GL04426

Geothermal Resources Council, TRANSACTIONS Vol. 5, October 1981

SOLID-SAMPLE GEOCHEMISTRY STUDY OF WESTERN DIXIE VALLEY, CHURCHILL COUNTY, NEVADA -- PART I, PETROCHEMISTRY

Elaine J. Bell[1] and Russell W. Juncal[2]

[1]Mackay School of Mines
Mackay Minerals Research Institute
University of Nevada
Reno, Nevada 89557

[2]Geothermal Development Associates
251 Ralston Street
Reno, Nevada 89503

Abstract

Numerous thermal springs present in northern Dixie Valley, Nevada, are the surface expression of a deep-seated geothermal system. The structural setting, a complex asymmetric graben possibly bifurcating to the north, controls the location of surface springs and migration of thermal fluids to the surface.

A large-scale surface soil geochemical survey for mercury and arsenic and petrochemical analysis for selected trace elements in subsurface samples from two deep exploratory wells allowed for identification of steam and hot water entries and delineation of associated geochemical zonations.

Data thus far indicate the Dixie Valley geothermal system is dynamic, with temperatures greater than 200°C at depths of 2500 m to 3000 m and access to thermal fluids controlled by structural and temporal parameters.

Introduction

The specific portion of the Dixie Valley geothermal prospect investigated for this study is bounded by the Stillwater Range and the Humboldt Salt Marsh on the west and east, respectively, and extends northward from Dixie Meadows to the Boyer Ranch (Figure 1). Two deep exploratory wells (DF 45-14, TD = 9022 ft; DF 66-21, TD = 9780 ft) had bottom hole temperatures approaching or exceeding 200°C (Denton and others, 1980).

Solid-sample geochemical investigations were undertaken to define the surface and subsurface distribution of hot water and/or steam and the associated geochemical zonations. The surface sampling was based on broad scale and detailed grid networks and traverse lines within a 77 Km^2 area, with 464 samples analyzed for mercury and arsenic. The soil geochemistry is presented in a companion paper (Juncal and Bell, this volume). Subsurface data were developed by analyzing whole rock and heavy mineral (+3.3) fraction samples for representative intervals (optimally 100-ft composites) within each well for lead, zinc, arsenic, antimony and mercury.

Geologic Setting

The regional stratigraphy is characterized by Mesozoic and younger lithologies. Upper Triassic

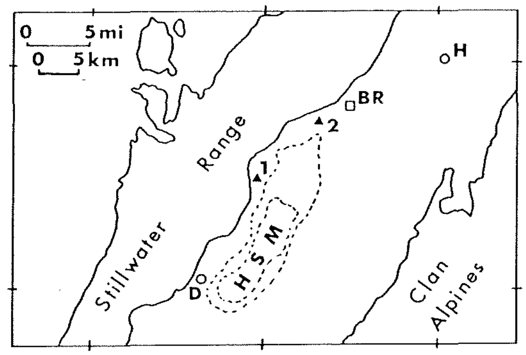

Figure 1. Location map of Northern Dixie Valley hot springs; BR=Boyer Ranch; H= Hyder Hot Springs; 1=DF 45-14; 2=DF 66-21; HSM=Humboldt Salt Marsh.

metasediments, mostly phyllite and slate, are estimated to be as much as 3000 m thick, with the base unexposed. Locally, this complexly deformed unit is overthrust by an upper Triassic massive limestone. The Jurassic metavolcanic sequence consists chiefly of fine-grained slaty andesite tuffs, breccias, and andesite flows, in excess of 1600 m thick. The Humboldt grabbroic complex (Humboldt Lopolith of Speed, 1976) includes intrusive phases of gabbroic to dioritic composition and extrusive basalt flows, tuffs and breccias. The Fencemaker thrust (Speed, 1976) transported Jurassic quartzites over lower Jurassic units. Four Jurassic to Miocene volcanic sequences 600 to 1300 m thick include acidic tuffs and breccias and basaltic andesite flows. The lower units are intruded by late Cretaceous granitic plutons which accentuated and coarsened the metamorphic fabric of the intruded units.

A widespread Miocene volcanic sequence, up to 1300 m thick, includes tuffs, breccias and flows ranging in composition from latite through rhyolite. Riehle and others (1972) have placed the Miocene volcanic center in the southern Clan Alpines.

Plio-Pleistocene to Recent deposits include lacustrine and fluvial sediments, locally interbedded with acidic ash, tuff, and flows. Pliocene basalt flows, up to 500 m aggregate thickness, are present in the lower portions of the sequence. Large alluvial fans extend from mountain canyons to coalesce and form alluvial plains. The valley floor is dominated by a large playa and the Humboldt Salt Marsh which serves as a regional drainage sink. A lake contemporaneous with but separate from Pleistocene Lake Lahontan reached an estimated depth of 73 m, with remnant shorelines, bars and delta deposits locally preserved. Moderately to poorly developed arid soils reflect the geographic position of these young surfaces.

The structural complexity of Dixie Valley is a product of late Cenozoic faulting superimposed on older geologic relationships. Figure 2 depicts a structural model of northern Dixie Valley indicating the various tectonic elements, including major basement faults and Basin-and-Range normal and arcuate faults. Additionally, a northeast trending graben is probably present just south of the Tobin Range. These faults are still active as evidenced by seismicity and surficial geomorphic expression in Holocene age alluvial deposits (Whitney, 1980). Recent seismic activity includes not only microseismic events but also a major earthquake in 1954 of M = 6.8 that produced up to 3 m of vertical offset. High heat flow values up to 3 HFU (Sass and others, 1971), maximum focal depths of approximately 16 km, a relatively thin crust (16-18 km; Smith, 1978) and high rates of crustal extension (0.4 mm/yr; Thompson and Burke, 1973) characterize Dixie Valley.

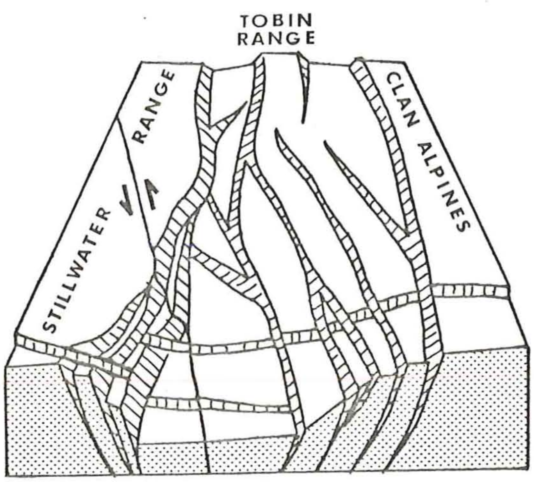

Figure 2. Structural model of northern Dixie Valley, with alluvium removed and bedrock surfaces restored (from Whitney, 1980).

Petrochemistry

Lead (Pb), zinc (Zn), arsenic (As), mercury (Hg) and antimony (Sb) concentrations within whole rock and, in particular, heavy mineral fractions were examined as indicators of activity of the geothermal system encountered by wells DF 45-14 and DF 66-21. Specific values and depth intervals are given in Denton and others (1980, App. F-2, p. 85-88). Trace element data were compared with temperature, depth, mineralogy, lithology and known or inferred fracture systems.

The reservoir, self-sealed and peripheral zone concepts of Bamford and others (1980) can be applied to the distribution of trace elements and known physical parameters of the wells. Statistical bivariate scattergram analyses were used to distinguish zone depths. Figure 3 depicts reservoir zoning models for DF 45-14 and DF 66-21.

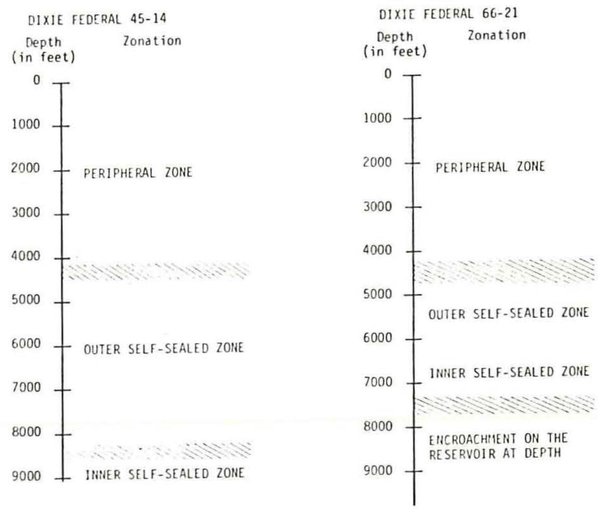

Figure 3. Reservoir zoning model for DF 45-14 and DF 66-21.

In DF 45-14, a peripheral zone is characterized by low Pb and Zn values, with As, Sb and Hg concentrations associated with a localized self-sealed zone. The self-sealed zone is characterized by high Pb concentrations with Zn. Arsenic is high but decreases somewhat with depth as Sb increases; Hg increases with depth. A transitional boundary from outer to inner self-sealed zone is defined by As and Sb enrichment; Pb and Zn remain fairly constant.

In DF 66-21, the peripheral zone is characterized by low Pb and constant concentrations of Zn, As, Sb and Hg. Mercury, zinc, and arsenic concentrations characterize the outer self-sealed zone with broad gradation to an inner self-sealed zone in which Hg and As increase somewhat and Zn remains fairly constant. Encroachment on the reservoir zone at depth is evidenced by a general increase in Hg, high As and Pb, and significant concentrations of Zn. Active and self-sealed fractures are present within the self-sealed zones of both wells.

In contrast, anomalous concentrations of these trace elements as determined by the use of log probability graphs exhibit a distinctly different distribution with depth in each well. Comparison of the anomalous trace element values with mineral occurrences and selected physical parameters of the wells are depicted as composite logs in Figures 4 and 5.

The pyrite dominated portion of DF 45-14 reflects the pervasive influence of the geothermal system, with intervals characterized secondarily by epidote and/or barite(?) correlating with fractures and indicating localized intense hydrothermal activity associated with the fracture systems. The 400- to 1600-foot interval is characterized by high

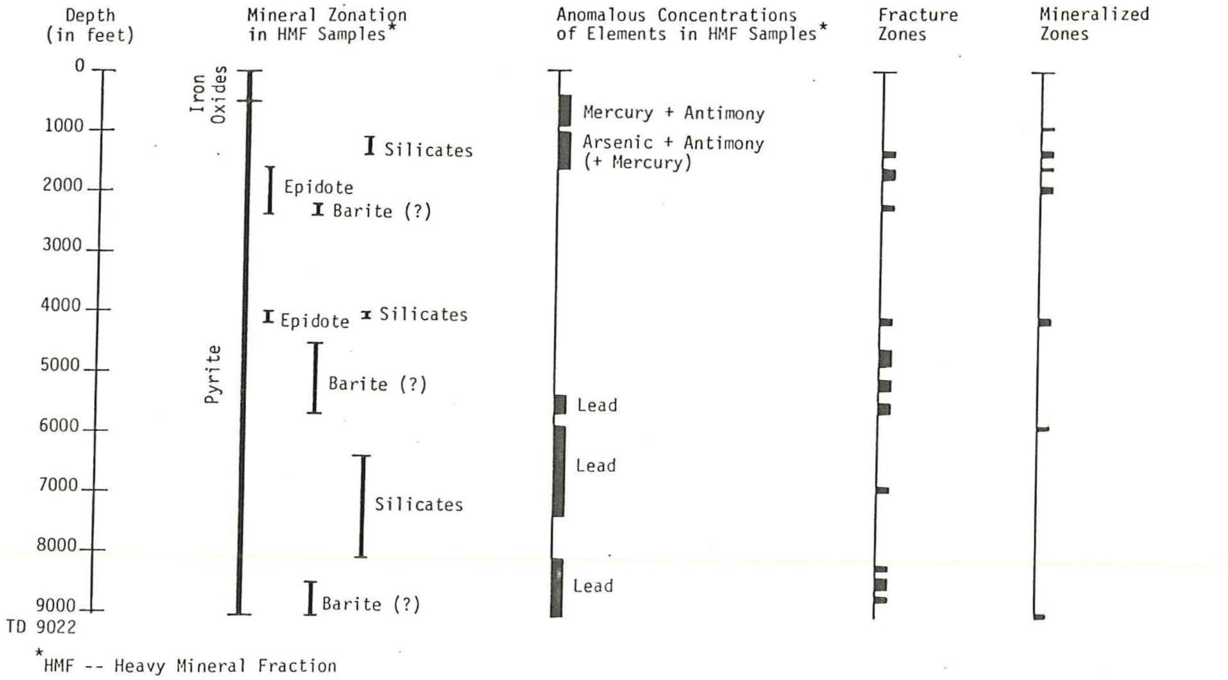

Figure 4. Composite of logs for DF 45-14 indicating selected physical parameters, mineral occurrences and anomalous element concentrations in heavy mineral fraction samples.

As (1800-4500 ppm) concentrations and an overlying halo of high Hg (2.3-14.2 ppm) concentration, with Sb (88-586 ppm) fairly uniformly distributed throughout the interval. This interval is a product of fracture-controlled permeability with fluids migrating from depth through fractures associated with tuffaceous units between 1300 and 1800 feet. The anomalous concentrations of Pb in three intervals (700, 700-1500, and 1000-2200 ppm) in the lower portions of the well are interpreted as lead halos overlying the reservoir at depth and are in association with barite(?) in fracture zones in these intervals. The magnitude of the Pb anomalies suggests development over a relatively long time period, with possible secondary enrichment by halo migration toward the heat source as it cooled or by fluid migration through fracture zones within the interval from 8100 to 9022 feet. The degree of cementation and fracture-filling within most fault zones and fractures encountered in the well above 8100 feet is indicative of significant decrease in connection with the reservoir at depth.

DF 66-21, however, is interpreted as a more dynamic system with significant connections with the reservoir and a developing geochemical signature. Anomalous Pb (2500 ppm) and Hg (9ppm) concentrations from 2200 to 2400 feet are associated with the low permeability boundary at the top of a red clay-alluvial sequence; the source of the lead and mercury is uncertain. From the lowermost portion of the clay-alluvial sequence to total depth, the rocks show an increasingly pervasive influence of the geothermal system: silicate minerals (primarily epidote) with minor pyrite are replaced by a pyrite dominated assemblage. A major fault zone between 4800 and 5400 feet is marked by a Zn anomaly (10,800 ppm) in the most active portion of the fault zone where, during drilling, hot fluids under high pressure were encountered. The most significant indication of mineralization in this interval is the presence of flakes of native gold in the heavy mineral fraction. A halo of Hg (6.3 to 39 ppm) overlies the fault zone, the result of adsorption of mercury on the low permeability clays. The lower portion of the well is marked by four zones of anomalous trace element concentrations, each a result of active fluid migration through a fracture system. The range of concentrations for lead (4000 to 11,500 ppm), zinc (250 to 10,800 ppm), and mercury (3.2 to 39 ppm) is believed related to possible variations in fluid compositions and may also reflect the significance of the fracture zone as a conduit.

Discussion

The reservoir zoning and petrochemical analysis techniques generate models of the two deep wells that are generally consistent and significant with respect to developing an understanding of the history of the Dixie Valley Geothermal System. In general, DF 45-14 represents a longer history of geothermal activity: the reservoir zones are more distinct and extend over larger depth intervals; self-sealing is more complete; a halo of anomalous lead concentrations has developed in the lower portions of the well that, while it may be secondarily enriched by fracture-controlled fluids, is a pervasive concentration; and fluid migration through fracture systems is limited. DF 66-21 exhibits a younger, more dynamic history of geothermal activity: while the peripheral zone is well defined, the self-

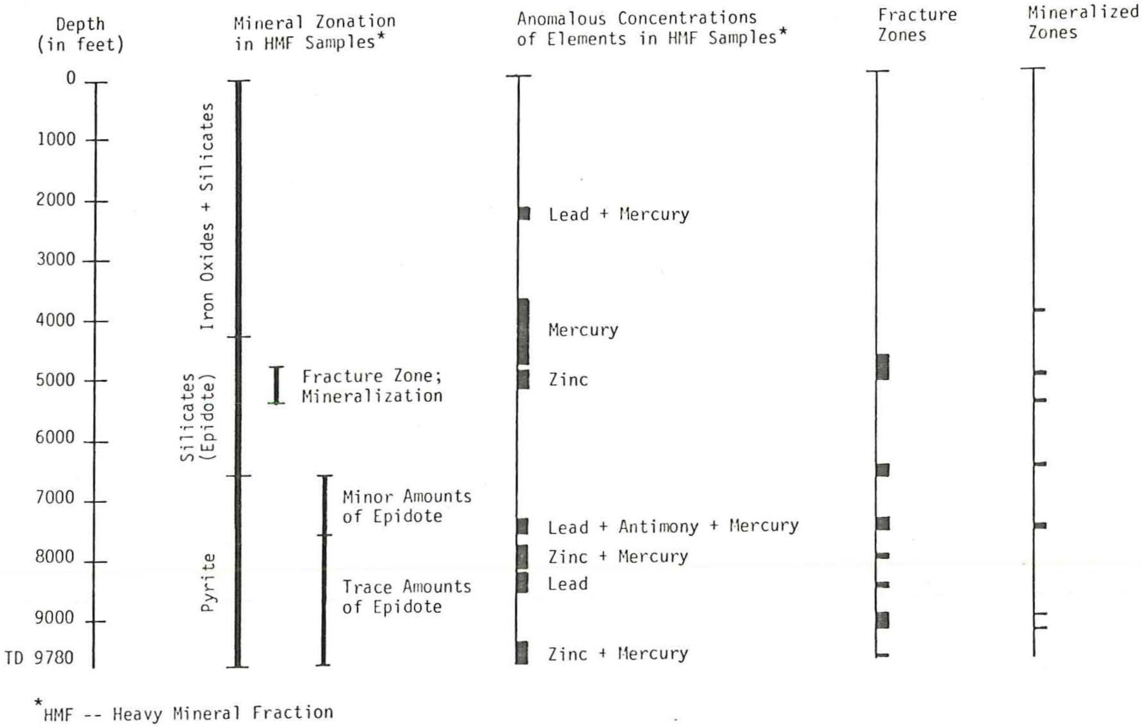

Figure 5. Composite of logs for DF 66-21 indicating selected physical parameters and the mineral occurrences and anomalous concentrations of elements in heavy mineral fraction samples.

sealed zone extends over a relatively narrow depth interval and has not yet developed geochemical signatures which differentiate well-defined outer and inner self-sealed zones; the inner self-sealed zone encroaches on the reservoir at depth; fracture zones are generally not self-sealed and actively conduct significant volumes of thermal fluids; and anomalous trace element concentrations exist in fairly narrow intervals associated primarily with active fracture systems.

References

Bamford, R.W., Christensen, O.D., and Capauno, R. M., 1980, Multielement geochemistry of solid material in geothermal systems and its applications, Part I: The hot-water system at the Roosevelt Hot Springs KGRA, Utah: Univ. Utah Res. Inst., Earth Sciences Lab. Rept. 30, DOE contract DE-AC03-79ET27002, 168 p.

Denton, J.M., Bell, E.J., and Jodry, R.L., 1980, Geothermal reservoir assessment case study--northern Dixie Valley, Nevada: Final Report: Report prepared for U.S. Dept. of Energy, DOE/ET/27006-1, NTIS.

Riehle, J.R., McKee, E.H., and Speed, R.C., 1972, Tertiary volcanic centers, west-central Nevada: Geol. Soc. America Bull., v. 83, p. 1383-1396.

Sass, J.H., Lachenbruch, A.H., Monroe, R.J., Greene, G.W., and Moses, T.J., Jr., 1971, Heat flow in the western United States: Jour. Geophys. Res., v. 76, p. 6376-6413.

Smith, R.B., 1978, Seismicity, crustal structure, and intraplate tectonics of the interior of the western Cordillera, in Smith, R.B., and Eaton, G.P., Cenozoic tectonics and regional geophysics of the western Cordillera: Geol. Soc. America Mem. 152, p. 111-144.

Speed, R.C., 1976, Geologic map of the Humboldt Lopolith and surrounding terrane, Nevada: Geol. Soc. America Map MC-14, 4 p.

Thompson, G.A., and Burke, D.B., 1973, Rate and direction of spreading in Dixie Valley, Basin and Range Province, Nevada: Geol. Soc. America Bull., v. 84, p. 627-632.

Whitney, R.A., 1980, Structural-tectonic analysis, in Denton, J.M., Bell, E.J. and Jodry, R.L., 1980, Geothermal Reservoir assessment case study--northern Dixie Valley, Nevada: Final Report: Report prepared for U.S. Dept. of Energy, DOE/ET/27006-1, NTIS.

Acknowledgement

Support for this work was provided by Southland Royalty Company under U.S. Department of Energy contract DE-AC08-79ET27006.