Geothermal Resources Council, TRANSACTIONS Vol. 5, October 1981

EVALUATION OF THE MERCURY SOIL MAPPING GEOTHERMAL EXPLORATION TECHNIQUES

J. S. Matlick,* M. Shiraki**

*Republic Geothermal, Inc.
**Idemitsu Geothermal Co., Ltd.

ABSTRACT

In order to evaluate the suitability of the soil mercury geochemical survey as a geothermal exploration technique, soil concentrations of mercury are compared to the distribution of measured geothermal gradients at Dixie Valley, Nevada; Roosevelt Hot Springs, Utah; and Noya, Japan. Zones containing high-mercury values are found to closely correspond to high geothermal gradient zones in all three areas. Moreover, the highest mercury values within the anomalies are found near the wells with the highest geothermal gradient. Such close correspondence between soil concentrations of mercury and high-measured geothermal gradients strongly suggests that relatively low-cost soil mercury geochemical sampling can be effective in identifying drilling targets within high-temperature areas.

Introduction

Several workers (Matlick and Buseck, 1976; Phelps and Buseck, 1978; Capuano and Bamford, 1978) have illustrated that anomalously high-mercury (Hg) concentrations exist in soils that overlie high-temperature geothermal systems, and that the Hg soil mapping survey could successfully be utilized as a geothermal exploration technique. Although all of these previous studies convincingly demonstrate that Hg anomalies and geothermal activity coincide, these earlier workers were not able to compare their Hg soil mapping results with the results of thermal gradient surveys, the most widely accepted positive indicator of a geothermal resource (Ward et al., 1981). This report compares thermal gradient anomalies with Hg soil anomalies at two areas in the USA (northern Dixie Valley, Nevada; Roosevelt Hot Springs, Utah) and one in Noya, Japan. In these areas it is possible to evaluate the applicability of the Hg soil mapping technique in widely differing types of geology and geothermal activity.

Northern Dixie Valley, Nevada

Northern Dixie Valley, located approximately 75 miles northeast of Reno, is bounded by the Stillwater Range to the west and the Clan Alpine Mountains to the east. The valley appears to be a complex asymmetric graben containing recent alluvial deposits whose known maximum thickness exceeds 5,000 feet. The mountain ranges (developed on upfaulted horsts) contain basalt, tuff, gabbro, metasediments, and metavolcanic rocks. Recent geological events in the area include large magnitude earthquakes in 1903, 1915, and 1954. Faulting associated with these earthquakes has exposed highly altered rocks along the range front. Additional geothermal manifestations include active hot springs, active fumaroles, silica sinter deposits, travertine mounds, and active sulfur deposition.

The Hg concentrations in northern Dixie Valley soils (Runcal, 1980) range from 8 to 1,720 ppb (Figure 1). Frequency distribution calculation of the Hg concentrations indicates a background value of 20 ppb. The 120 ppb Hg contour outlines one major and one minor Hg anomaly. The major Hg anomaly, which covers approximately two square miles, has a peak-to-background ratio of 43:1.

Temperature gradient surveys, situated in and near the Republic Geothermal, Inc. (RGI) "Lamb Ranch" lease block, indicate the existence of a NW-SE trending thermal gradient ridge (Figure 2). Thermal gradients measured in six holes whose depths range from 300 to 1,850 feet are between 5.1°F and 13.0°F/100 feet. The deepest hole, RGI's RDV-7, illustrates the normal, near-surface, conductive-type gradient (Figure 3) encountered in all six holes. This hole's gradient (10.1°F/100 feet) and bottom-hole temperature (300.2°F) confirm that the prospect is a valid high-temperature geothermal area.

Northern Dixie Valley Hg and temperature gradient data exhibit a positive correlation. The major Hg anomaly coincides with the thermal gradient ridge. Further examination reveals that the highest reported Hg value (1,720 ppb) occurs near the highest gradient (13.0°F/100 feet).

Roosevelt Hot Springs KGRA, Utah

The Roosevelt Hot Springs KGRA is situated on the western flank of the Mineral Mountains approximately ten miles northeast of Milford, Utah. Locally, alluvium mantles Tertiary granitic rock and Precambrian gneiss. A proven high-temperature (>500°F), liquid-dominated geothermal system, which appears to be structurally controlled by northerly trending faults, exists beneath the KGRA. Surface geothermal manifestations include silica sinter and extinct hot springs.

FIGURE 1
MERCURY SOIL CONCENTRATIONS (ppb) IN NORTHERN DIXIE VALLEY, NEVADA (AFTER RUNCAL, 1980)

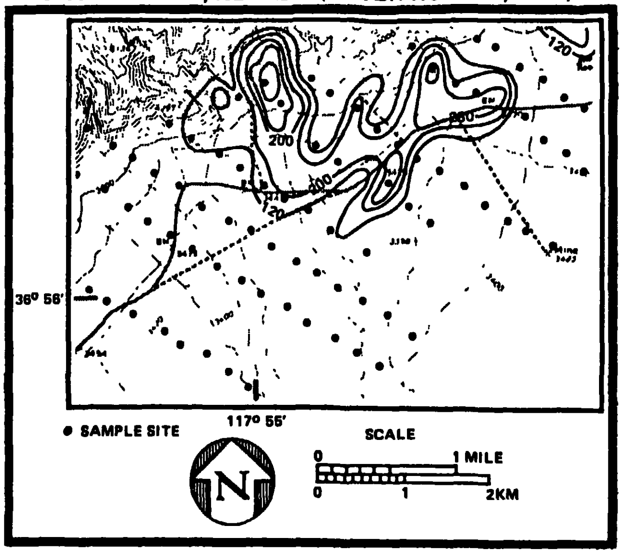


FIGURE 2
NORTHERN DIXIE VALLEY, NEVADA
TEMPERATURE GRADIENTS (°F/100')

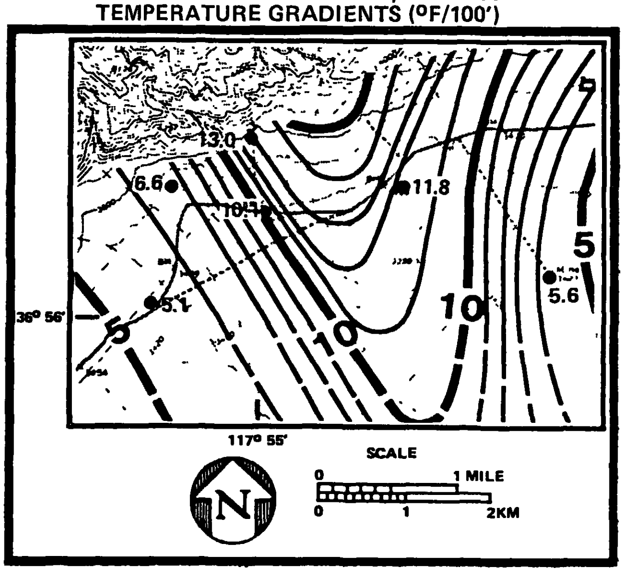
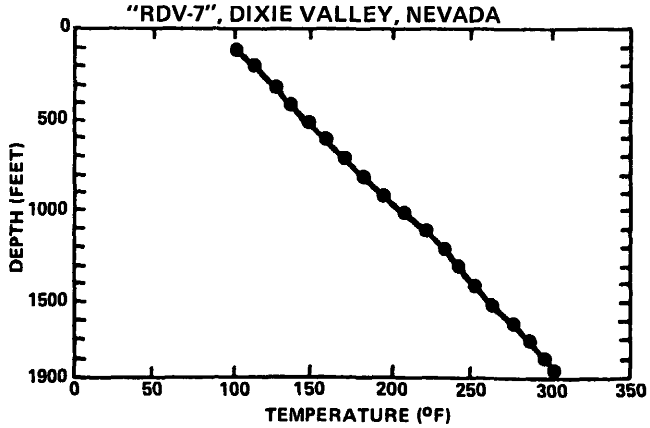


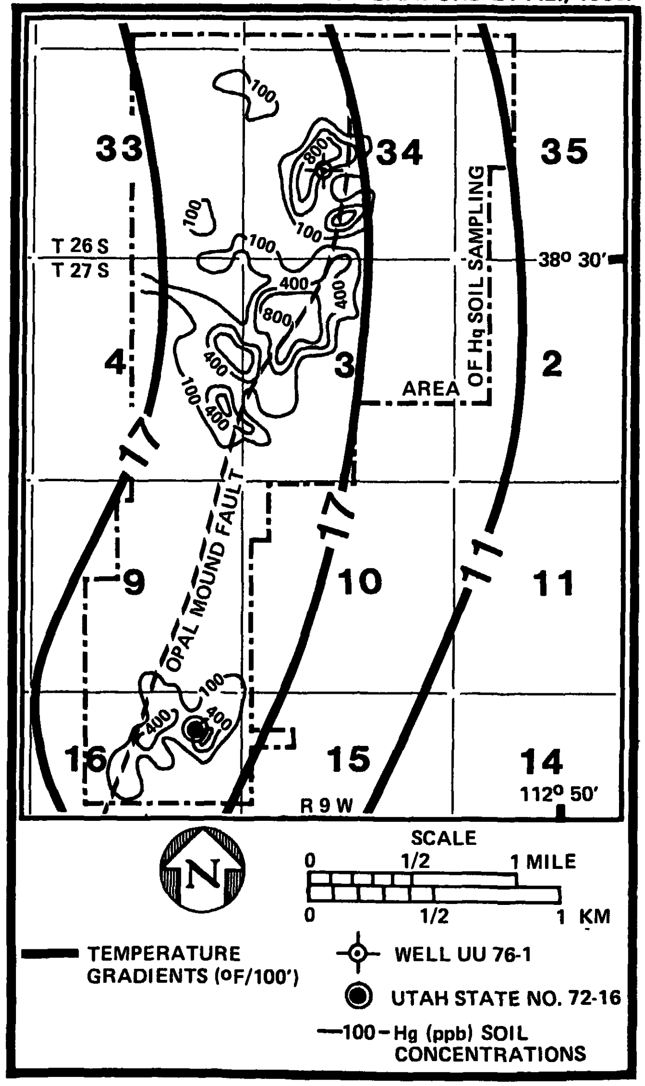
FIGURE 3
SUBSURFACE TEMPERATURES
IN REPUBLIC GEOTHERMAL'S
"RDV-7", DIXIE VALLEY, NEVADA



Hg soil mapping at Roosevelt Hot Springs (Bamford et al., 1980), though limited to the Opal Mound fault area, reveals highly anomalous concentrations of Hg. Hg soil values exceed 3,200 ppb with a calculated background value of 29 ppb. Two separate Hg anomalies occur along the Opal Mound fault (Figure 4). The southern anomaly is located in the Opal Mound silica sinter deposit area, and the larger Hg anomaly is sited at the mouth of Negro Mag Wash, where it appears to be located near fault intersections.

Thermal gradient data from 39 holes (Sill and Bodell, 1977) reveal that the thermal gradient anomalies in the Roosevelt Hot Springs KGRA are also aligned along the Opal Mound fault and decrease rapidly to the east and west of the fault. The temperature gradients at 330 feet below the surface range from 1.2°F to 23.2°F/100 feet. Figure 4 shows that temperature gradients in the

FIGURE 4
TEMPERATURE GRADIENTS (°F/100')
AND MERCURY SOIL CONCENTRATIONS (ppb)
AT ROOSEVELT HOT SPRINGS, UTAH. TEMPERATURE GRADIENTS FROM SILL AND BODELL, 1977. MERCURY SOIL CONCENTRATIONS FROM BAMFORD ET AL., 1980.



Hg soil sampling area along the Opal Mound fault exceed 17°F/100 feet.

The Hg soil anomalies occur entirely within the higher gradient area. The northern Hg anomaly coincides with hole UU 76-1 which has the hottest measured temperature (Sill and Bodell, 1977). Utah State #72-16, a 1,254-foot-deep well, produces a total mass flow of 1 million pounds/hour with a wellhead temperature of 432°F within the southern Hg anomaly.

<u>Noya, Japan</u>

The Noya geothermal prospect is located on the southern Japanese island of Kyushu in a large graben filled with Neogene volcanics and volcanic-derived sediments. Several recently active volcanoes, including Kuju and Tsurumidake, exist in the immediate area. Geothermal manifestations within the Noya prospect comprise hydrothermally altered rocks and two shallow (~150-foot) wells that vent steam.

The Noya Hg concentrations range from 4 to 1,000 ppb with a background value near 25 ppb (Shiraki, 1980). The Hg values outline an anomalous area that covers approximately five square miles (Figure 5). This anomaly contains ten soil samples whose Hg concentrations exceed a 4:1 peak-to-background ratio.

Thermal gradients at 500 feet below the surface range between 0°F and 32.8°F/100 feet in nine temperature gradient holes drilled at Noya by Idemitsu Geothermal Co., Ltd. The gradient contours outline a comma-shaped anomalous area (Figure 6), and five of the nine gradients within this anomaly exceed 8.0°F/100 feet. The highest absolute temperature recorded in the Noya holes is 351°F at a subsurface depth of 2,300 feet (Shiraki, 1980).

The Noya Hg anomaly directly overlies the Noya thermal gradient anomaly. The shapes of both Noya anomalies appear to be similar with a main NNE-SSW axis and a protrusion to the south. The highest Hg soil concentrations occur in the highest thermal gradient area. It is important to note that both of the Noya shallow steam wells are also sited within the highest Hg value contours.

<u>Discussions and Conclusions</u>

In all three study areas, Hg anomalies that exceed the background Hg value by a ratio of 4:1 were detected. The highest observed Hg peak-to-background ratio was 110:1 at Roosevelt Hot Springs KGRA. The existence of such Hg anomalies in geothermal areas is consistent with and supports the conclusions of Matlick and Buseck (1976).

Subsurface temperature measurements indicate that anomalously high thermal gradients exist in all three areas. Subsurface static temperatures exceeding 300°F indicate that high-temperature geothermal systems exist within all three areas.

FIGURE 5
MERCURY SOIL CONCENTRATIONS AT NOYA, JAPAN

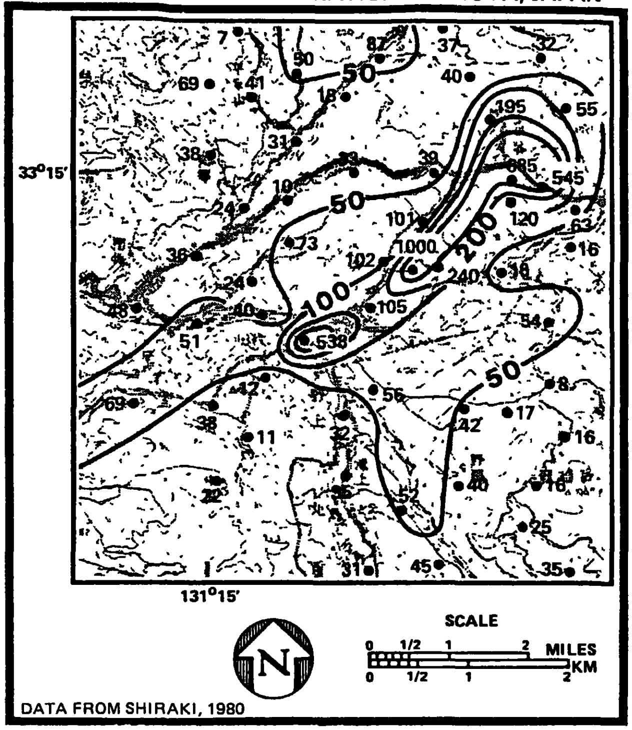
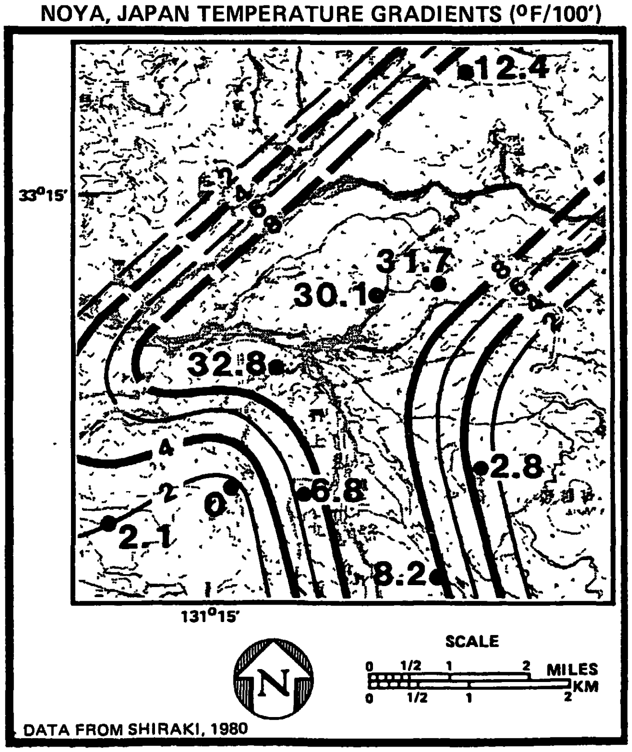


FIGURE 6
NOYA, JAPAN TEMPERATURE GRADIENTS (°F/100')



The Hg and thermal gradient anomalies in all three areas always overlap, with the highest Hg soil concentrations occurring near the highest measured gradient.

The coincidence of Hg soil anomalies and high thermal gradients, combined with low survey costs, appears to make Hg soil mapping a very cost-effective geothermal exploration method.

It should, however, be noted that minor variations in sampling and analytical procedures can severely affect the outcome of Hg soil mapping surveys; therefore, the services of a qualified field geochemist are required to insure success.

References

Bamford, R.W., Christensen, O.D., and Capuano, R.M., 1980, Multielement geochemistry of solid material in geothermal systems and its applications: U.S. Dept. of Energy, DOE/ET/27002-7, 168 p.

Capuano, R.M., and Bamford, R.W., 1978, Initial investigations of soil mercury geochemistry as an aid to drill site selection in geothermal systems: Univ. Utah Research Inst., Earth Science Laboratory Report IDO/78-1701-b. 3.3, 32 p.

Matlick, J.S. III, and Buseck, P.R., 1976, Exploration for geothermal areas using mercury: a new geochemical technique, in Proc. 2nd U.N. Symposium on Development and Use of Geothermal Resources, Pezzotti, C., ed.: U.S. Govt Printing Office, v. 1, p. 785-792.

Phelps, D.W., and Buseck, P.R., 1978, Natural concentrations of Hg in the Yellowstone and Coso geothermal fields: Geothermal Resources Council, Transactions, v. 2, p. 521-522.

Runcal, R.W., 1980, Mercury and arsenic soil geochemistry: Geothermal Reservoir Assessment Case Study, Northern Basin and Range Province, Northern Dixie Valley, Nevada, Mackay Mineral Research Inst., v. III.

Shiraki, M., 1980, Idemitsu Geothermal Co., Ltd., personal communication.

Sill, W.R., and Bodell, J., 1977, Thermal gradients and heat flow at Roosevelt Hot Springs: Univ. Utah, Dept. of Geol. and Geoph., Tech. Report 77-3, 46 p.

Ward, S.H., Ross, H.P., and Nielson, D.L., 1981, Exploration strategy for high-temperature hydrothermal systems in Basin and Range Province: AAPG, v. 65-1, p. 86-102.