

Chemistry and Thermometry of Geothermal Water From Mountain Home Test Well MH-2B S: Preliminary Results

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ABSTRACT

A geothermal test well at Mountain Home AFB in southwestern Idaho encountered artesian flow of geothermal water from a depth of 1,745 m. Samples taken from the well head after 12 hours of flow had a pH of 9.59, and an electrical conductivity of 870 μ S. The high pH suggests that the water is at equilibrium with weathered basalt at the measured temperature. The water is high in sulfate relative to chloride and bicarbonate, and high in sodium relative to calcium and magnesium, but has a TDS content of only 1,120 mg/L. Pyrite is probably the source of the sulfate. Deuterium and oxygen-18 levels are -88 and -3.2 per mil, respectively, suggesting that the water is old, not meteoric, and/or has undergone significant fractionation. Calculated equilibrium temperatures vary from ~134°C to ~154°C. The calculated temperatures are similar to those measured in the test well. The data suggest a potential electric-grade resource. Further work is in progress.

Introduction

The Snake River Geothermal Drilling Project, aka Project Hotspot, seeks to understand the thermal system associated with the Snake River-Yellowstone hotspot (Shervais et al., 2011; Potter et al., 2011; Sant et al., 2011; Kessler and Evans, 2011). The Snake River Plain (SRP) volcanic province preserves a record of Pleistocene and Holocene volcanic activity, with basalts as young as 200 ka in the west and 2 ka in the east. The SRP is characterized by high surface heat flows, numerous hot springs, and two passive geothermal districts (Boise and Twin Falls). There is significant potential for power generation using binary generation systems, which can exploit intermediate temperature resources, like Raft River (Sanyal and Butler, 2005; Neely and Galinato, 2007).

Three test wells were drilled in 2010 and 2011 as part of the Snake River Geothermal Drilling Project to characterize three distinct settings within the SRP thermal province, to explore heat distribution at depth, and to determine the best ways to harness this resource. One of these wells was on the US Air Force Base in Mountain Home, Idaho. Drilling was stopped at 1,250 m when drilling funds were exhausted. The well was taken over by the USAF and deepened to a final depth of 1,821 m as Phase 2: Geothermal Drilling MH AFB.

An artesian geothermal system was encountered at 1,745 m depth in a zone of highly fractured and altered basalt. We report here on the chemistry of this geothermal water and its implications for heat production from this system. Additional papers on this project are published in this volume (Armstrong et al., 2012; Delahunty et al., 2012; Nielson et al., 2012).

Setting: The Snake River Plain Volcanic Province

Project Hotspot's primary goal is to evaluate the geothermal potential of the SRP in three distinct settings: (1) high sub-aquifer geothermal gradients in the axial volcanic zone of the central and eastern SRP; (2) valley-margin settings where hot springs are most common; and (3) a sedimentary basin adjacent to range-front faults in a large complex graben. The first two settings are found within the central Snake River Plain and represent previously untested targets for geothermal exploration. The third setting is found within the western SRP graben (Shervais et al., 2005).

The western SRP graben is a complex structure with steep range front faults that display a minimum throw of over 3 km, based on offset of the basalt-rhyolite contact as exposed in the Danskin Mountains (Teapot Dome area near Mountain Home) and as intercepted in the Bostic 1A wildcat oil well. A large positive gravity anomaly that transects the western plain at an oblique angle has been interpreted to represent a buried horst block within the graben (e.g., Shervais et al., 2011; Armstrong et al., 2012). Previous test wells near this structure (Bostic 1A, MH-1 on Mountain Home AFB; see Figure 1) documented high thermal gradients, but neither well encountered geothermal fluids or fracture systems capable of sustaining flow (Lewis and Stone, 1988; Arney, 1982; Arney et al., 1982, 1984). In particular, a

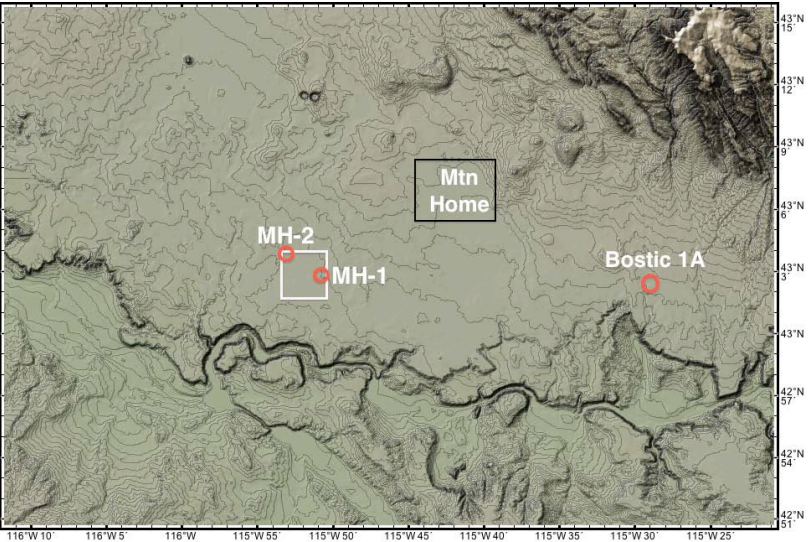


Figure 1. Shaded relief-topographic map of Snake River Plain derived from NASA 10m DEM data and contoured at 10m intervals. Red circles = drill site locations.

prior attempt at geothermal exploration at Mountain Home AFB produced a 1,342-m deep well, MH-1, with a BHT of 93°C but no flow (Lewis and Stone, 1988; Armstrong et al., 2012).

Methods

Drilling at Mountain Home AFB

Drilling operations commenced at Mountain Home in July 2011 as part of Project Hotspot: the Snake River Geothermal Drilling Project. Problems with collapsing sediments forced abandoning the original hole (MH-2A) and drilling a second hole (MH-2B). As a result, drilling funds were exhausted in mid-October 2011. The USAF took over the project and subsequently drilled to 1,821 m in January 2012. An artesian geothermal system was encountered at 1,745 m depth (Nielson et al., 2012; Armstrong et al., 2012). Geothermal fluid flowed to the surface at 0.65 L/s through NQ rod (60.3 mm ID), and was sampled after flowing for about 12 hours. The water flowing from the well head was clear and apparently free of drilling fluids. The DOSECC BHT tool indicated bottom hole temperatures ~150°C when the geothermal zone was encountered; while the well was flowing, a thermistor at 1,355 m recorded a temperature of 134.6°C. Later temperature logging indicated bottom hole temperatures of ~135-140°C (Nielson et al., 2012).

Sampling and Analysis of the Geothermal Water

Six water samples were collected from the flowing test well at Mountain Home about 12 hours after the flow was encountered. The six samples consisted of: (1) 60 mL of filtered and acidified water for ICP and chloride analysis of major ions and metals; (2) 50 mL of filtered but unacidified water for deuterium (D) and oxygen-18 (18-O) analysis; (3) 125 mL of unfiltered and unacidified water for carbon-13 (13-C) analysis;

(4) 1 L of unfiltered and unacidified water for tritium analysis; and (5) 250 mL of filtered and acidified water, and (6) 500 mL of unfiltered and unacidified water for duplicate analysis.

Sample (1) was analyzed by the Utah State University Analytical Laboratory for major ions and metals. The duplicate samples (5 and 6) were sent to Thermochem Labs (Santa Rosa, California) for elemental analysis, and were analyzed for trace metals and halides. The Thermochem samples were also analyzed for D and 18-O. The separate D and 18-O sample was analyzed by the Stable Isotope Ratio Facility for Environmental Research (SIRFER) at the University of Utah. The 13-C analysis (3) is being performed by Geochron Laboratories, a division of Krueger Enterprises, located in Billerica, MA, and the tritium sample (4) is being analyzed at Brigham Young University.

Temperature (the drillers reported that it was over 37°C after flowing for one hour), pH, electrical conductivity, salinity, and alkalinity were measured in the field at the time of sampling (Table 1). A Yellow Springs Instruments Model YSI 30 was used to measure temperature, conductivity, and salinity. An Orion Model 230A was used to measure pH. Alkalinity measurements were made within 20 mg/L using a Hach-Alkalinity Test Kit, Model AL-AP MG-L.

Results

Chemical analysis of the geothermal water (Table 1) shows that it is rich in sulfate relative to chloride and bicarbonate, and rich in sodium relative to calcium and magnesium (Figure 2).

Table 1. Field measurements and major ion chemistry of geothermal water from Mountain Home well MH-2B (all values in mg/L unless otherwise stated, except for pH which is in pH units).

Temperature (OC)	Conductivity (micro Siemens)	pH	Salinity (ppt)	Alkalinity (mg/L)	
31.3	870	9.59	0.4	100	
Ca	Mg	Na	K	Cl	SO4
8.71	0.16	288	9.02	74.8	477

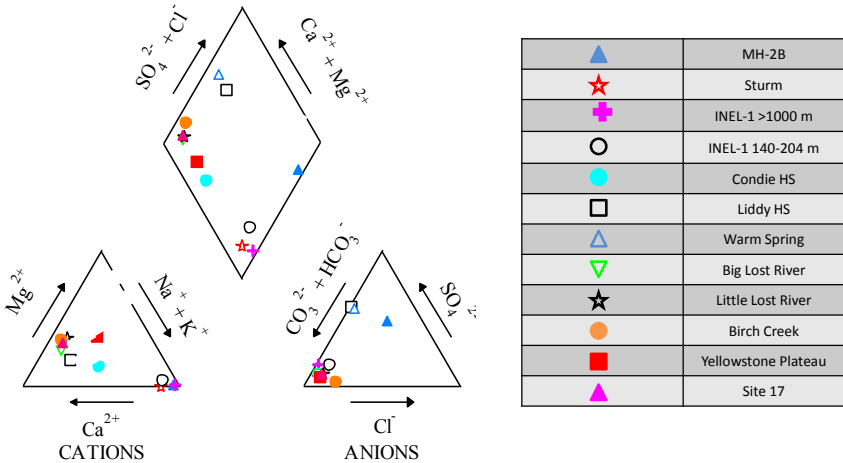


Figure 2. Piper plot of geothermal waters from Mountain Home well MH-2B and other geothermal systems.

While the relatively high sodium is consistent with other geothermal water from the SRP, the high sulfate is a unique anomaly. The calculated TDS content of the water is relatively low at only 1,120 mg/L, which is consistent with the low electrical conductivity (870 μ S). Deuterium and 18-O levels are -88 and -3.2 per mil, respectively.

Discussion

Preliminary geochemical results for geothermal water from the MH-2B test well indicate that the water has a high pH (9.59) and is relatively high in sulfate. This result suggests that the water is at equilibrium with the altered basalt at the measured temperature. High-temperature sulfides (pyrite) have been observed on fracture faces in the lower sections of the Mountain Home core, and this probably is the source of the sulfate.

Calculated equilibrium temperatures vary from ~132–138°C (quartz, Fournier and Potter, 1991), ~134°C (Na/K, Fournier, 1981), ~139°C (Na-K-Ca, Fournier, 1981), to ~154°C (Na/K, Giggenbach, 1988, 1991), and are consistent with the measured temperatures in the geothermal zone. This suggests that the system is at equilibrium, and that mixing with lower temperature shallow groundwater is negligible. The latter conclusion is supported by the heavy D and 18-O levels, which suggests that the water is old, is not meteoric, and/or has undergone significant fractionation.

Finally, the unique chemistry of the geothermal water will most likely be a boon to the development of this potential electric-grade resource. While the water is relatively high in sulfate and sodium, it is low in calcium, bicarbonate and chloride. This suggests that problems with encrustation and/or corrosion of piping will not be very serious. This supposition is supported by the relatively dilute nature of the water, as indicated by the low electrical conductivity (870 μ S) and low calculated TDS (1,120 mg/L).

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