SELF-POTENTIAL SURVEY

McGREGOR RANGE
FORT BLISS MILITARY RESERVATION
NEW MEXICO

by

Howard P. Ross and James C. Witcher

completed for

Southwest Technology Development Institute
New Mexico State University

Earth Sciences and Resources Institute
University of Utah
Salt Lake City, Utah 84108

May 12, 1995

SUMMARY

A self-potential (SP) geophysical survey was carried out in the McGregor Range and Meyers Small Arms Range areas of the Fort Bliss Military Reservation in April 1995. The survey was completed as one part of an integrated geothermal exploration effort being undertaken by Fort Bliss (Department of the Army), New Mexico State University and the University of Texas-El Paso.

Two areas of approximately 4 km^2 each were covered in detail, and these were tied together by a 2 km long tie line. Three significant SP anomalies were identified which lie along the higher temperature-gradient trend within the Hueco Tanks geothermal area, as mapped from existing drill hole information (James Witcher, personal communication). The anomalies may result from upflow zones of thermal fluids, but other explanations are possible. The anomalous areas are considered good target areas for further testing by electrical resistivity profiles or shallow thermal gradient drilling. If a positive relationship between these anomalies and thermal fluid upflow zones is established, it may be desirable to expand the SP survey to include other promising areas identified by geologic and geochemical studies but not covered by this initial SP survey.

INTRODUCTION

An extensive low- to moderate-temperature geothermal resource, known as the Hueco Tanks geothermal area, occurs in the southern Tularosa basin, about 20 to 25 miles (32 to 40 km) northeast of El Paso, Texas. The resource area occurs on the Fort Bliss Military Reservation. Shallow wells with observed temperatures of 30-71°C and high temperature gradients (NOAA and NMEI, 1980; NOAA and TBEG,1982) occur over a large area in a north-south orientation.

The U.S. Army Air Defense Artillery Center and Fort Bliss, Directorate of Public Works and Logistics, El Paso, Texas are sponsoring studies by the New Mexico State University (NMSU) and the University of Texas-El Paso (UTEP) to evaluate the geothermal potential and possible utilization of this geothermal resource. NMSU entered into a subcontract with the Earth Sciences and Resources Institute, University of Utah (ESRI/UU) to undertake self-potential (SP) surveys to assist in identifying areas of higher-temperature geothermal fluids.

SELF-POTENTIAL (SP) SURVEY

The self-potential (SP) method is an established geophysical technique which measures naturally occurring voltage differences at the surface of the earth. It was first used for mineral exploration in Europe in the 1800's. SP has been used increasingly for engineering, hydrologic, environmental, and geothermal applications since the early 1970's (Corwin, 1990). The

application of the SP method in geothermal exploration has been described in detail by Corwin and Hoover (1979). SP anomalies are generated by electrokinetic (moving fluids) and thermoelectric phenomena. The polarity and magnitude of the anomalies are determined by the source mechanism, depth to the source area, the electrical resistivity of the fluids, reservoir, and overburden, and cross-coupling coefficients.

Self-potential surveys have been very successful in locating geothermal fluid upflow zones, especially when these fluids rise within 1,000 ft (300 m) of the ground surface (Ross et al., 1990; 1991; Ross and Witcher, 1992). The method has a low environmental impact, requiring only the digging of small holes for the porous pot electrodes, and walking across the terrain. The surveys are often employed to define areas of interest that will later be tested with more costly geophysical methods, such as electrical resistivity, or thermal gradient drill testing.

Fort Bliss SP Surveys

Self-potential surveys were completed on Fort Bliss from 10 April to 21 April, 1995. The work was completed by a two-man crew, Howard Ross (ESRI/UU) and James Witcher (NMSU). Two areas of approximately 4 km^2 each were initially surveyed in a reconnaissance mode, and then connected with a 2 km long tie line to provide a common reference potential and some fill-in between the areas. The two areas are near Davis Dome on the McGregor Range and the northern part of the Meyer Small Arms Range (Figure 1). Approximately 490 stations were measured along 85,500 line feet (26.1 line-km) in an area of about 3.5 mi^2 (9.0 km^2).

In the reconnaissance mode, profiles up to 4,200 feet (1,280 m) long were measured from a central base station, using a station spacing of 200 feet (60 m). The survey was completed using a high-impedance digital voltmeter and copper-copper sulfate porous pot electrodes connected by a spooled, 4,260 ft (1,300 m) light weight single-conductor wire. A basic radial or "spoke" survey technique was used so that many potential measurements could be made directly with respect to a stationary electrode at the base station. Additional base stations were established to extend the survey and additional lines with a reduced station spacing (100 ft; 30 m) were used to provide more detailed coverage of the more interesting SP anomalies.

Electrode holes were dug 10 to 30 cm deep in the local sands to access continuous soil moisture. Holes were moistened with a small amount of water while laying out the line, and voltages were read on the return after infiltration voltages became very small. SP voltages were generally read to 0.1 mV, and after drift corrections and base station adjustments, are reported to 1 mV.

Significant noise levels (0.5 to 2.0 mV) were observed near grounded power lines (i.e. east of Davis Dome) and communications facilities. Rather poor repeatability (+/- 8 mV) was noted for several stations near and west of B.S.#1, when referenced to B.S.#1, when repeat measurement were made. The reason for these poor repeat measurements in not known. It did not appear to be due to telluric currents or variable infiltration potentials, but rather from varying

base level values in this vicinity. The entire SP survey was conducted in an active area of Fort Bliss, and numerous grounded power lines are present. Normal avoidance measures were followed for individual grounded power and communication poles, but a varying amplitude of ground return currents may be present over larger areas. The overall quality of the SP survey and its results are not significantly compromised.

All SP values have been referenced to an assigned zero (0 mV) value at Base Station (B.S.#1), located about 2,500 feet west of Davis Dome in an area without power lines or known grounded structures. The location of all base stations used for reference electrode positions, are shown on Figure 1. Base station values with respect to B.S.#1 were established by direct measurement or multiple tie points. These values are: B.S.#2, -6 mV; B.S.#3, +25 mV; and B.S.#4, -43 mV. All SP values were corrected for electrode drift which was determined after each survey line. Survey position control was achieved using a 200 foot (60 m) chain and Brunton compass to determine position and bearing from numerous road intersections, hills, and base facilities.

SP Results

The survey results are shown in Figure 1 as a contoured map of SP voltages, expressed in mV. Moderate positive values (+20 to +40 mV) with little station-to-station variation are observed at the western and southeastern survey limits, suggesting that the regional background level may vary, and that the 0 mV level assigned to B.S.#1 is within a relatively low (below background) area. There is substantial variability at the +/- 10 mV level within parts of the survey area while many areas are fairly flat with only a few mV variability. Topography is very flat and soil conditions are quite uniform in much of the survey area. Three significant anomalies have been defined, and are shown in more detail on Figures 2 and 3.

Anomaly sp-1 is a broad, well-defined anomaly located about 3,500 feet (1,070 m) northwest of Davis Dome and east of the main McGregor Range base complex. Several values of -50 to -54 mV were recorded in the center of the anomaly while completing detailed (100 ft; 30 m) verification of the anomaly. There is an east-west elongation of the anomaly. The anomaly appears to be independent of grounded power poles and a fenced and energized enclosure east of the anomaly center. The SP source area appears to be up hydrologic gradient from one of the hottest wells in the area. The profiles across the anomaly are generally too variable to provide reliable depth estimates, but simple depth estimates for some of the smoother profiles suggest depths in the 200-400 ft (60-120 m) range. This anomaly could arise from upflowing thermal fluids, and should be tested with electrical resistivity and/or temperature gradient drilling.

Anomaly sp-2 is a smaller anomaly (1,000 ft; 300 m long) with an amplitude of -20 to -35 mV, located about 500 feet (150 m) southwest of the airfield near Davis Dome. The amplitude of the anomaly fluctuated considerably during three days of observations in this area. This variation could be attributed to variable fluid flow in a thermal fluid upflow zone, or to

grounded current returns from unknown structures. A qualitative evaluation of these profiles suggest source depths in the 100-300 ft (30-90 m) range, but possibly less.

Anomaly sp-3 occurs along a southeast-trending power line road about 6,000 ft (1,830 m) north of the Meyer Small Arms Range. An area of more than 5,000 ft (1,500 m) northwest by 3,500 ft (1,070 m) northeast is more than -35 mV with respect to B.S.#1. Higher positive values, +18 to +40 mV, (background or positive dipolar?) are observed to the east and south. The anomaly is not completely defined as it was located at the end of the survey period. Large negative values, -50 to -75 mV were observed along the eastern margin of the anomaly, adjacent to what may be a dipolar high. These most negative values may be due in part to ground return currents for a complex of intersecting power lines which trend along part of the anomaly, but this is uncertain. The extension of the anomaly 500 to 2,000 ft northwest and west of the powerlines indicates a natural anomaly source, at least at the -35 mV level. This area should be evaluated further by radon, electrical resistivity, or possibly temperature gradient drilling.

Other anomalies with small lateral extent and/or low amplitude may reflect local geologic variability in the near-surface, but probably do not relate to the hydrothermal system. A limited correlation with radon soil-gas results should offer some insight as to possible causes and importance.

DISCUSSION

Three significant SP anomalies have been identified which could arise from fluid circulation related to the hydrothermal system. Anomaly sp-1, northwest of Davis Dome, is located up the hydrologic gradient from the hottest well in the area, and could arise from an upflow of thermal fluids. This anomaly should be tested with a temperature gradient hole, and should also be considered for a dipole-dipole resistivity line.

Anomalies sp-2 and sp-3 also appear to have geologic sources at shallow- to moderate-depth and could arise from additional thermal fluid upflow zones. There is some concern that the larger amplitude part of sp-3 may result in part from ground return currents of a complex intersection of power poles. A preliminary search of records indicates no buried grounded structures in the vicinity of sp-2. Both of these anomalies should be correlated with radon results and existing temperature gradient data. Temperature gradient drilling may be advisable. If a positive correlation between these SP anomalies and higher temperatures is established, additional SP survey work may be warranted at a later date.

REFERENCES

Corwin, R.F., 1990, The self-potential method for environmental and engineering applications; in Geotechnical and Environmental Geophysics, v.1, pp.127-145, Society of Exploration Geophysicists, Tulsa.

Corwin, R.F. and Hoover, D.B., 1979, The self-potential method in geothermal exploration; Geophysics, v.44, pp.226-245.

National Oceanic and Atmospheric Administration and Bureau of Economic Geology-The University of Texas at Austin, 1982, Geothermal Resources of Texas (map at a scale of 1:1,000,000).

National Oceanic and Atmospheric Administration and New Mexico Energy Institute at New Mexico State University, 1980, Geothermal Resources of New Mexico (map at a scale of 1:500,000).

Ross, H.P. and Witcher, J.C., 1992, Self-potential expression of hydrothermal resources in the southern Rio Grande Rift, New Mexico; Geothermal Resources Council Transactions, v. 16, pp. 247-253.

Ross, H.P., Blackett, R.E., Shubat, M.A., and Mackelprang, C.E., 1990, Delineation of fluid upflow and outflow plume with electrical resistivity and self-potential data, Newcastle geothermal area, Utah; Geothermal Resources Council Transactions, v. 14, pp. 1531-1536.

Ross, H.P., Blackett, R.E., and Shubat, M.A., 1991, Exploring for concealed hydrothermal resources using the self-potential method, Escalante Desert, Utah; Geothermal Resources Council Transactions, v. 15, pp. 279-287.

FIGURE CAPTIONS

Figure 1. Self-Potential Survey, McGregor Range Area, Fort Bliss, New Mexico.

Figure 2. Self-Potential Survey, McGregor Camp Area, Fort Bliss, New Mexico.

Figure 3. Self-Potential Survey, Meyer Range Area, Fort Bliss, New Mexico.