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LEAD AND STRONTIUM ISOTOPE DATA FOR THERMAL WATERS OF THE
REGIONAL GEOTHERMAL SYSTEM IN THE TWIN FALLS AND OAKLEY
AREAS, SOUTH-CENTRAL IDAHO

R. H. Mariner and H.W. Young

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ABSTRACT

Thermal fluids obviously related to aquifers in both rhyolite and limestone occur in the Twin Falls-Oakley area of south-central Idaho. Limestone-related waters (high calcium with low silica and fluoride) occur in the middle and upper (southern) parts of the area. Rhyolite-related waters (low calcium but high in silica and fluoride) occur in the lower (northern) part of the area. The relation of thermal fluids in Paleozoic limestone to thermal fluids in Tertiary rhyolite is unknown. Thermal fluids from limestone are dilute, so water-rock reaction in rhyolite could obliterate chemical evidence of fluid residence in a limestone. However, isotopic tracers such as $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, $^{208}\text{Pb}/^{204}\text{Pb}$, and $^{87}\text{Sr}/^{86}\text{Sr}$ might preserve evidence of fluid residence in limestone. Systematic relations between these isotopes and dissolved constituents in the water demonstrate the presence of limestone beneath most if not all of the study area and that aquifers in the limestone and rhyolite are hydrologically connected.

INTRODUCTION

Thermal fluids occur at many locations along virtually the entire length of the Snake River Plain in southern Idaho (Mitchell and others, 1980). In south-central Idaho, thermal waters occur principally between the Snake River and the mountains of northern Nevada. Topographically the area consists of a plain which slopes gently upward from the Snake River to northern Nevada. Numerous wells scattered over the plain and near the Snake River (fig. 1) draw on thermal water in the regional geothermal system. Several perennial streams cross the plain in deeply incised canyons and a low range of hills along the Twin Falls-Cassia county line separates the Salmon Falls Creek and Goose Creek drainages.

Quaternary and Tertiary volcanics and Paleozoic marine sediments underlie the plain (Lewis and Young, 1989). Basalts of Quaternary age occur in the northern part of the study area. These basalts are variable in thickness and individual flows do not exceed 50 feet (Lewis and Young, 1989). Slightly older basalts and detrital units of the Glenns Ferry Formation (lower Pleistocene and upper Pliocene) are exposed in the northern part of the area. The Glenns Ferry Formation is probably less than 500 feet thick in the area (Lewis and Young, 1989). The Miocene Banbury Basalts may be up to 1,000 feet thick in this area (Malde and Powers, 1972). Although locally significant, these basalts are not as ubiquitous as the Idavada Volcanics (Miocene and Pliocene) which are comprised of silicic welded tuffs and occasional basalt flows. The Idavada Volcanics are at least 2,000 feet thick in part of the area and have been considered to be the major aquifer for the thermal water (Lewis and Young, 1989). The thickness and extent of Paleozoic...
rocks (principally limestone) beneath the Tertiary cover is unknown. Up to 5,000 feet of Paleozoic rock has been reported in the mountains of northern Nevada (Schroeder, 1912).

The hydrothermal system in the study area was not extensively utilized until the mid-1970's. Most development has been near the Snake River. Water temperatures in most wells are between 25° and 70°C (Mariner and others, 1991). The fluid is used for space heating, greenhouse operations, irrigation, and aquaculture. Well depths range from 350 to 2,200 feet (Lewis and Young, 1989). As a result of increased utilization, well-head pressures have declined as much as 25 pounds per square inch (~60 ft. of water head), and some previously flowing wells must now be pumped.

The conceptual model for the system, proposed by Lewis and Young (1989), consists of a single 2,000 foot thick aquifer in the Idavada Volcanics with recharge near the Idaho-Nevada boundary. The fluids are heated by deep circulation. Near the Idaho-Nevada boundary, thermal water is often recovered from Paleozoic rock (limestones). The widespread presence of thermal fluid in Paleozoic rock beneath the known geothermal system in the Tertiary volcanics is a distinct possibility throughout the area. If thermal fluids from Paleozoic limestones are leaking upward into the shallower Tertiary volcanic rocks then the amount of thermal fluid available is larger and the viable life of the system under development could be expected to be appreciably longer. The purpose of this study is to determine if lead and strontium isotopic values (206Pb/204Pb, 207Pb/204Pb, 208Pb/204Pb, and 87Sr/86Sr) in the thermal waters of the Twin Falls-Oakley area indicate the presence of separate geothermal systems in the Paleozoic limestones and Tertiary volcanics or if only one integrated system exists with fluid from the deeper limestone aquifer feeding the shallow aquifer in the Tertiary volcanics. 206Pb/204Pb, 207Pb/204Pb, and 208Pb/204Pb values should be higher in the Paleozoic limestones than in Tertiary volcanics because 238U, 235U, and 232Th in the Paleozoic rocks have decayed for a much longer time period than they have in the volcanics. For example, limestones in the region have 206Pb/204Pb values greater than 19 (Doe, 1976; Leeman, 1977), whereas rhyolites have 206Pb/204Pb values less than 18 (Leeman, 1977; Doe et al., 1982). 87Sr/86Sr may also be sufficiently different in the two environments to make it a useful tracer. Water samples from 29 thermal wells and one cold spring in south-central Idaho and the adjacent part of northeastern Nevada were collected for lead and strontium isotopic analysis (fig. 1).

**Data**

Water from thermal wells in the Twin Falls area (Table 1) (fig. 1) ranges in temperature from 26° to 70°C and is moderately to slightly alkaline in pH (7.3 to 9.6). Water from wells in limestone (limestone-related water) are low in silica (20-30 mg/L), sodium (10 to 24 mg/L), and fluoride (generally less than 2 mg/L). Water from wells in rhyolite (rhyolite-related water) is variable in composition but the most clearly rhyolite-related waters are rich in silica (> 70 mg/L), sodium (>100 mg/L), and fluoride (>15 mg/L). Figure 2 illustrates the range in composition of the thermal waters. The different concentrations of silica, calcium, and fluoride shown in Table 1 and Figure 2 could be due to chemical reactions occurring as the fluids move from limestone to rhyolite. Silica should increase along with fluoride, although fluoride could not begin to increase until calcium concentrations have decreased; the waters are generally saturated with respect to fluorite. Increases in pH due to feldspar dissolution could lead to calcite deposition and loss of calcium from solution.

![Fig. 2 Concentrations of bicarbonate, sodium, silica, chloride, fluoride, and calcium for selected samples.](image)

Values for 206Pb/204Pb, 207Pb/204Pb, 208Pb/204Pb, and 87Sr/86Sr are given in Table 2. A plot of 206Pb/204Pb versus 208Pb/204Pb (fig. 3) shows that waters clearly related to limestone are higher in 206Pb/204Pb and 208Pb/204Pb than water from most rhyolites and that there is a strong positive linear trend among most of the samples. Values for rhyolite-related waters are much more variable than for limestone-related waters. Some rhyolite-related waters have values that partially overlap the values of limestone-related waters and some 208Pb/204Pb values from rhyolite-related waters completely overlap the values of limestone-related waters. This could indicate that fluid from some wells with water compositions typical of a rhyolite source has spent most of its circulation time in a Paleozoic limestone at greater depth. We will use 206Pb/204Pb values in the following discussions because they are more diagnostic of a limestone or rhyolite source than are 208Pb/204Pb or 207Pb/204Pb values. Samples 1, 3, 7, and 30 do not plot on the same trend as most of the data in Figure 3, indicating that these waters have derived at least part of their lead from some other formation. Sample 1, 3, and 7 are all along the Snake River at the northeastern edge of the study area. Based on 14C, dissolved helium, and stable isotope data, Mariner and others (1991) proposed that two thermal waters
Table 1. - Chemical composition of thermal waters, Twin Falls area
[Concentrations in milligrams per liter; - , no data]

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1 Total alkalinity as HCO₃⁻
2 Chemistry for 9S17E29ACC1

Mix or join along a line approximated by the Snake River. Fluid south of the Snake River recharges in the mountains of northern Nevada and moves northward to join another thermal system with thermal water moving from east to west beneath the Snake River Plain. The origin of the east to west moving thermal water is unknown but it is higher in total dissolved helium and lower in 14C, indicating that it is an older water. Samples 1, 3, 7, and to a smaller extent, 14, could be from this older water. The older water clearly has a different history and it probably has a different lead isotope composition. Alternately, sample 1 could be influenced by circulation through granitic rock. Cretaceous (?) granite is exposed to the west in the Bruneau-Grand View area (Young and Whitehead, 1975). Cretaceous (?) granite also occurs near sample 30, a cold spring in the mountains of northern Nevada.

A plot of silica versus 206Pb/204Pb (fig. 4) produces a distribution of data points extending from low silica-high 206Pb/204Pb (limestone-related water) to high silica-low 206Pb/204Pb (rhyolite-related water). Most data plot between these extremes and could represent limestone waters which have picked up silica from the rhyolite and the lead isotopes have partially shifted to the value for the rhyolite. Samples 17, 20, 23, 27, and 28 represent waters clearly issuing from
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limestone. Samples 7, 9, and 22 represent waters which have extensively reacted with rhyolite. Samples 2, 3, 18, and 24 (rhyolite-reacted limestone waters) represent limestone waters which have reacted with rhyolite to increase dissolved silica but have not reacted with enough rhyolite to take on the lead isotope composition of the rhyolite.

Waters from the Goose Creek drainage and along the Twin Falls-Cassia county line (samples 16, 18, 19, 20, 21, 22, 23, 27, and 29) range from rhyolite-related water (sample 22) to limestone-related waters (samples 20 and 23). Samples 18 and 29 are rhyolite-reacted limestone waters. Samples 16, 19, and 21 are also rhyolite-reacted limestone waters but they have reacted more extensively with a rhyolite. Waters in the Upper Salmon Falls Creek area (samples 17, 24, 25, 26, and 28) range from limestone-related waters (samples 17 and 28) to rhyolite-reacted limestone waters (sample 24, 25, and 26). Waters in the Twin Falls area (samples 9, 10, 12, 13, 14, and 15) range from rhyolite-related waters (sample 9) to rhyolite-reacted limestone waters (samples 10, 12, 13, 14, and 15). In and near Twin Falls, the limestone component is more obvious to the south and the rhyolite component is more obvious to the north and west. In the Castleford to Hagerman area (samples 1, 2, 3, 4, 5, 6, 7, and 11) water compositions range from rhyolite-related water (sample 7), to rhyolite-reacted limestone waters (samples 1, 2, 3, 4, 5, 6, 7, and 11). A significant point is that no rhyolite-related water is as low in 206Pb/204Pb as the rhyolite rock (fig. 4). Therefore, no thermal water has circulated solely in rhyolite; all thermal waters in the area have circulated through limestone and most have circulated through both limestone and rhyolite.

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Table 2. Lead and strontium isotope data for thermal and nonthermal waters in the Twin Falls area

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Fig. 3. 206Pb/204Pb versus 206Pb/204Pb for waters in the study area.

Fig. 4. Plot of dissolved silica versus 206Pb/204Pb for waters in the study area. Limestone 206Pb/204Pb > 19. Rhyolite 206Pb/204Pb < 18.
Sample 8 is clearly anomalous on figures 3 and 4, and it is also high in $^{207}\text{Pb}/^{204}\text{Pb}$ (Table 2). Chemically it is a rhyolite-related water but is more enriched in $^{206}\text{Pb}/^{204}\text{Pb}$, $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{208}\text{Pb}/^{204}\text{Pb}$ than any limestone-related waters sampled in the region. The most likely explanation is that it is a limestone water which has moved up and into the rhyolite where it chemically reequilibrated. Drillers logs for a 2,000 foot well near Buhl (about 8 miles WSW of sample 8) record the presence of limestone at a depth of 1,600 feet. Unfortunately this well no longer exists but fluid from this or a similar Paleozoic limestone could be the source of the waters in sample 8.

A plot of dissolved silica versus $^{87}\text{Sr}/^{86}\text{Sr}$ (fig. 5) shows that the limestone-related waters have a wider range in $^{87}\text{Sr}/^{86}\text{Sr}$ values than the rhyolite-related waters and that no shift in $^{87}\text{Sr}/^{86}\text{Sr}$ occurs as silica concentration increases. Strontium concentrations are appreciably higher in limestone than in rhyolite, therefore much more water-rock reaction must occur before an obvious trend toward the $^{87}\text{Sr}/^{86}\text{Sr}$ values of the rhyolite can develop. Rhyolite from the area has $^{87}\text{Sr}/^{86}\text{Sr}$ values of more than 0.711 (Leeman and other, 1977; Doe and others, 1982; Bullen, written comm.). It appears that $^{87}\text{Sr}/^{86}\text{Sr}$ is preserving evidence of thermal water circulation through a limestone. Based on the lead and strontium isotope data most wells in the study area tap rhyolite-reacted limestone waters and all thermal waters in the area appear to have a limestone component.

**SUMMARY**

Lead isotope data indicate that fluid from Paleozoic limestone is leaking upward into the Tertiary rhyolites where most wells intersect it. The fluids react with the volcanic rock to produce silica rich, calcium poor fluids typical of thermal fluids in rhyolite but the lead and strontium isotope compositions are not as easily changed, preserving evidence of the limestone aquifer at greater depth. Limestone-related waters which have not reacted with rhyolite occur only near the upper and middle (southern) parts of the system. The lead and strontium isotope data coupled with dissolved silica concentrations require that limestone exists beneath most if not all of the study area and that fluids from this deep aquifer are leaking upward into the Tertiary rhyolite. This means that the volume of fluid in the geothermal system is appreciably larger than if the fluids were restricted to the rhyolite. It could also mean that thermal fluids at higher temperatures may be obtained from the deeper limestone aquifer.

**ACKNOWLEDGEMENTS**

This work was supported by the U.S. Department of Energy under contract number DE-A101-91CE31020. Such support does not constitute an endorsement by DOE of the views expressed in this publication. Tom Bullen and Yousif Kharaka provided helpful reviews.

**REFERENCES CITED**


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