LEAD AND STRONTIUM ISOTOPES INDICATE DEEP THERMAL-AQUIFER IN TWIN FALLS, IDAHO, AREA

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KEY WORDS

stable isotopes, thermal water, $^{208}Pb/^{204}Pb$, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, rhyolite, limestone, Twin Falls, Idaho

PROJECT BACKGROUND AND STATUS

Thermal fluids occur at many locations along the entire length of the Snake River Plain in southern Idaho. Near Twin Falls in south-central Idaho, thermal waters occur between the Snake River and the mountains of northern Nevada. Topographically the area is a plain that slopes gently upward from the Snake River toward northern Nevada. Numerous thermal wells scattered over the plain and near the Snake River draw on thermal water in a regional geothermal system. Quaternary and Tertiary volcanics and Paleozoic marine sediments underlie the plain.

The Tertiary 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. They consist of Miocene to Pliocene silicic welded tuffs and occasional basalt flows. The thickness and extent of the Paleozoic rocks (principally limestone) are unknown, but up to 5,000 feet of Paleozoic sediments have been described in the mountains of northern Nevada. Most geothermal development is near the Snake River and uses 25° to 70°C water for space heating, greenhouses, aquaculture, and irrigation. Pressure heads have decreased as much as 25 lbs/in^2, and some previously artesian 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 surface recharge to the system near the Idaho-Nevada boundary.

PROJECT OBJECTIVES

The objective of our study was to determine if the thermal fluid recovered from the Tertiary rhyolite had ever circulated in a deeper aquifer in the Paleozoic limestone. Previous studies left some confusion in the relationship between thermal fluids recovered from wells in Paleozoic limestone located along the Idaho-Nevada boundary and the thermal fluids recovered from wells completed in Tertiary rhyolite at Twin Falls and along the Snake River both east and west of Twin Falls. Geologic considerations indicated that the Paleozoic and Tertiary rocks slope gently to the north, but the northern extent of the Paleozoic limestone is unknown. All producing wells along the Snake River and in Twin Falls are completed in Tertiary rhyolite and have chemical constituents typical of thermal waters in young rhyolite.

Technical Objectives

- Use isotopes of lead dissolved in the thermal waters to determine if fluids recovered from wells in rhyolite have a component of fluid from the deeper limestone.

Expected Outcomes

- Determine if thermal fluids in the Paleozoic limestone are providing pressure support and appreciable fluid volumes to the shallow geothermal system in the rhyolite. If the aquifers in the Tertiary rhyolite and Paleozoic limestone are connected, then the volume of fluid available will be greatly increased and the useful life of the system would be greatly extended.

APPROACH

Lead isotope values of Paleozoic limestone and Tertiary rhyolite are very different. Water samples for isotopic and chemical analysis were collected from selected wells for which some previous chemical data were available. Wells were selected which had limestone-related waters (low silica and fluoride but high calcium), rhyolite-related waters (high silica and fluoride but low calcium), and waters of intermediate character. The waters of intermediate composition tended to be very similar to the clearly rhyolite-related waters, but they were not as high in pH, silica, and fluoride and had more calcium than clearly "end-member" rhyolite-related waters.

Previously existing water chemistry data were used to determine which wells to sample, but new samples were collected for basic dissolved constituent analysis to see if any significant changes in the major element chemistry and/or stable isotope compositions had occurred. A separate set of samples were collected for Pb-isotope analysis. Pb-isotopes were considered the best candidate for preserving evidence of fluid circulation through limestone because their values will change slowly as new lead is dissolved from the rhyolite. Pb-isotopes should preserve evidence of circulation in limestone much better than normal chemical constituents such as silica, sodium, calcium, bicarbonate.

RESEARCH RESULTS

Thermal wells in the Twin Falls area (Mariner and others, 1991) produce water which ranges in temperature from 26° to 70°C and is moderately to slightly alkaline in pH (7.3 to 9.6). Wells in limestone provide water that is low in silica (20 to 30 mg/L), sodium (10 to 24 mg/L), and fluoride (generally less than 2 mg/L). Wells in rhyolite yield waters that are variable in composition, but the most typical "rhyolite" waters are rich in silica (>70 mg/L), sodium (>100 mg/L), and fluoride (>15 mg/L). The different concentrations of silica, calcium, and fluoride could be due to chemical changes occurring in the fluids as they move from limestone to rhyolite. Silica should increase along with fluoride, although fluoride could not begin to increase until calcium concentrations have decreased. Increases in pH due to feldspar dissolution could lead to calcite deposition and loss of calcium from solution.

A plot of $^{206}Pb/^{204}Pb$ versus $^{208}Pb/^{204}Pb$ (Figure 1) shows that waters from limestone are higher in $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ than water from most rhyolites and that there is a strong linear trend among most of the samples. Isotopic ratios for waters from rhyolites are much more variable than those for waters from limestones; some waters from rhyolites have ratios that completely overlap the ratios for water from the limestones. This overlap could indicate that waters with compositions typical of a rhyolite source have circulated for a long time in Paleozoic limestone. Samples 1, 3, 7, and 30 do not plot on the same trend as most of the data, indicating that these waters have derived at least part of their lead from some other rock type. Sample 1, 3, and 7 are all along the Snake River at the western edge of the study area. Sample 30 is from a cold spring in the mountains of northern Nevada.

A plot of silica versus $^{206}Pb/^{204}Pb$ (Figure 2) produces a distribution of data points extending from low silica-high $^{206}Pb/^{204}Pb$ (limestone-type water) to high silica-low $^{206}Pb/^{204}Pb$ (rhyolite-type water). Most data points plot between these extremes and probably represent limestone-type waters which have picked up silica from the rhyolite. The lead isotopes have partially shifted toward the value for the rhyolite. Samples 17, 20, 23, 27, and 28 represent waters from limestone. Samples 7, 9, and 22 represent waters which have extensively reacted with rhyolite. Samples 2, 3, 18, and 24 represent limestone-type waters which have reacted with rhyolite to increase dissolved silica but have not reacted with enough rhyolite to assume the lead isotope composition of rhyolite.

Sample 8 is clearly anomalous; chemically it is a rhyolite-type water, but it has higher ratios of $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ than any limestone-type 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 from town) 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.

$^{87}Sr/^{86}Sr$ values for all sampled waters were within the range expected for Paleozoic limestone. None of the waters were as enriched in $^{87}Sr/^{86}Sr$ values as the rhyolite, and no shift in $^{87}Sr/^{86}Sr$ was observed as dissolved silica concentrations increased. Strontium concentrations are appreciably higher in limestone than in rhyolite; therefore much more water-rock reaction must occur in the rhyolite before sufficient strontium dissolves from the rhyolite to change the dissolved $^{87}Sr/^{86}Sr$ values. It appears that dissolved $^{87}Sr/^{86}Sr$ values are preserving evidence of circulation through a limestone for at least a significant part of all thermal waters in the area.

Lead and strontium isotope data indicate that fluid from Paleozoic limestone is leaking upward into the Tertiary rhyolites where wells intersect it. The fluids react with the volcanic rock to produce silica rich, calcium poor compositions typical of thermal fluids in rhyolite, but the lead isotope compositions are not as easily changed, preserving evidence of the limestone aquifer at depth. Most thermal fluids in the area appear to be a limestone water which has reacted with rhyolite. Limestone waters which have not reacted with rhyolite occur only near the upper and middle parts of the system. Rhyolite dominated waters occur in the lower and eastern parts of the system. The lead and strontium isotope data coupled with dissolved silica concentrations require that a limestone aquifer exist beneath most if not all of the study area and that fluids from this deep aquifer leak upward into the Tertiary rhyolite. Isotopic evidence indicates that the thermal fluids in the rhyolite and limestone are hydrologically connected even though they have differences in major element chemical constituents, and that the volume of fluid in the geothermal system may be appreciably larger than if the fluids were restricted to the rhyolite.

FUTURE PLANS

Do additional sampling of Tertiary rhyolite and Paleozoic limestone are required to better define the range of Pb-isotope values possible in the study area. Take additional water samples from wells along the Snake River to better define changes in water characteristics as influenced by thermal fluid from the east which enters the study area beneath the Snake River and to see if sulfate-water isotope geothermometer values might be preserving evidence of temperatures in the deeper limestone aquifer. Obtain enough samples to demonstrate that either numerous upflow sites exist which permit thermal water from the deeper limestone to flow upward into the rhyolite where they spread laterally, or to demonstrate that the thermal fluids are deflected upward into the rhyolite along a single structure.

INDUSTRY INTEREST AND TECHNOLOGY TRANSFER

Organization(s)	Type and Extent of Interest
Idaho Water Resources Research Institute	Interested in the technology and data which require the presence of a deep aquifer beneath the aquifer presently being utilized. They need the data for the development of conceptual and computer models of the geothermal system.
Idaho Department of Water Resources	Interested because this is a ground-water management area and better understanding of the system will lead to better management.
Private companies	Aquaculture and space heating (greenhouse) users than depend on the heat and fluid to sustain their operations.
Public entities (City of Twin Falls, College of Southern Idaho, and the Twin Falls School District)	These entities use the resource extensively for heating public buildings.

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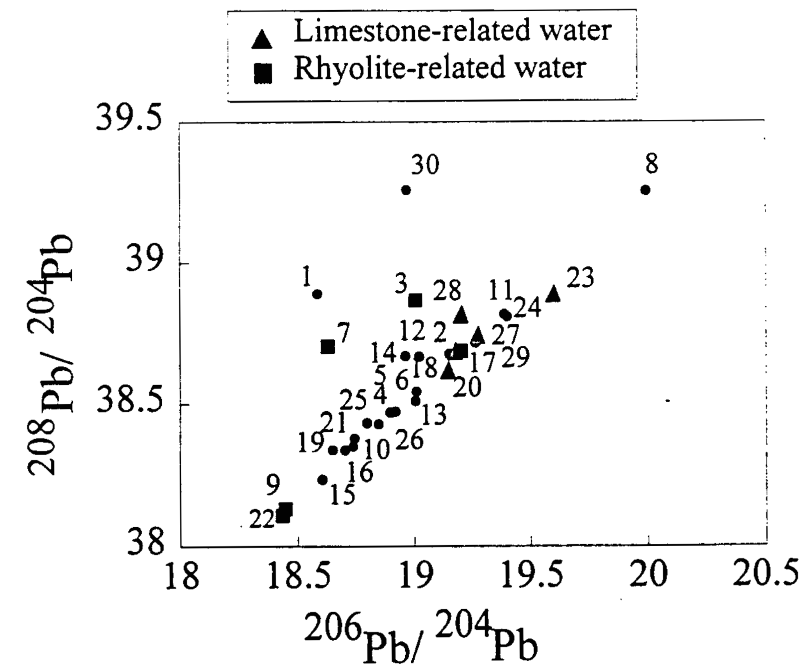

Figure 1. 208Pb/204Pb versus 206Pb/204Pb for waters in the study area.

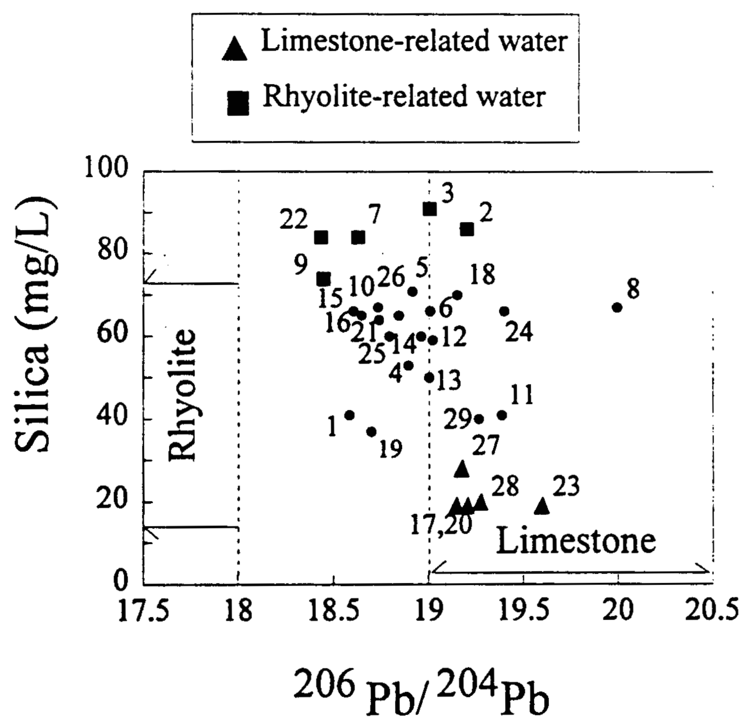

Figure 2. Dissolved silica versus 206Pb for waters from the study area,
Limestone 206Pb/204Pb > 19
Rhyolite 206Pb/204Pb < 18.