4.

Observations - From Table 4-1 the range of δD values for thermal waters (>20°C) sampled in the Nampa-Caldwell area is from -136 to -151 $^{o}/oo$. The range of $\delta^{18}O$ values is from -15.5 to -18.0 $^{o}/oo$. For cold waters (<20°C) sampled in and around the Nampa-Caldwell area, the range of δD value is from -123 to -135 $^{o}/oo$ and the $\delta^{18}O$ of cold waters ranges from -15.0 to -16.7 $^{o}/oo$. The thermal waters are therefore depleted by about 20 $^{o}/oo$ in δD and by about 2.3 $^{o}/oo$ in $\delta^{18}O$ relative to cold water from in and around the Nampa-Caldwell area.

As shown by figure 4-1, the Nampa-Caldwell waters are somewhat similar to other geothermal waters in Idaho. They most closely resemble waters studied by Rightmire, Young, and Whitehead (1976) and Young and Lewis (1980) in the Bruneau-Grand View area but are displaced still further to the right of the meteoric water line and exhibit a somewhat greater spread between thermal and nonthermal water. This heavy isotope enrichment for cold waters (displacement to right of meteoric water line) for cold waters is typical of some arid and .semiarid localities. The relatively isotopically lighter thermal waters (displaced downslope from cold waters) are, however, distinctive. Figure 4-1 shows that all of the high temperature thermal waters are derived from meteoric waters on their trend line, while the thermal waters from Weiser, Bruneau-Grand View and Nampa-Caldwell areas cannot be derived directly from the plotted nonthermal waters.

Figure 4-4, which is an enlarged version of a portion of figure 4-1, shows that most of the data fall on, or near, one of a group of straight lines that converge to intersect well 2N-3W-27bba1 at a δD of -150 $^{o}/oo$ and a $\delta^{18}O$ of -18 $^{o}/oo$. Most cold waters sampled are observed to plot in the upper right portion of the graph near the upper right extremities of the lines. Exceptions are those samples of thermal waters taken outside the Nampa-Caldwell area, which also plot in this section of the diagram. Most thermal waters plot in the lower left portion of the plotting field.

It should be noted that other straight lines can be drawn through other data points (i.e., line a, and a line from 6N-1W-25bbd1 to 4N-3W-19adc1). Other straight line data do not include all data points, do not correlate with temperature data (see below), nor do they have cold waters as one end member and thermal water as the other.

Figures 4-5 and 4-6 are plots of measured surface temperatures of water from wells versus δD and $\delta^{18}O$, respectively. Several points which do not fall on any of the established converging lines generally are higher temperature water from deeper wells or water from thermal wells sampled outside the Nampa-Caldwell area. Straight line plots are obtained for certain data points which again converge toward the sample from well 2N-3W-27bba1. A comparison of figure 4-4 with figures 4-5 and 4-6 reveals a 63% correlation of data points for line 1. If deep water data are not included, the correlation is 71%. A comparison of figure 4-4 with figures 4-5 and 4-6 for line 2 reveals a 67% correlation between figures 4-4 and 4-6. If deep water data is ignored, the percent correlation is 75%. Table 4-2 summarizes the common data points of lines 1 and 2 for figures 4-4, 4-5 and 4-6. There is little or no correlation for

TABLE 4-2

Correlation of data points for line 1 and 2 between figures 4-4, 4-5, and 4-6

Line 1 Data			Line 2 Data		
δD vs. $\delta^{18}O$ figure 4-4	δD vs. t figure 4-5	$\delta^{18}O$ vs. t figure 4-6	δD vs. $\delta^{18}O$ figure 4-4	δD vs. t figure 4-5	$\delta^{18}O$ vs. t figure 4-6
16dba	16dba	16dba	36daa1	36daa1	36daa1
17bad	17bad	17bad	3bbc1		
16daa1			6aba1	6aba1	6aba1
19adc1**			31bbb1	31bba1	31bbb1
17abb1	17abb1	17abb1	26ddb1*	26ddb1	26ddb1
22acd1			30ddd1		
4dcc1***	4dcc1	4dcc1	31dcb1		
27bba1*****	27bba1	27bba1	8acb1	8acb1	8acb1
			34daa1		
			9ccb1	9ccb1	9ccb1
			34bda1**		
			35cca1	35caa1	35caa1
			22bdc1****	22bdc1	22bdc1
			27bba1*****	27bba1	27bba1
			10acc1**		

* Probably analytical or sampling error, see text.

** Thermal water from sources deeper and hotter than the aquifer from within the "blue clay."

*** Conductively cooled (?) water, see text.

**** In this region of the graphs, lines are so close together as to lie within each others "window" of analytical precision. It is difficult to assign a given value to a given line. Sample 22bdc1 has been assigned to line 2, as temperature verses δD and $\delta^{18}O$ graphs of figures 4-5 and 4-6 indicate that this is a more reasonable location.

***** In making the percent calculation, the sample from well 2N-3W-27bba1 was included in the calculation for both lines 1 and 2 of Table 4-2. The agrument can be made that the data is therefore biased in favor of the mixing hypothesis. If the data point from well 2N-3W-27bba1 is not included, the agrument can be made that this has biased the data in favor of some other hypothesis. If the data point is not included in the percent correlation of lines 1 and 2 data of Table 4-2, the correlation is still greater than 50 percent with the other reasonable assumptions included. The correlation is considered significant and can only be adequately explained by mixing of thermal and nonthermal waters in various proportions with no conductive cooling. Note line 5 date not included.

line 3 (line 4 ?) data on figures 4-4, 4-5, and 4-6. Line 5 data appears on figures 4-4 and 4-6 only. On figure 4-5, line 5 data plots on line 2. There is considerable scatter in the data related to lines 3 and 4 of figure 4-4 when compared to line 3 of figures 4-5 and 4-6, and making definite interpretations from this data is difficult. The argument can be made that lines 3 and 4 of figure 4-4 are really one line which would fall between lines 3 and 4. Due to the window of analytical precision, the lines cannot be separated.

Plots of fluoride and chloride versus δD and $\delta^{18}O$ were studied in an effort to determine if changes in their concentration were related to the isotopic composition of the water. The figures merely showed that dissolved concentrations of these elements are low in the sampled waters and are not related to the isotopic composition; therefore, the diagrams are not included as part of this report.

Discussion - There are several interpretations or theories which might be applied to explain the above mentioned observations of the data plotted in figures 4-1, 4-4, 4-5 and 4-6. White, Barnes and O'Neil (1973), and Truesdell and Hulston (1980), interpreted data of a similar nature to that of figure 4-4 from the California coast ranges, and Long Valley, California to represent fluid mixtures in various proportions of end member waters. Water from well 2N-3W-27bbal probably represents unmixed geothermal water from the Glenns Ferry Formation derived from an aquifer within or below the "blue clay" (see Chapter 3 of this report for a discussion of the "blue clay"). Records for this well show unperforated casing extending from within the "blue clay" layers to the surface. Most other wells in the Nampa-Caldwell area are perforated, either continuously, or in various zones, or have large sections of hole uncased. The drillers logs show that many wells take water from several zones. Well 2N-3W-27bbal water may, therefore, represent one parent water from which most other well waters of the Nampa-Caldwell area are derived. The other parent water(s) may be represented by either Lake Lowell or Snake River water, (line 1) Reynolds, or similar elevations (line 2), or Payette River and/or Willow Creek water (line 3). Data points falling on or near the lines could represent mixtures of the parent waters in various proportions. Well 1S-2W-17abbl, which plots on the Snake River mixing line (line 1), was drilled within a few hundred meters of the Snake River. Well 4N-3W-19adcl (Richardson #1, line 1) may be a mixture of water represented by 2N-3W-27bbal water, Lake Lowell and/or Snake River, or perhaps Boise River water. The temperature depth profile (from Smith, this report, figure 5-10) indicates water from well 4N-3W-19adcl is a mixture from at least three zones. On line 2, well

2N-2W-34bdal may represent water which is a mixture of 2N-3W-27bbal type water with a water represented by well 2S-3W-36daal near Reynolds in Owyhee County, 50 air kilometers due south of Caldwell in the Owyhee Mountains, or similar elevations. The ratio of the length of the line segment connecting data points 2N-3W-27bbal and 2N-2W-34bdal, to the length of the segment connecting 2N-2W-34bdal and 2S-3W-36daal (line 2, figure 4-4) represents the fraction of the hot water end member. These data indicate that a significant proportion of the recharge for the shallow groundwater (above the "blue clay") may come from the aquifer within or below the "blue clay," and also from several other sources, including perhaps Reynolds Creek Basin, or similar elevations, Lake Lowell and the Snake River through applied irrigation, and possibly leakage from Lake Lowell and its canal systems. The direct temperature-isotope dependence for the data points on lines 1 and 2 of figures 4-5 and 4-6 is a result that would be expected if the waters are mixtures of warm and cold water from two sources. In mixing of warm and cold water (no other processes taking place) the resultant temperature of the mixture would depend only on the initial temperatures of the warm and cold waters and their volumes involved in mixing. Isotopic composition of the mixed water would also be proportional to the volumes of end member waters.

The temperature-isotope dependence is not interpreted as being caused by depletion or enrichment due to kinetic responses of the isotopes, but rather to mixing of parent waters of different isotopic compositions; one warm, the other cold, in various proportions, with little conductive cooling, either within aquifers, or within well bores as the result of man-made aquifer unions.

In order for the isotope data to indicate mixing, the data must fit corresponding lines of all three figures, or reasonable assumptions made as to why the data does not plot on corresponding lines.

Various points of figures 4-4, 4-5 and 4-6 do not fall on any lines and this could be due to several processes including isotope exchange reactions with aquifer or permeable zone constituents, further evaporative enrichment or depletion in heavy isotopes from already enriched surface irrigation water as a result of sprinkler and corrugate irrigation practices, seasonal changes in isotopic composition of the recharge water, multiple mixing, conductive and/or convective cooling of mixed waters, or waters from deeper and hotter aquifers with the same or different isotope ratios, or analytical or sampling errors. The high measured surface temperature of water from well 4N-3N-19adc1 (Richardson #1) arises because the water ascends rapidly from hotter sources deeper than the "blue clay" aquifer.

An example of conductive or convective cooling might be represented by water from well 4N-4W-4dcc1 which plots on line 2 of figure 4-4, but plots 6.5-7°C to the left of line 2 on both figures 4-5 and 4-6. If 6.5°C is added to the temperature of this well, it will also plot on line 2 of both figures 4-5 and 4-6. Perhaps, after mixing, the water cools by 6.5°C by conductive or convective heat transfer as the water flows through the aquifer and up the well bore.

An example of sample or analytical error might be shown by water from well 3N-2W-26ddb1 which plots on line 2 of figure 4-5 only. If a $\delta^{18}O$ value of -.3 $^{o}/oo$ is subtracted from the $\delta^{18}O$ value of -16.6 $^{o}/oo$ reported in the analyses for well 3N-2W-26ddb1, this data will plot on line 2 of figures 4-4, 4-5, and 4-6. The parallelism of line 5 to line 2 of figures 4-4 and 4-6 suggests that a systematic error, either in the sampling or analyses of line 5 data is possible. If -.9 $^{o}/oo$ to -1.0 $^{o}/oo$ is added to the $\delta^{18}O$ values found in Table 4-1 this data will plot on line 2, as it does in figure 4-5. The sample from well 3N-2W-23bcd1 (line 5) was taken from a 100 meter long, 15 cm diameter discharge pipe only partially full of water. This may have allowed atmospheric gasses to mix with the water, or more importantly, allowed some evaporation of thermal water to take place before sample 3N-2W-23bcd1 was collected. Steam was seen emerging from the discharge pipe, along with the thermal water. The slight depletion in δD (1 $^{o}/oo$) over sample 2N-3W-17bda1 could be due to Rayliegh type (non-equilibrium) evaporation from sample 3N-2W-23bcd1. This would indicate two wells in the area with parent geothermal water compositions of $\delta D = -150$ and $\delta^{18}O = -18$.

Line a of figure 4-4 represents a line of slope 5 which runs through Lake Lowell (16bda) and Snake River (17bad) data points (Mariner, 1981, personal communication). The fact that several lines of slope 5 can be drawn through the data of figure 4-4 may be indicative of the effects of evaporation to dry air of meteoric water before recharge to the ground water system. This could indicate a pre-evaporation isotopic composition $\delta D = -150$ $^{o}/oo$ and $\delta^{18}O = -20$ $^{o}/oo$ (Ellis and Mahan, 1977 p. 75). Thermal water of isotopic composition $\delta D = -150$ $^{o}/oo$ and $\delta^{18}O$ -18 $^{o}/oo$ could be derived from the pre-evaporated water composition by an enrichment of $\delta^{18}O$ of 2 $^{o}/oo$ in the parent thermal water brought about by oxygen isotope exchange of water with aquifer or reservoir minerals. Isotopic exchange is the generally accepted method of explaining the trend line (oxygen shifts) observed in isotopic compositions of water from many of the higher temperature geothermal systems

(Larderello, Geysers, Heckla, Mount Lassen, and Steamboat Springs) of the world (figure 4-1). Pre-evaporation isotopic compositions of Payette River, Boise River, and Snake River water are unknown at present but might be similar to integrated isotopic values of spring water within upper reaches of their drainage basins. River waters, particularly Snake River water, would be modified by many influences during downstream flow and pre-evaporation isotope values might be difficult to obtain. δD isotope values of meteoric waters in recharge areas of the Payette River drainage basin seem to be near -128 to -131 $^{o}/oo$ (Lewis and Young, 1980) and in the Boise River drainage basin may be near -135 to -139 $^{o}/oo$. This would seem to rule out the Payette and Boise rivers as sources of recharge of the goethermal parent water with subsequent $\delta^{18}O$ enrichment by isotopic exchange, provided the isotopic composition of spring waters in upper reaches of these drainages is indicative of pre-evaporative isotopic composition of the river water. These conclusions are speculative and more data investigating the possibility of recharge to the thermal systems from river waters are needed before the conclusions can be substantiated.

Several other lines, parallel to line a (slope 5) might be drawn through the data on figures 4-4. These lines do not include all data points, do not correlate with temperature data, do not have cold waters as one end member and thermal water as the other, lead to even lower δD values than exist in the thermal waters if interpreted as evaporation lines, and would mean that water from nearly every sampled well has undergone differing amounts of evaporation from five or six unidentifable sources, a conclusion which seems highy unlikely. These lines are not considered further in this report.

Regarding the origin of the geothermal water, Rightmire, Young and Whitehead (1976) interpret light thermal waters, or displacement downslope for thermal water in the Bruneau-Grandview and Weiser areas, to mean precipitation at higher elevations where climatic conditions are cooler, or precipitation during a period of time when the climate was cooler than that prevailing today. Cooler temperatures at higher elevations will result in depleted isotope values, but these should be reflected in cold water in the sampled area also, unless the cold water is recharged at lower elevations. A time period which was generally cooler than the Holocene (present) geologic Epoch was the Pleistocene Epoch or ice age that ended approximately 7,800 to 11,000 years ago. Young and Lewis (1980) proposed that Bruneau-Grand View area thermal waters might be at least 2,400 to 3,300 years old and could be be as much as 8,000 years old, or older, or could have come from elevations of

460 to 825 m higher in elevation than cold springs they sampled. Mayo (1981, personal communication) reported that thermal waters in the Blackfoot Reservoir area of southeastern Idaho have been age dated at 14,000 to 36,000 years old. If Pleistocene precipitation is the source water, then circulation times for recharge of the thermal aquifers may be relatively long (7,800 to 11,000 years or greater if old water is being displaced by new recharge), or there may be relatively little present day recharge for the system. Relatively little present day recharge could mean the waters are being mined.

Water levels in wells in the Bruneau-Grand View area were reported by Young and Whitehead (1973) to have declined, which suggests mining or recharge insufficient for present withdrawal (recharge over long periods). Stevens (1962) noted rising water levels in wells in the Dry Lake area south of Lake Lowell, which he attributed to increased irrigation from surface water. Recently, however, water levels were noted to drop sharply, as much as 15 meters in one year (Norman Svaty, personal communication, 1979). This could reflect additional groundwater pumpage or the drought conditions of 1976, which would indicate recharge times of about 3 years (if drought related), but perhaps only for the aquifers above the "blue clay."

Alternate hypotheses which could explain the isotopically light (depleted) thermal waters in the Nampa-Caldwell area are: (1) exchange of hydrogen and oxygen isotopes between water and other hydrogen and oxygen containing sources within aquifers or permeable zones. Methane gas and some hydrogen sulfide is suspected in some wells in the area and organic debris was accumulated within the sediments as they were deposited. Methane gas, hydrogen sulfide, and organic accumulations could be a source of hydrogen. However, estimated aquifer temperatures do not seem high enough for appreciable exchange to have occurred. (2) Fractionation of isotopes by semipermeable membrane processes in clays may also occur. Sufficient data is not available at present to evaluate this effect. (3) The thermal water may be isotopically lighter because of subsurface boiling and steam separation in deep aquifers with the separated steam phase recondensing and reequilibrating chemically in aquifers above those where steam separation occurs. Again, aquifer temperatures do not appear high enough at shallow depth where boiling could occur, and the isotope data do not show the characteristic oxygen shift of high temperature systems (figure 4-1) unless the evaporated river water hypothesis as a source of the geothermal water is accepted. (4) The trend line could represent a meteoric water line for the Nampa-Caldwell and adjacent areas; however, this does not explain the temperature-isotope ratio relationship (figures

4-5 and 4-6) found in the data, nor does it explain why most cold water plots near one end of the trend line and thermal water plots near the other extremity.

Figure 4-7 is a modified plot of isotope data obtained by Young and Lewis (1980) from the Bruneau-Grand View area in southwest Idaho. Convergence of these data points to a water of the same composition as that of the parent geothermal water in the Nampa-Caldwell area ($\delta D = -150$, $\delta^{18}O = -18$) is indicated by the diagram. If the parent water is real in the Bruneau-Grand View area it would indicate (1) considerable mixing of thermal waters in the Bruneau-Grand View area, more so than previously realized, and (2) parent geothermal waters in both areas are from the same source and/or time or the systems are interconnected. Also, isotope ratios from geothermal waters found in Ada County near Boise plot on lines 2 and 4. This could indicate that in the Boise area geothermal waters might be mixtures of geothermal water of near identical isotopic composition with water from well 2N-3W-27bbal and waters of isotopic composition similar to Payette River and/or Reynolds Creek water. However, more data from the Boise area are badly needed to confirm this assumption.

It appears, from the above arguments, that the hypothesis that most easily explains the isotopic data on lines 1 and 2 of figures 4-4 through 4-6 is mixing of thermal water of constant temperature and isotopic composition $\delta D = -150$ °/oo and $\delta^{18}O = -18$ °/oo with cooler waters of several distinctive isotopic compositions. The origin of line 3 (line 4?), data on figure 4-4, apparently involves thermal water represented by water from 2N-3W-27bbal which may have undergone systematic isotopic changes not presently recognized or completely understood. As no temperature-isotopic ratio correlation is observed for line 3 (line 4?), factors other than mixing may be involved.

The hypothesis that appears to best explain the origin of the thermal waters with available data in both the Nampa-Caldwell and Bruneau-Grand View areas is that of old water originating as precipitation during an extended time interval when climatic conditions were cooler than at present. Alternatively, the thermal water might have originated as evaporated river or lake water with subsequent ^{18}O enrichment through oxygen isotopic exchange with aquifer or permeable zone minerals at temperatures in excess of 100°C very deep (>2 km) within the geothermal system(s). The easiest way to distinguish between the two hypotheses may be through age dating of the geothermal waters using unstable isotope techniques.

<u>Isotope Data and its Relations to Lineaments</u> - Figure 4-2 shows locations of major lineaments in the western Snake

River Plain and isotope sample locations. The linear features were drawn from Landsat false color infrared images obtained from satellite data at 1:1,000,000, 1:500,000 and 1:250,000 scale, enhanced by the EROS Data Center.

Lineament features are noted that cross the Snake River Plain as well as those that nearly parallel the Plain axis as the majority of them do. The lineaments appear as faint cultural features and patterns, and, in the case of the lineaments parallel to the Plain's axis (northwest trending), they are associated with some parts of minor drainages which are parallel to the axis. Outside the culturally disturbed area, several of the lineaments parallel to the Plain's axis coincide with volcanic cones, buttes, and domal structures. Some of the northeast trending lineaments (perpendicular to the Plain's axis) can be traced into the mountain ranges flanking both sides of the Plain. In the culturally disturbed portion of the Plain, the lineaments represent edges of topographic features (hills, valleys, and drainages) which force cultivation patterns that become apparent as linear features. These hills, valleys and drainages are thought, in some cases, to be fault bounded. Because of the huge scale of the features at which ground observations or air photo reconnaissance are made, these patterns are not apparent on the ground or on air photos. The correlation of lineaments parallel to the Plain's axis with volcanic features (L_1 and L_2, figure 4-2) indicates that some of these lineaments may represent some type of fault, fissure, or perhaps a large scale deep seated joint system. Several correlate well with faults found on reflective seismic data (L_3 and L_4) and in the shallow well log data (L_1 and L_4). The fact that several lineaments are seen to cross the Plain and extend into the mountain ranges on either flank indicates that minor recurrent crustal instability may have occurred along the lineament after formation of the major features of the western Snake River Plain. The lineament (L_2) corresponds approximately with Stevens (1962 p. 20) groundwater divide. This lineament passes through Powers Butte, Initial Point and Little Joe Butte in southern Ada County. Other volcanic domes, cones, and buttes are found in similar alignment along both sides of this lineament. The lineament could explain the groundwater divide (see Chapter 3, this report). Isotope data (figure 4-4) seem to ignore this divide as data from wells plotting on mixing lines 1, 2, and 3 are found on both sides of the divide. The divide apparently influences the shallow groundwater system and not the deep regional groundwater system (Whitehead, 1981, personal communication).

The warm water isotope data (line 2, figure 4-4) generally are found in wells near the Reynolds Creek-Freestone

Creek lineament (L_5, figure 4-2), as might be expected if the lineament represents a migration path for recharge water into the Nampa-Caldwell area. Most cold water samples, except near Reynolds, were taken from wells north of Lake Lowell. The position of the sampled cold water wells form a linear relation parallel to the Plain axis. However, well construction, zones perforated, and aquifers penetrated, may have more bearing on which line of figure 4-4 the isotope data from a particular well plots than does its location with respect to other geologic features.

The isotope data is considered remarkably consistent for an area as large as encompassed by this study and as complex as the water regime in the area appears to be. The isotope data furnish constraints within which interpretations of other geochemical data must lie in order to be considered valid.

CONCLUSIONS

When observed in its entire perspective, and in view of the complicated nature of the Nampa-Caldwell groundwater systems and possible surface water sources mixing with groundwaters, the isotopic data from the Nampa-Caldwell area of southeastern Idaho is consistent in its interrelations to itself and other types of data. This consistency lends credence to the following conclusions.

(1) Geothermal waters are depleted in heavy isotopes which may mean recharge from precipitation in areas of higher elevation (geographic displacement) or during a time when the climate was colder than that prevailing today. If recharge occurred during the Pleistocene Epoch (ice age) the water is equal to or greater than 11,000 years old. Alternatively, depleted water could be the result of evaporation of river water with subsequent ^{18}O enrichment, or result from semipermeable membrane clay layer processes.

(2) Recharge may be taking place over a long period of time or, there may be relatively little present day recharge to the thermal system.

(3) Mixing of thermal and nonthermal waters is widespread in the Nampa-Caldwell area occurring within aquifers and well bores due to well construction. The total effects on the geothermal and nonthermal aquifers or permeable zones due to migration and mixing of thermal and nonthermal waters on the longevity of the geothermal aquifers for use as a heat source is not known.

(4) Cold water recharge, for aquifers above the "blue clay," appears, from isotope data, to be from Reynolds Creek basin south of the Snake River Plain or similar elevations, the Snake River, Lake Lowell and canals due to irrigation practices, perhaps the Payette River, Boise River, and Willow Creek areas north of the Snake River Plain.

(5) Temperatures of the aquifer within the "blue clay" appear to be only about 30°C and may be fairly uniform over large areas.

(6) Thermal water of isotopic composition $\delta D = -150$ $^{o}/oo$ and $\delta^{18}O = -18$ $^{o}/oo$ appears to be widespread in the western Snake River Plain region and may be the parent geothermal water in the Nampa-Caldwell

area, the Boise area, and the Bruneau-Grandview area and perhaps other areas. This indicates the water in these areas may be from the same source(s) and/or times of recharge, or the geothermal system may be interconnected.

RECOMMENDATIONS

The isotope data may be interpreted to indicate that thermal waters in the Nampa-Caldwell area, and indeed other areas in Idaho, including Weiser, Bruneau-Grandview and Boise areas may be old waters (11,000 years or greater). It is not known if present withdrawals of old water are being replaced with present day recharge. If not, the thermal waters are being mined and large scale withdrawals, i.e., for space heating or other purposes could eventually deplete the aquifer(s) to a point where further economic use is not feasible. To maximize the longevity of the resource until recharge can be proven or disproven, it is recommended that for space heating or other geothermal purposes, consideration be given to the use of down hole heat exchangers (heat exchangers located within the well bores adjacent to, or within the aquifers). These have proven practical at other localities such as Klamath Falls, Oregon. Down hole heat exchangers have two advantages: (1) they do not deplete the water resource, (2) there is little or no chemical pollution, as little or no geothermal water is brought to the surface.

Investigations of effects of widespread artificial aquifer connections by well drilling on the longevity of the thermal aquifers and their use for a heat source should be conducted.

Investigations to delineate possible recharge of the thermal aquifers should be undertaken to determine if recharge is presently occurring. These could include further stable isotope work in suspected recharge areas in the mountains on both sides of the Snake River Plain, tritium age dating, and dating using ^{12}C, ^{13}C, and ^{14}C and inert gas methods to determine absolute age of thermal water from various thermal aquifers.

More work is needed to determine clay layer semi-permeable membrane effects on the stable isotope ratios in the Nampa-Caldwell area. This particular study would be in the realm of institutions with adequate research facilities for such studies.

Monitoring of potentiometric surfaces to detect stress effects in the aquifer would provide early warning of water level declines should these take place due to increased pumpage from geothermal development.

Isotope data has proved to be a very valuable tool in this investigation and should be incorporated as standard water quality data in other areal investigations where deemed appropriate. Isotope studies should be integrated in any groundwater study of the Boise Front Geothermal system.

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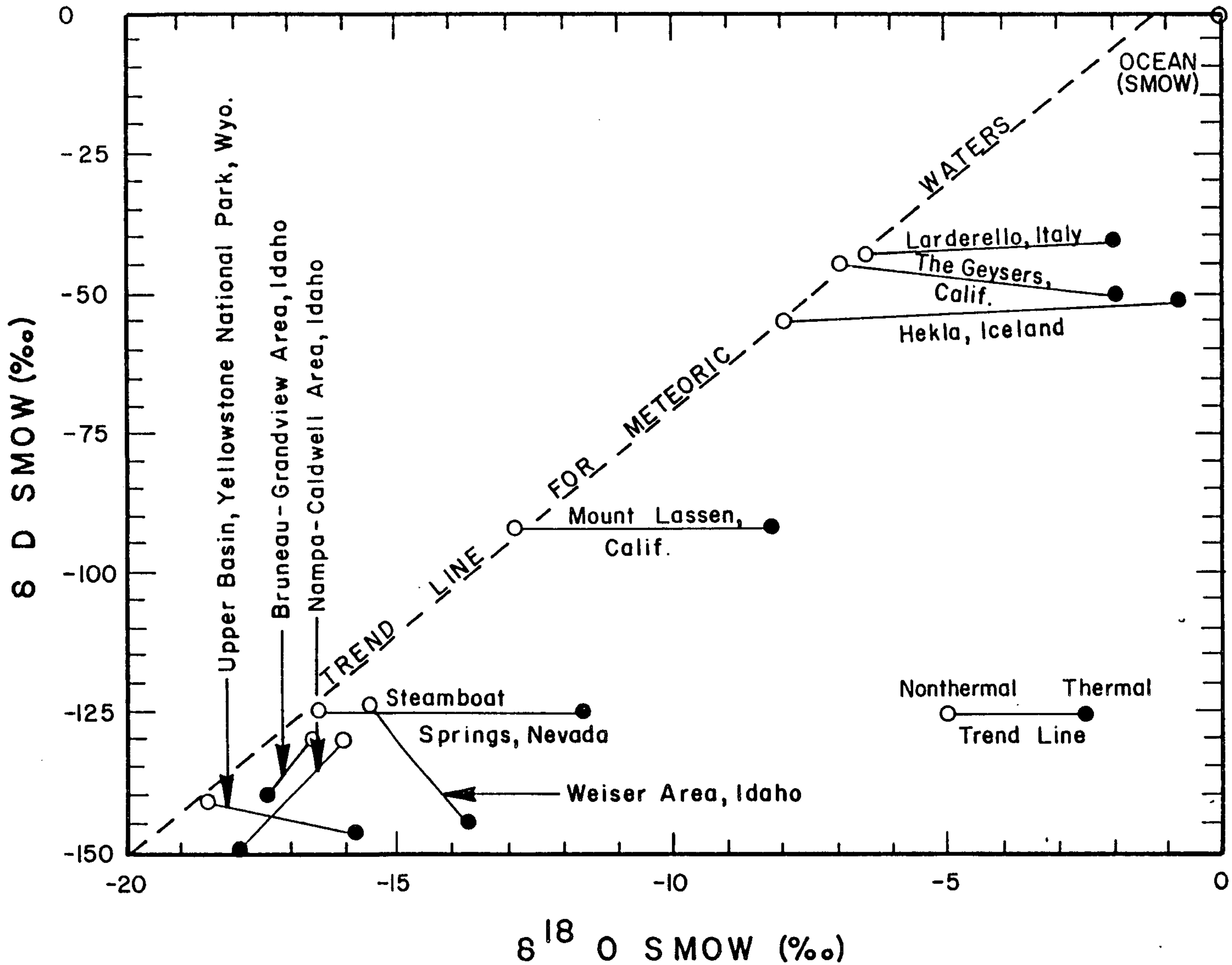


FIGURE 4-1. Isotopic composition of thermal and nonthermal waters of the Nampa-Caldwell area, Canyon County, Idaho compared with meteoric waters and waters of selected geothermal systems of Idaho and the world. [Modified from Rightmire, Young and Whitehead (1976) after White, Barnes, and O'Neil (1973).]

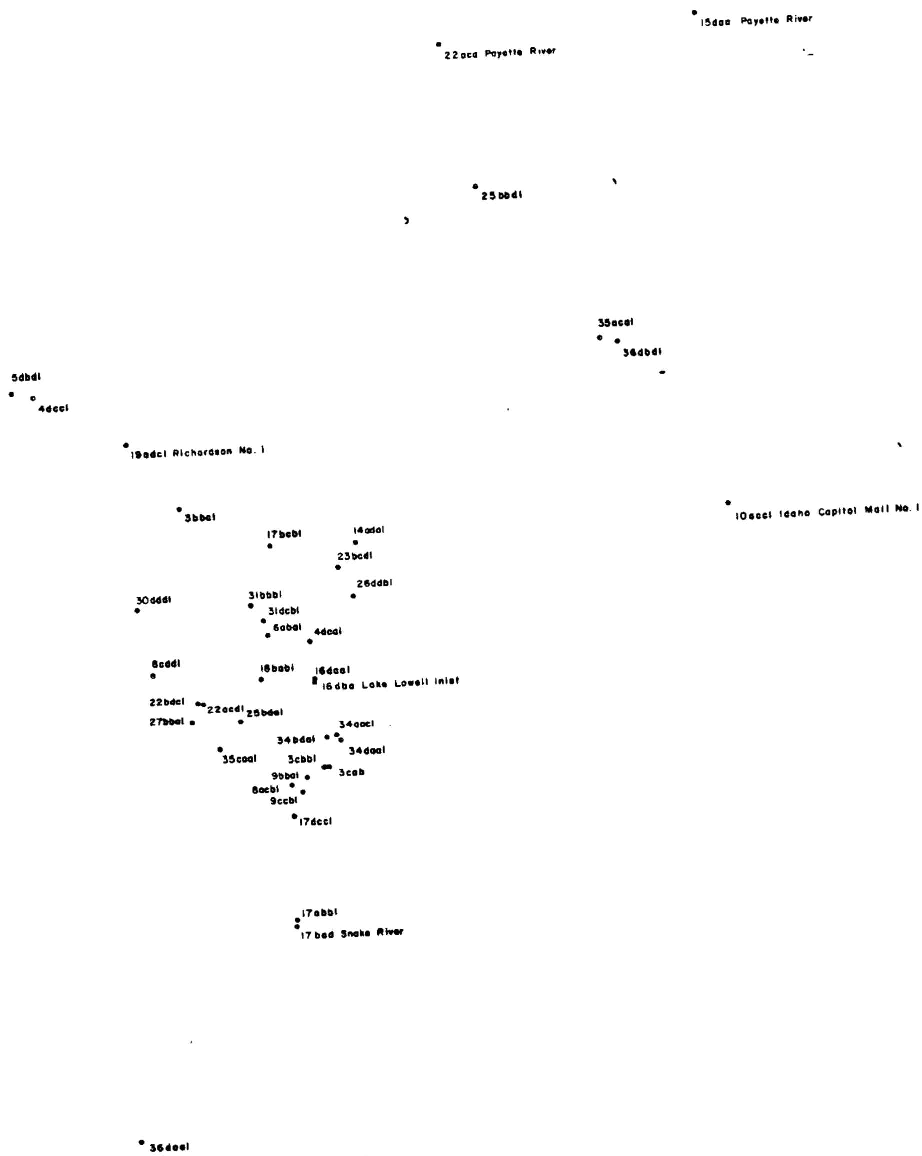
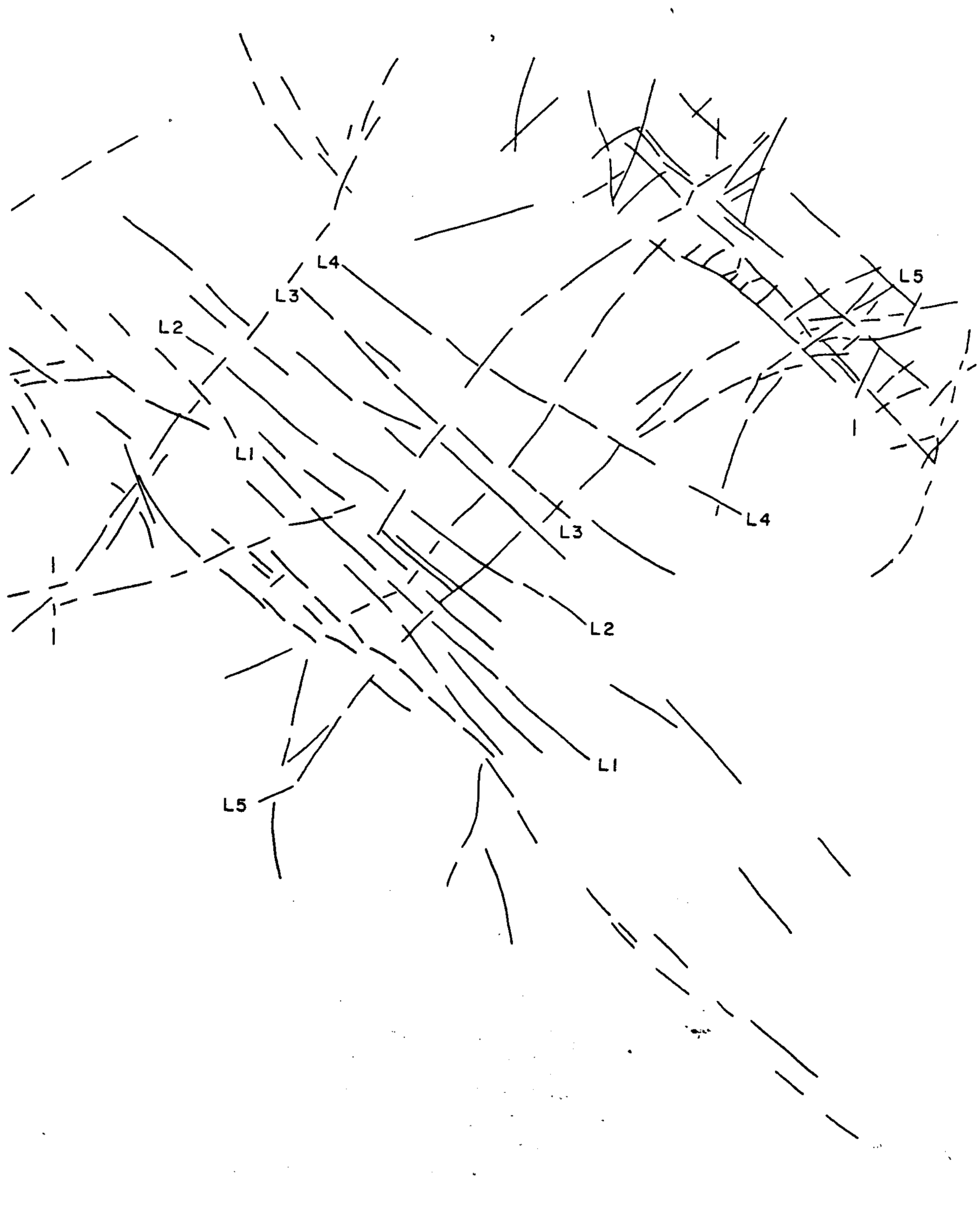


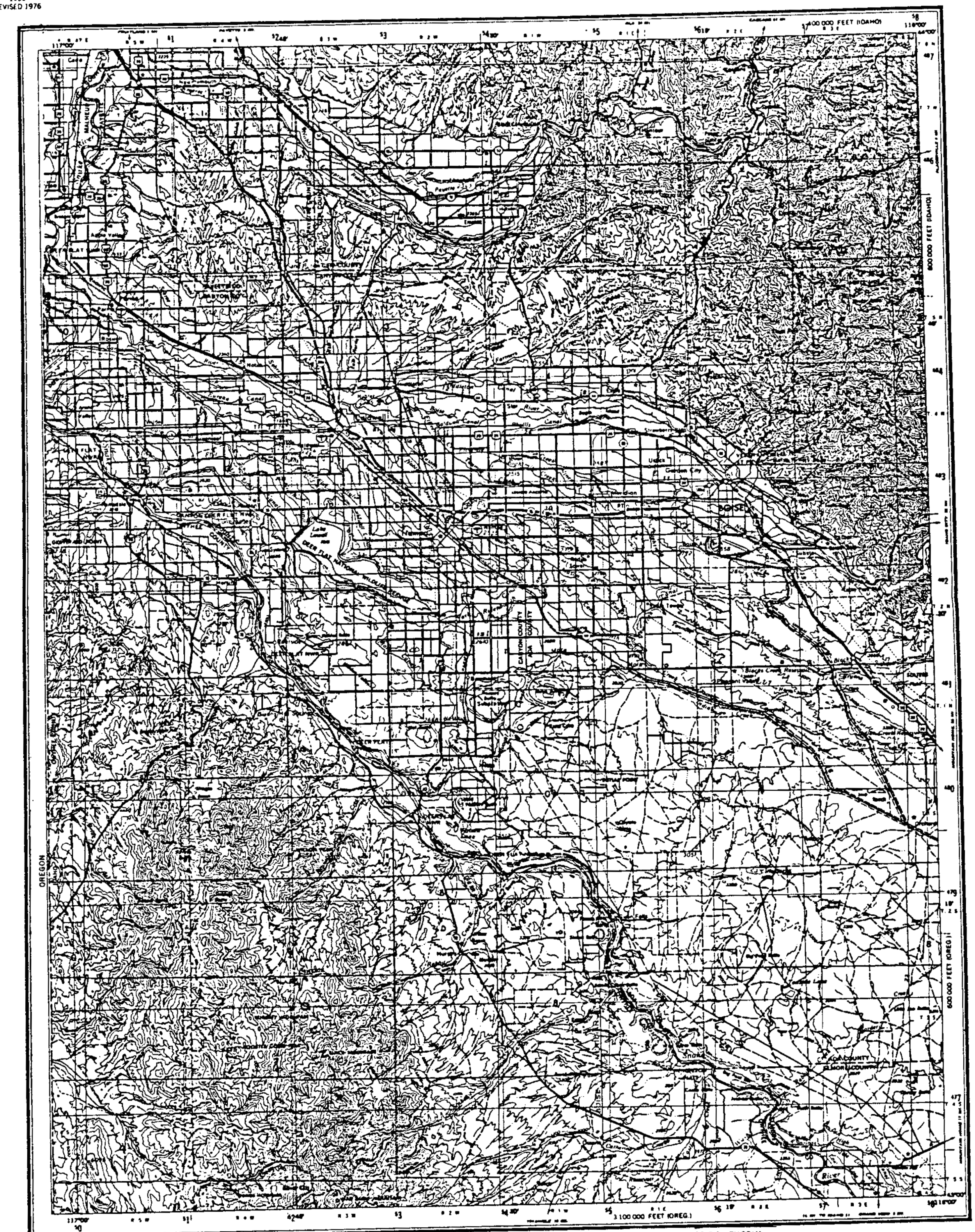
FIGURE 4-2. Index map of a portion of southwestern Idaho showing isotope sample locations and major lineaments in the western Snake River Plain and adjacent areas. Lineaments are a composite of independent work of Anderson and of Mitchell (1980).

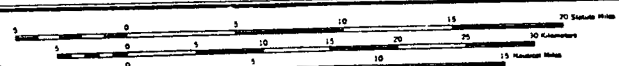

L4
L3
L2
L1
L5
L5
L4
L3
L2
L1

BOISE, IDAHO; OREGON

1955
REVISED 1976

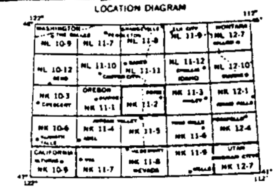
NK 11-2





CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

LOCATION DIAGRAM



SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

TOWNSHIP OR RANGE LINE
LAND GRANT BOUNDARY

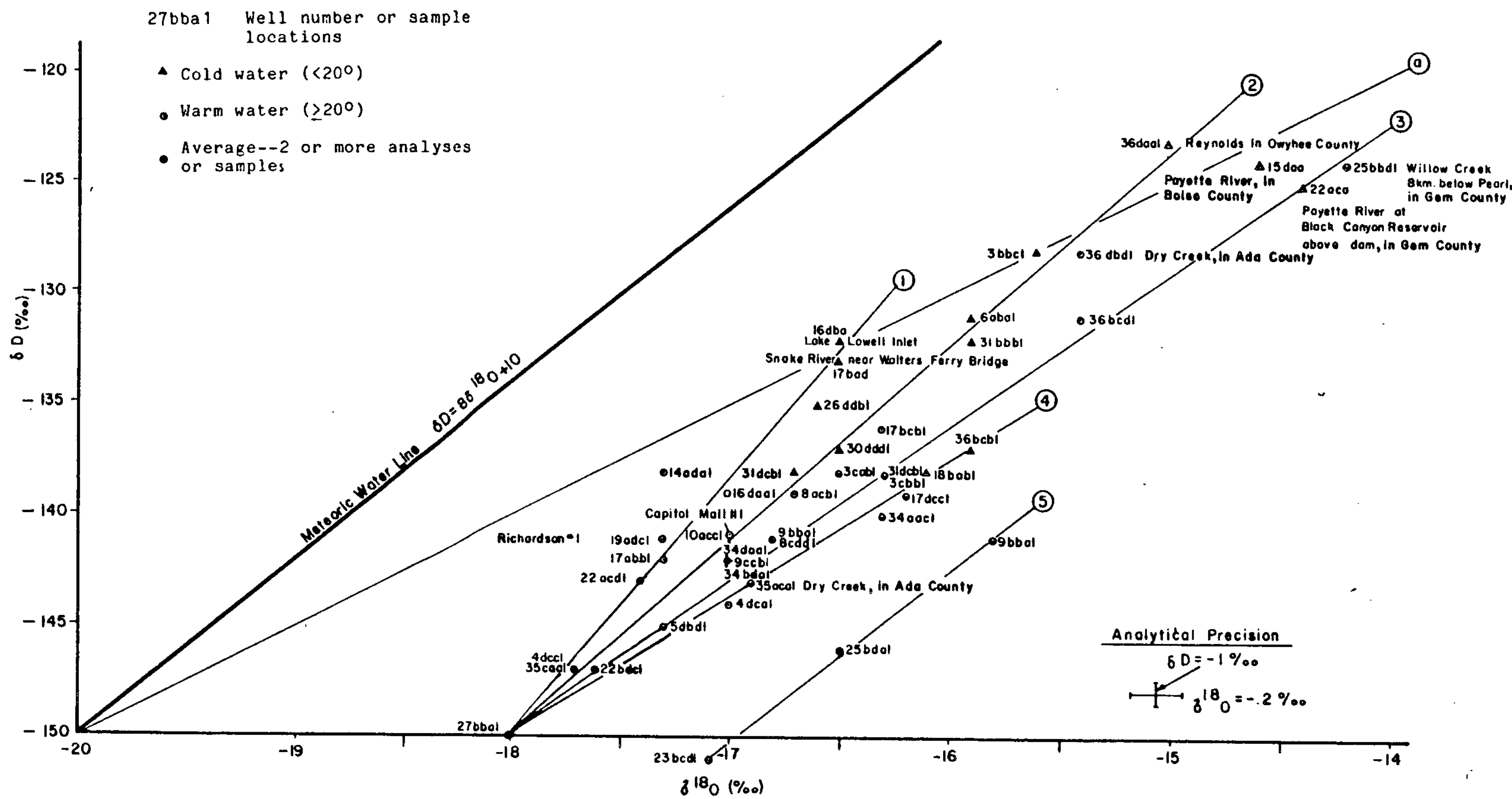


FIGURE 4-4. Isotopic composition of thermal and nonthermal waters from selected wells and surface waters in the Nampa-Caldwell and adjacent areas of Southwest Idaho.

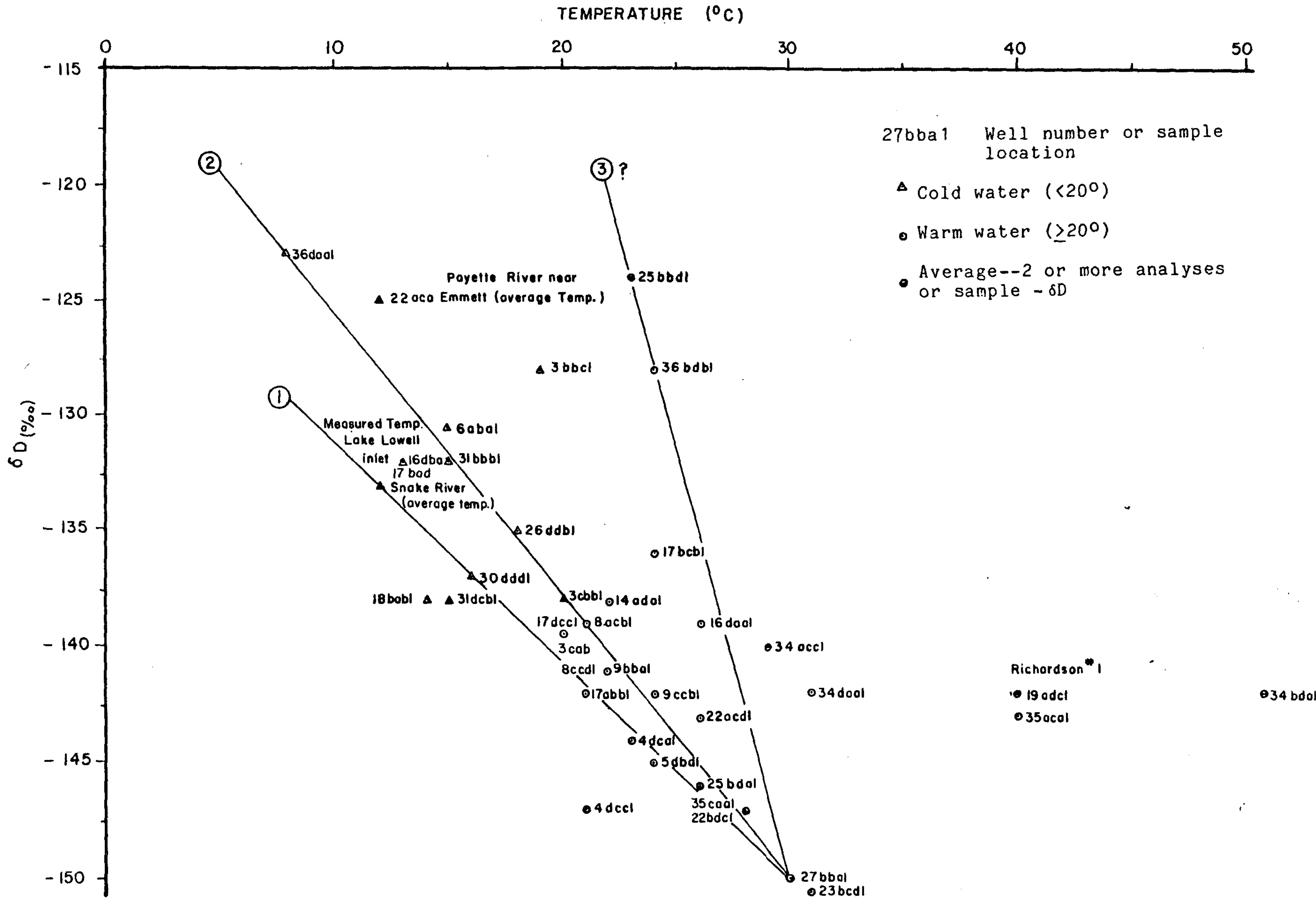


FIGURE 4-5. Measured surface temperatures of selected wells and surface waters versus δD in the Nampa-Caldwell and adjacent areas of southwestern Idaho.

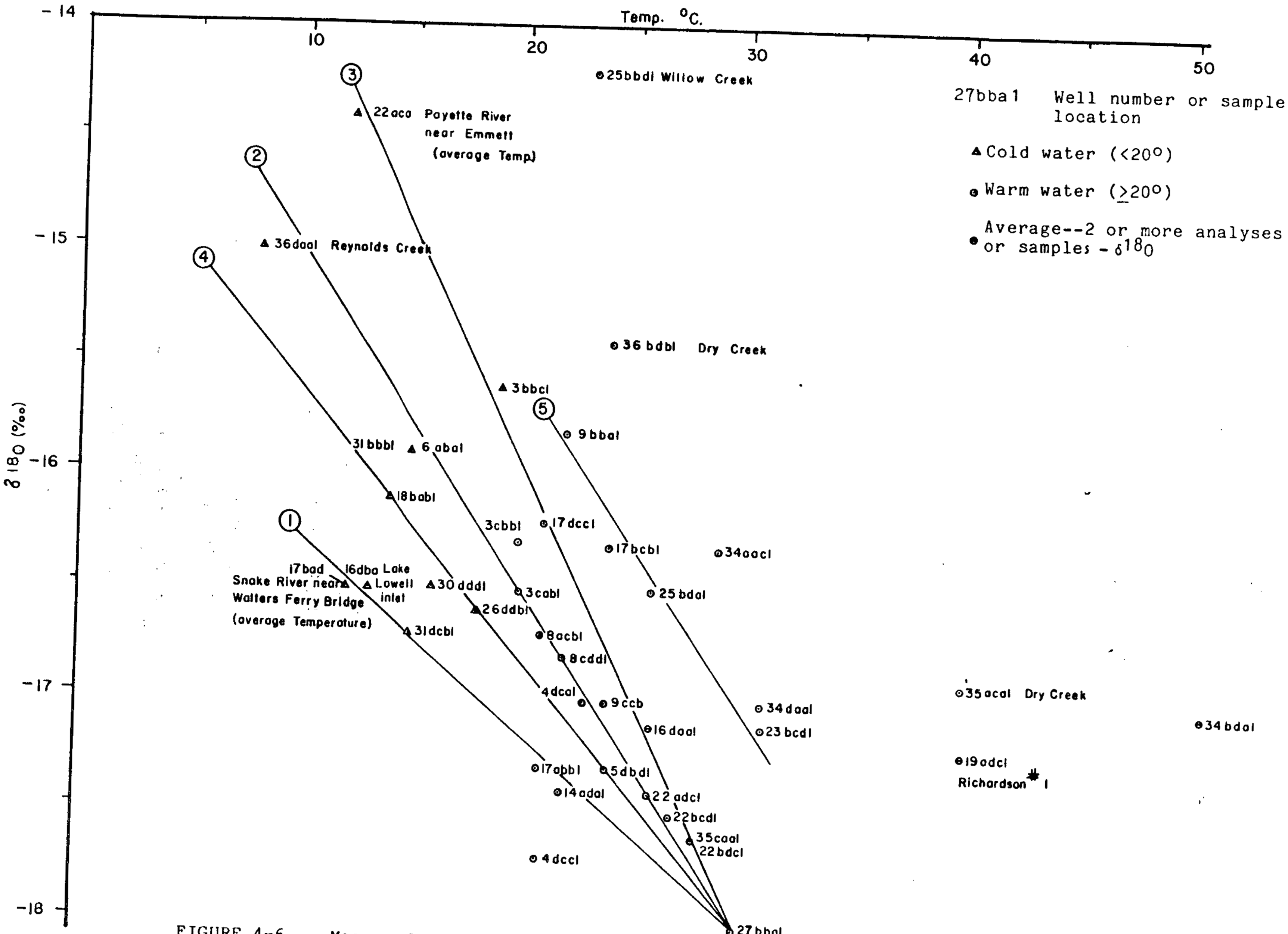


FIGURE 4-6. Measured surface temperatures of selected wells and surface waters versus δ18O in the Nampa-Caldwell and adjacent areas of southwestern Idaho.

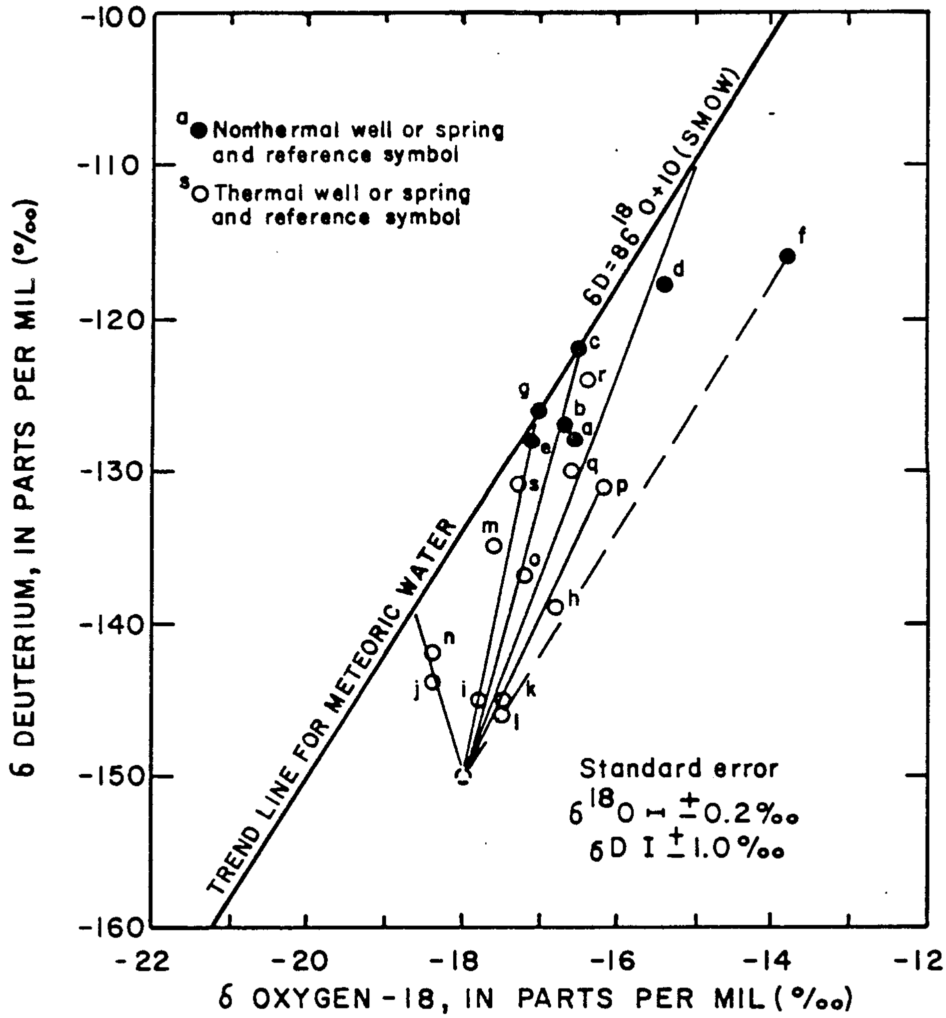


FIGURE 4-7. Isotopic compositions of thermal and and nonthermal waters from selected wells and springs in the Bruneau-Grand View and adjacent areas, Owyhee County, Idaho. Modified from Young and Lewis (1980, p. 19).

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