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SELF-POTENTIAL SURVEY RESULTS FROM THE BEOWAWE KGRA, NEVADA

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ABSTRACT

A dipolar self-potential anomaly of about 500 mV peak-to-peak amplitude and about 500 m peak-to-peak wavelength has been measured over an area of near-surface geothermal activity at the Beowawe KGRA, Nevada. The anomaly does not appear to be caused by topographic effects, and shows little correlation to changes in surface soil properties such as moisture content, conductivity, pH, or temperature.

A source mechanism by which surface self-potential anomalies are generated by sub-surface flow of fluid or heat along faults that separate regions of different electrokinetic or thermoelectric coupling coefficients was used to model the Beowawe anomaly. The model study results indicated that the measured anomaly could be generated by geothermal activity along a set of nine steeply dipping faults extending from about 50 to 250 m deep. Six of the faults lie along the trend of the Malpais fault zone, a major structural feature of the region, and two modelled faults running perpendicular to this trend may represent significant near-surface offsets of shallow geothermal activity along the Malpais fault zone. However, the data sampling density was not sufficient for reliable determination of the existence of these cross faults.

INTRODUCTION AND SURVEY DESCRIPTION

The Beowawe Known Geothermal Resource Area (KGRA) is located about 9 km southwest of the town of Beowawe, Nevada, within the Battle Mountain heat flow high. A zone of geysers, fumaroles, and hot springs gives evidence of near-surface hydrothermal activity, and studies by Chevron Resources Company presently are underway to determine whether an economic geothermal resource is present in the area. The geology and geophysics of the Beowawe geothermal system are discussed by Swift (1979), Zoback (1979), and Garside and Schilling (1979).

The self-potential survey was run using a fixed base electrode and sufficient cable to reach each survey point. Copper-copper sulfate electrodes and a digital multimeter having an input impedance of 10 megohms were used to make the readings. No water was added to the electrode holes to reduce contact resistance, as this procedure was found to give erroneous readings (Corwin, 1979). The survey was run by Chevron Resources Company. The data are publicly available as part of the Department of Energy/Division of Geothermal Energy Industry Coupled Program Through the Earth Science Laboratory of the University of Utah Research Institute.

Survey data points for the area of detailed self-potential coverage are shown in Fig. 2. Because geothermal activity was known to reach the surface, the readings were made with small spatial separation in an effort to properly delineate short-wavelength anomalies. Most of the north-south survey lines were separated by 200 m and most readings along the survey lines were taken at 50 m intervals. As discussed below, an even finer grid may have been necessary for unambiguous determination of near-surface fault trends.

Soil conditions varied widely throughout the survey area, with clay-rich soil found in the flat areas; loose, dry sinter on the steep slopes; and sinter soaked with geothermal fluids in the vicinity of the surface geothermal activity. In an effort to determine how these changes in soil conditions may have affected the self-potential readings, soil temperature was measured and soil samples were taken from a number of survey stations and analyzed for moisture content, electrical conductivity, and pH (Morrison et al., 1979). Except for a few readings in wet soil close to the geysers, the effect of these soil property changes was less than about 10 mV, and no other significant correlation was seen between any of these soil properties and the magnitude or polarity of the self-potential readings within the anomalous region.

DATA ANALYSIS

The contoured self-potential field data are shown in Fig. 3. The major feature of the contours is a dipolar anomaly, positive to the northwest and negative to the southeast, with the zero mV contour roughly following the northeast trend of the topography. Significant offsets of the major dipolar trend are seen in the central portion of the survey area. However, it must be noted that the data sampling density in this area was not sufficient to allow unambiguous contouring, and that different contours, leading to different interpretations of fault patterns in this region, could have been inferred from the same data.

Topography is known to sometimes affect self-potential data, with more negative readings usually found at higher elevations (Corwin and Hoover, 1979). This topographic effect probably is caused by streaming potentials generated by the downhill movement of ground water. The self-potential data shown in Fig. 3 obviously follows the general trend of the topography, and readings are more negative at higher elevations. However several arguments may be made against a topographic origin for this anomaly. First, the dipolar form of the anomaly is not typical of self-potential anomalies caused by topography, which usually follow topographic contours quite closely. Also, topographic anomalies of this amplitude usually are not found in arid regions such as north central Nevada. Finally, the topographic trend of the Malpais escarpment continues far to the southwest and northeast of the self-potential anomaly. Therefore, we conclude that the self-potential anomaly is not directly related to topography, although, as discussed below, they both probably have a common structural origin in the geothermally active Malpais fault.

A mechanism by which dipolar surface self-potential anomalies may be generated by the flow of fluid or heat along fault planes that separate regions of differing electrokinetic or thermoelectric coupling coefficients has been proposed by Fitterman (1979). Briefly, the change in coupling coefficient across the boundary of the fault plane in the presence of a component of flow parallel to the boundary produces a jump in a current producing potential across the boundary. This potential jump, which is the mathematical equivalent of a dipolar current distribution along the boundary, produces the surface self-potential anomaly.

For computational flexibility, the equivalent continuous current distribution can be replaced by a distribution of discrete point current sources and sinks along a pair of closely spaced parallel planes. This type of analysis has been applied successfully to self-potential data from the Cerro Prieto (Corwin et al., 1978) and East Mesa (Morrison et al., 1979) geothermal fields.

Assuming that this mechanism applies to the Beowawe anomaly (i.e., that the anomaly is generated by the flow of fluid or heat parallel to a number of fault planes that separate regions of differing coupling coefficients), a set of nine steeply dipping source planes giving a potential field that is a reasonable approximation to the measured anomaly was found by trial the error. The locations of the source planes are shown in Fig. 4, along with mapped faults shown by Zoback (1979). Current distributions and geometrical parameters of the source planes are shown in Fig. 6. The calculated anomaly produced by the source planes is shown in Fig. 5, for comparison with the measured anomoly shown in Fig. 3.

RELATION OF SELF-POTENTIAL SOURCE PLANES AND GEOTHERMAL ACTIVITY

Self-potential source plane sets A through F (Fig. 4) closely coincide with the location of the geothermally active Malpais fault (Zoback, 1979). It seems reasonable to assume, then that the major dipolar self-potential anomaly is generated by the upward flow of fluid and/or heat along the Malpais fault zone in the depth range from about 50 to 250 m. The necessary difference in coupling coefficients across the fault zone could be caused by the fault contacts between alluvium and basaltic andesite or by alteration produced by the flow of thermal fluids. The large magnitude of the anomaly is not surprising in view of the shallow depth to the source and the relative freshness of the thermal fluids (coupling coefficients are inversely proportional to pore fluid conductivity, and the 1400 ppm value for total dissolved solids (C. M. Swift, Jr., personal communication) for Beowawe fluids implies a low fluid conductivity).

Evidence of faulting roughly perpendicular to the main Malpais trend is provided by source planes G and H. However, as noted earlier, data sampling density was not sufficient for unambiguous delineation of these faults. The rather abrupt termination of the self-potential anomaly to the northwest and southeast also implies that major structural features perpendicular to the Malpais fault tend to limit shallow hydrothermal circulation to the area roughly defined by the surface geothermal activity mapped on Zoback.

No long-wavelength (1 km or greater self-potential anomaly such as those seen over the Cerro Pireto (Corwin et al., 1978) and East Mesa (Morrison et al., 1979) geothermal reservoirs is evident at Beowawe. This implies either that there is no major geothermal activity at depth along the Malpais fault zone (i.e., insufficient fluid and/or heat flow), or that coupling coefficient contrasts at depth are not large enough to generate measureable surface anomalies even in the presence of large fluid or heat flows.

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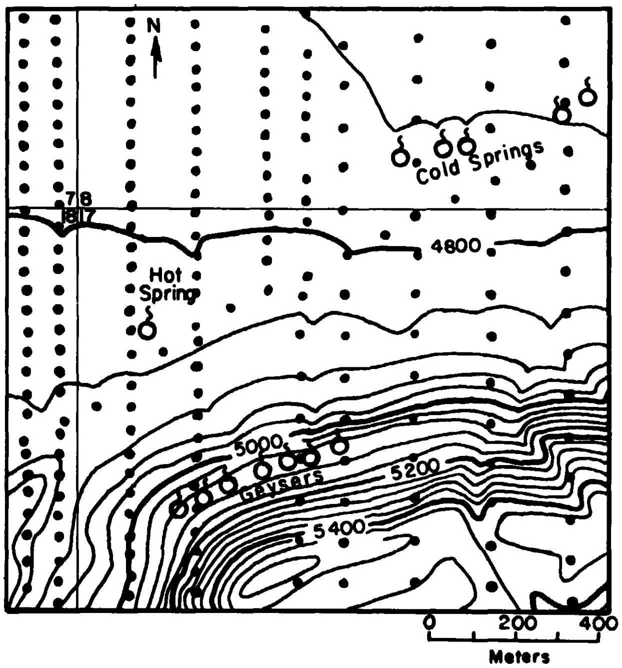

Figure 2. Self-potential survey stations, topography, and surface geothermal activity, Beowawe KGRA.

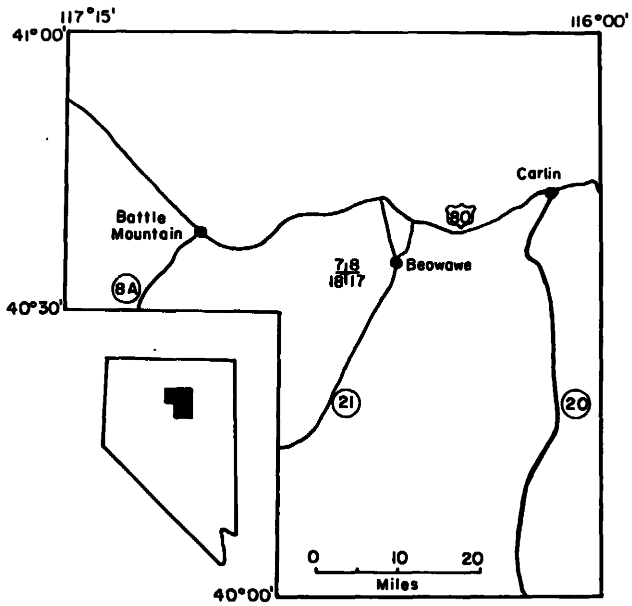

Figure 1. Map showing location of surveyed area. Section corner 7-8-18-17 is the reference location in figures 2-5.

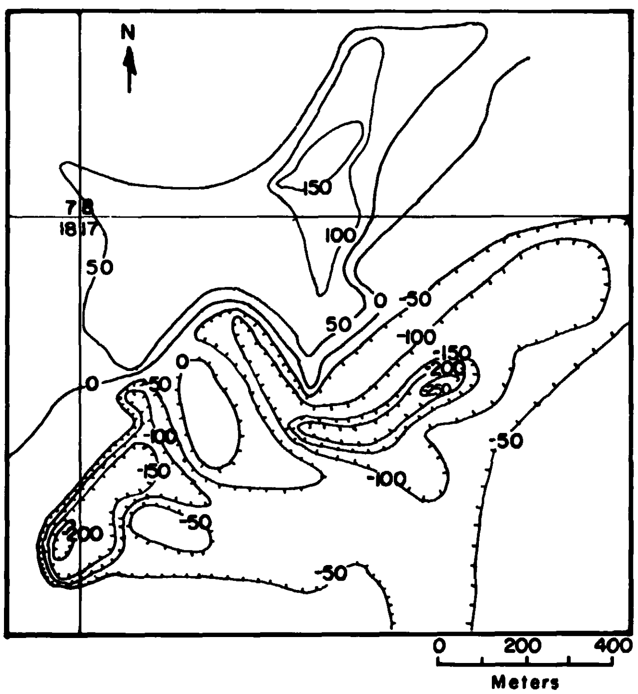

Figure 3. Measured self-potential contours, Beowawe KGRA. Contour interval is 50 mV.

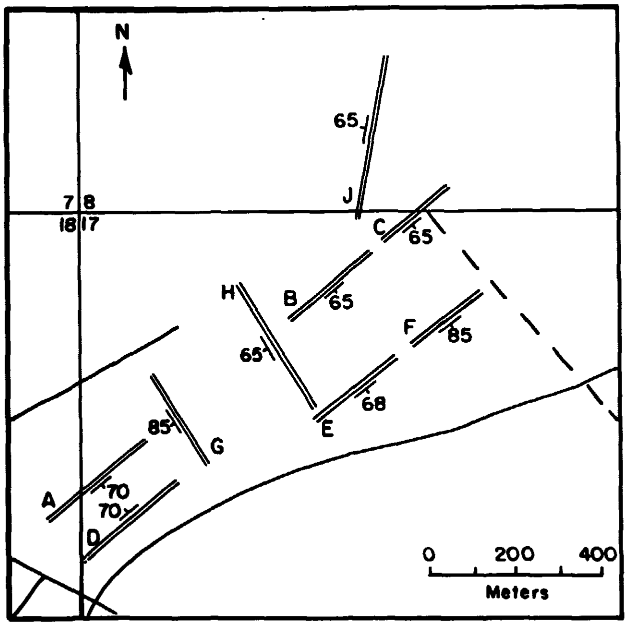

Figure 4. Northeast trending Malpais fault zone with cross-faults, dashed where questionable, (Zoback, 1979) and self-potential source planes, Beowawe KGRA.

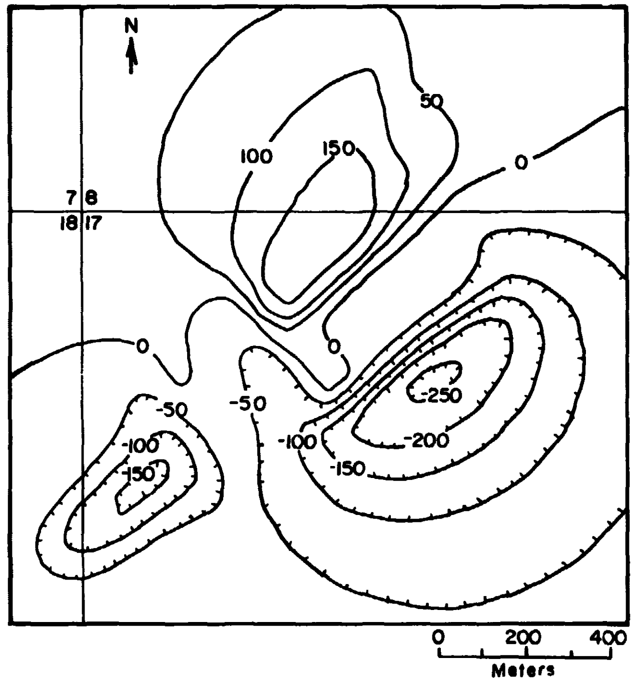

Figure 5. Self-potential anomaly generated by source planes shown in figures 4 and 6. Contour interval is 50 mV.

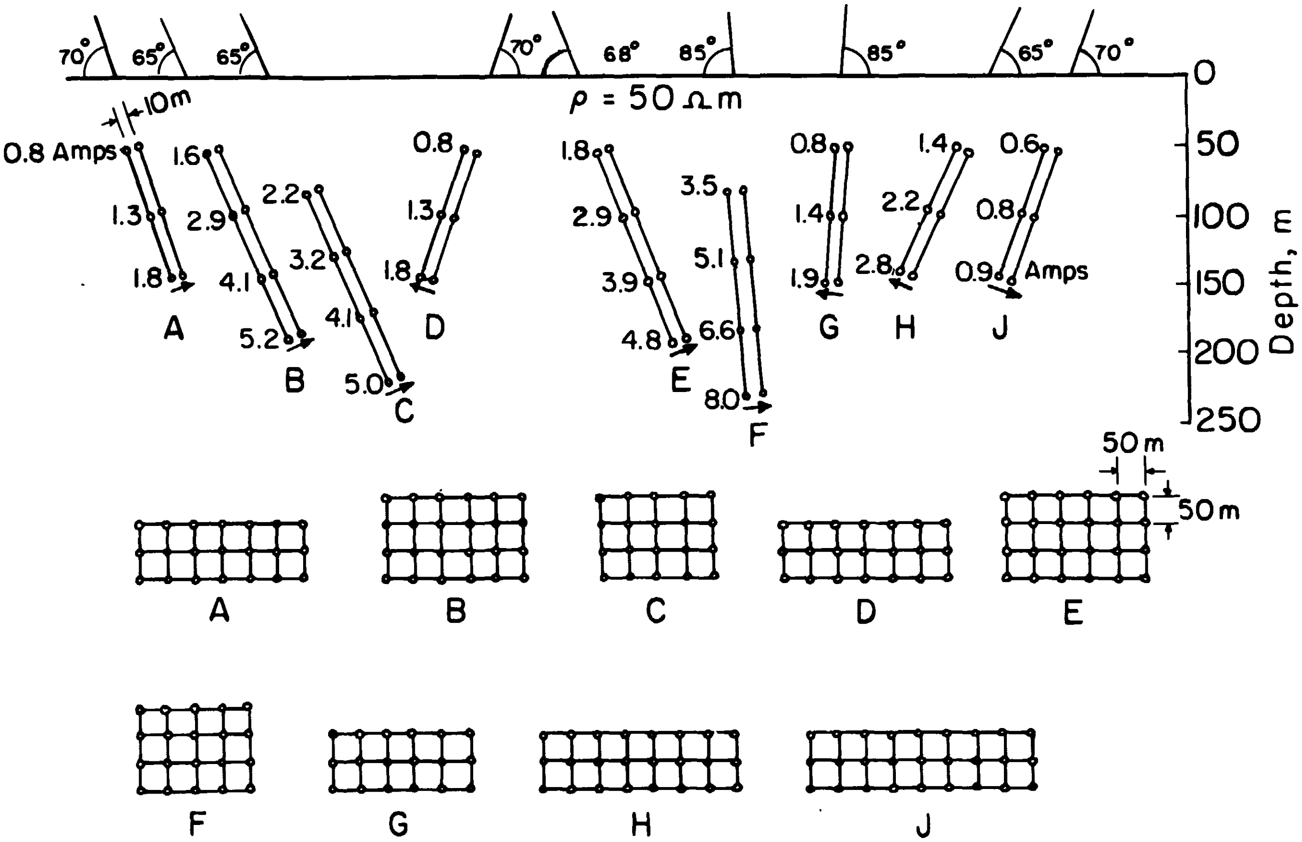

Figure 6. Geometry and current distribution of self-potential source planes. Model resistivity is 50 ohm-meters. Arrows show direction of positive current flow across source planes.