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GEOTHERMAL DRILLING SUCCESS AT BLUE MOUNTAIN, NEVADA

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ABSTRACT

Exploration in a blind prospect has led to the confirmation of a geothermal resource at Blue Mt. Nevada. The latest results include drilling of three production wells into Piedmont faults. These wells produce from a 185 to 190ºC dilute benign brine reservoir. Short flow tests have shown prolific flow rates and indications of reservoir continuity.

Well entries have shown that system permeability is fault-dominated. This is confirmed by the results of seismic reflection imaging. Young faulting in the area includes intersecting range front faults that strike NW, NS, and NE. Exposure of basement rock outboard from the segmented range front reveals a long history of hydrothermal activity in this complex fault intersection zone.

The current conceptual model suggests that geothermal fluids equilibrate at up to 250ºC at depth in NE-trending Piedmont faults off the range front. Upflow feeds an artesian reservoir at 190ºC in the fault zone and then rises into a widespread shallow warm aquifer. Warm outflow mixes with meteoric water during flow into the basin. This shallow aquifer provided the initial evidence of the commercial temperature system.

INTRODUCTION

Mineral exploration holes drilled in an area of intense silicification and alteration near Quaternary dikes revealed a warm water aquifer near Blue Mt, Nevada (Figure 1) in the 1990s. Fluid chemical indicators from this aquifer encouraged Nevada Geothermal Power to explore the geothermal potential of the area (e.g. Fairbank and Ross, 1999 and Ross et al, 1999). Exploration work included temperature gradient holes, fluid geochemistry, two DOE-funded slim wells, full-sized exploration wells, and a seismic reflection survey.

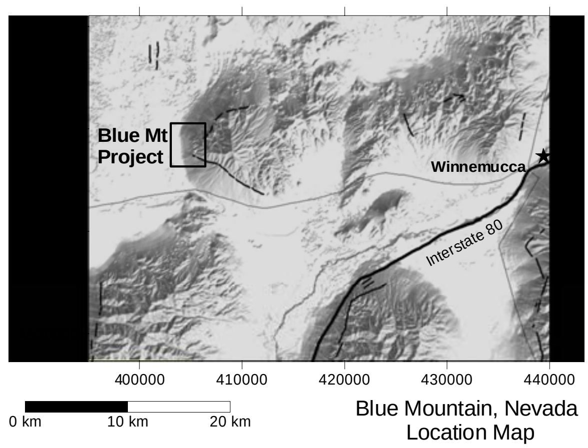

Figure 1. The black rectangle shows the location of the Blue Mt. project in NW Nevada on a background of shaded topography.

Current work is focused on continued production well drilling and resource evaluation. Plans include a thorough interference test and geomechanical studies of productive and unproductive wells in the project.

EXPLORATION WELLS

Following interpretation of the early exploration data, two slim wells were drilled with DOE support at DB1 and DB2 to 2115 and 3700 feet respectively (Figure 2) (Noramex, 2002 and Fairbank Eng., 2005). Together these wells generated thousands of feet of continuous core. These wells were targeted into faults projected below the shallow warm water aquifer that was revealed by temperature gradient holes. The two wells show measured temperatures up to 148 and 163ºC respectively. Although neither well would sustain flow, DB2 was stimulated to produce brine which provided high temperature geothermometry. The high temperature zone at DB2 is underlain by a mild but persistent reversal to TD.

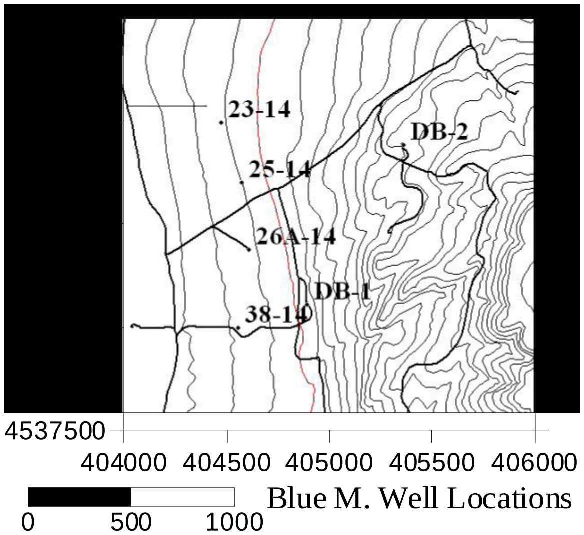

Figure 2. Well locations and roads at Blue Mt.

Four deep full-sized holes have been drilled at Blue Mt. into fault targets farther out from the range front. Three of these wells show prolific production of dilute neutral chloride brine at reservoir temperatures up to 190ºC. The other well was unproductive but only slightly cooler.

The discovery well, 26A-14, was drilled to 2830 feet total depth (TD) in 2006. The well was completed with 13 3/8" cemented casing to 1940 feet with the 12 1/4" hole at the bottom of the well left unlined (Hantelmann and Bailey, 2006). The productive entry in 26A-14 was associated with fault gouge observed in cuttings. The well has a shut-in WHP of 141 psi and has been flowed four times. It can produce about 7 MWe net, near the maximum productivity of a pumped geothermal well (Lovekin, 2006). The reservoir temperature in this well is about 186ºC. The high shut-in pressure reveals an artesian reservoir. The well flowed about 500 kph (thousands of pounds per hour) at 80 psig.

38-14 was drilled to 5426 feet in mid 2007. The well was targeted 1300 ft south of 26A-14 along the trend of a NNW-trending fault and near the intersection with a prominent NE-trending fault. This well showed a maximum temperature of 180ºC near 2600 feet depth before reversing to TD. The well also shows artesian shut-in pressure and when opened produces a trickle of water and gas.

23-14 was drilled 2000 ft. NNW of 26A-14 to 3415 feet TD (Casteel, 2007). The well was targeted outboard of the other wells in an area with a high temperature gradient. Drilling intersected an entry at greater depth and slightly higher temperature. This well shows prolific productivity from a reservoir at 191ºC and flowed more than 900 kph at 100 psig (Lovekin, 2007).

25-14 was recently completed to 2370 ft TD. Initial well tests show excellent flow rates and similar downhole temperatures.

During a two day flow test of 23-14 pressure interference was observed immediately in wellhead pressures at 26A-14. The interference confirms a direct connection between the wells. Implications for long term reservoir performance will be studied during a longer term, thoroughly instrumented interference test in the near future.

GEOCHEMISTRY

The wells produce dilute neutral Cl reservoir brine. Risks of abnormal scaling or high gas are not evident. Geothermometry from well samples shows a range of temperature estimates from near measured temperatures around 190ºC up to about 250ºC. The estimates are consistent between liquid and gas methods and show generally higher estimates for higher temperature wells and for slowly equilibrating geothermometers (Figure 3 and Table 1). Methane and carbon dioxide gas levels suggest equilibrium from Fisher-Tropsch reaction near 250ºC.

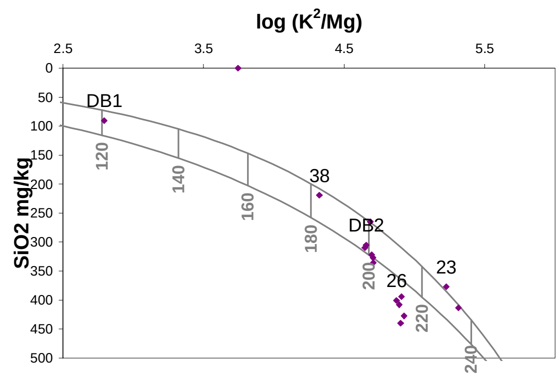

Figure 3. SiO2 and K/Mg geothermometers for wells 26A-14, 23-14, 16A-14, 38-14, DB2, and DB1. Plotting used Powell (2004)

FAULTS

Detailed mapping at Blue Mt by Szybinski (2004) in exposed Piedmont terrane showed faults with three main trends: NW, NS, and NE. Quaternary faults mapped in the area by the USGS and NBMG (2005) suggest that all three trends have young offset. Gravity data over buried Piedmont bocks show that the complex faulting mapped by Szybinski wraps around the NE side of the range underneath coalluvium (Figure 4).

Seismic reflection data across the faulted area were processed to allow interpretation of steep-dipping reflectors (Honjas et al., 1997).

Table 1. Temperatures and geothermometry in degrees Celcius for Blue Mt wells. Calculations used Powell (2004).

Well	T obs	Qtz	K Mg	Anhy drite	NaK Ca	CO2 Ar
DB1	148			173	199	
DB2	167	212	200	191	232	
38-14	182			203	223	
26A-14	186	236	211	223	232	246
23-14	191	232	232	212	249	243

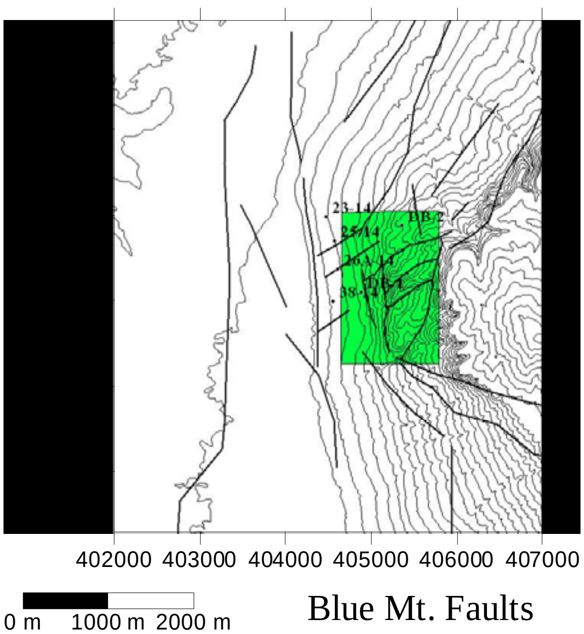

Figure 4. Fault interpretation from Szybinski (2004) in shaded area, USGS and NBMG (2005) at range front, and elsewhere from interpretation of gravity.

Seismic cross-sections were interpreted to show an 800 to 1000 m thick fault zone along the NW flank of Blue Mountain (e.g. Figure 5). Line to line correlation shows that the fault zone strikes N35E and dips 50ºNW. Secondary faults in the hanging wall appear steeper and create local graben and horst blocks. Optim (2007) noted that fault reflectors on correlate with productive wells. Closer inspection shows that reflections correlate with well entries and observed fault gouge in Piedmont faults on the basin side of the fault zone.

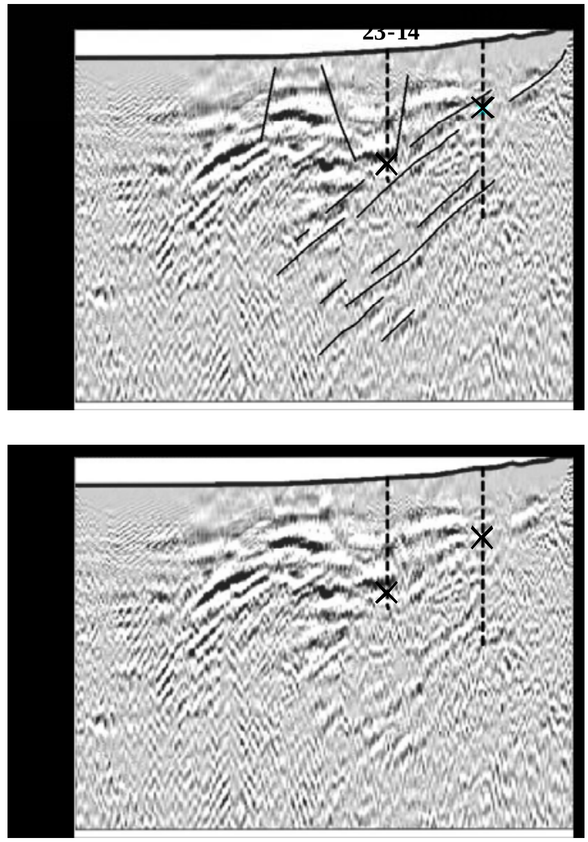

Figure 5. Seismic Images from Blue Mt. Data were processed by Optim (2007). The top image shows interpreted faults over the reflection cross-section, well projections, and entries (x). The bottom image is identical but without interpreted faults. No vertical exaggeration is shown. The prominent shallow nearly horizontal reflectors may be related to layering in imbricate-thrusted Mesozoic Singas formation. Well entries correlate directly with seismically- imaged faults in this and other cross-sections.

HYDROTHERMAL FLOW

A long history of hydrothermal activity occurred in the fault zone. Early activity produced alteration and intense silicification mapped in exposed Piedmont fault blocks. Silicification occurs in a nearly horizontal, NS-elongate area covering a square kilometer in the shaded area in Figure 4. This has been interpreted as a boiling zone (Syzbinski, 2004). Erosion through the silicified rock reveals underlying argillic alteration.

The hydrothermal system evident in the exposed mineralization was followed by current activity underlying much of the same area. The current system includes a widespread 60 to 80º C aquifer at depths of 300 to 1000 ft. as evident in temperature gradient and deep wells. Temperatures from 38-14 show a shallow section related to this aquifer (Figure 6).

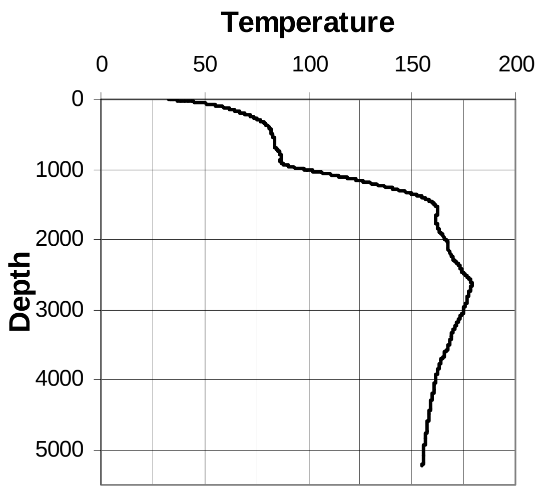

Figure 6. Static temperature profile for well 38-14. A shallow warm aquifer affects the temperature above 1000' depth.

Temperature gradients up to 400ºC/km (Blackwell, 2007) may be related to upflow in the shallow aquifer in two areas along the prominent NE-trending fault that was targeted by DB2. Argillic alteration is also extensive along this fault suggesting that both the active and older systems found permeability on NE-trending structures.

Mineralization also shows a thick set of steeply dipping chalcedony veins that are consistent for a half a mile along a NNW-trending fault adjacent to DB1 (Szybinski, 2004). This fault is associated with argillic alteration and dike emplacement and may have been permeable in the past.

The temperature profile of 38-14 in Figure 6 shows why this well is considered a candidate for redrill or recompletion. Although the existing completion shows very low permeability, the temperature profile suggests that the well lies close to or in the broader hydrothermal system.

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