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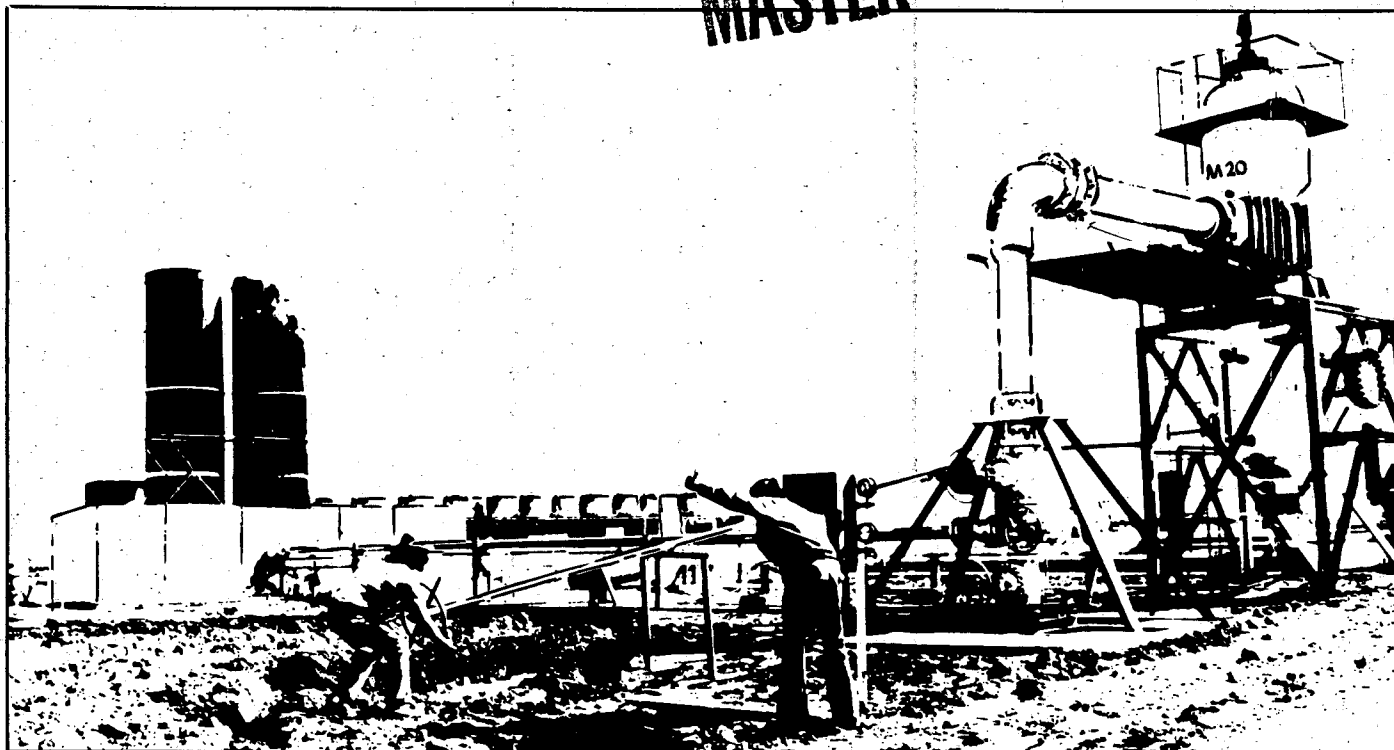
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MASTER



GEOLOGICAL INTERPRETATION OF SELF-POTENTIAL DATA FROM THE CERRO PRIETO GEOTHERMAL FIELD

Robert F. Corwin and David V. Fitterman

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79

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79

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ABSTRACT

A source mechanism based on concepts of irreversible thermodynamics and consisting of heat or fluid flow along a north-south trending zone of faulting is proposed for the self-potential anomaly measured over the Cerro Prieto geothermal reservoir. The source region is represented by a vertical plane of that separates regions of differing streaming potential or thermoelectric coupling coefficients. The coupling coefficient contrast could be caused by vertical offset of rock units along faults. The depth to the top of the source plane is about 1.3 km, its vertical extent is about 11 km, and its length along strike is about 10 km. Geological, geophysical, and mineralogical evidence support the existence of an important north-south geological trend roughly corresponding in location to the proposed self-potential source plane.

INTRODUCTION

The dipolar self-potential anomaly measured over the Cerro Prieto geothermal field (Corwin et al., 1979) may be caused by upward heat or fluid flow along a north-trending fault zone across which there is a change in thermoelectric or electrokinetic coupling coefficient. In this paper we present the results of an analytical study of the source region geometry for the Cerro Prieto anomaly and discuss the geological, mineralogical, and geophysical evidence for a zone of faulting corresponding to the inferred self-potential source region.

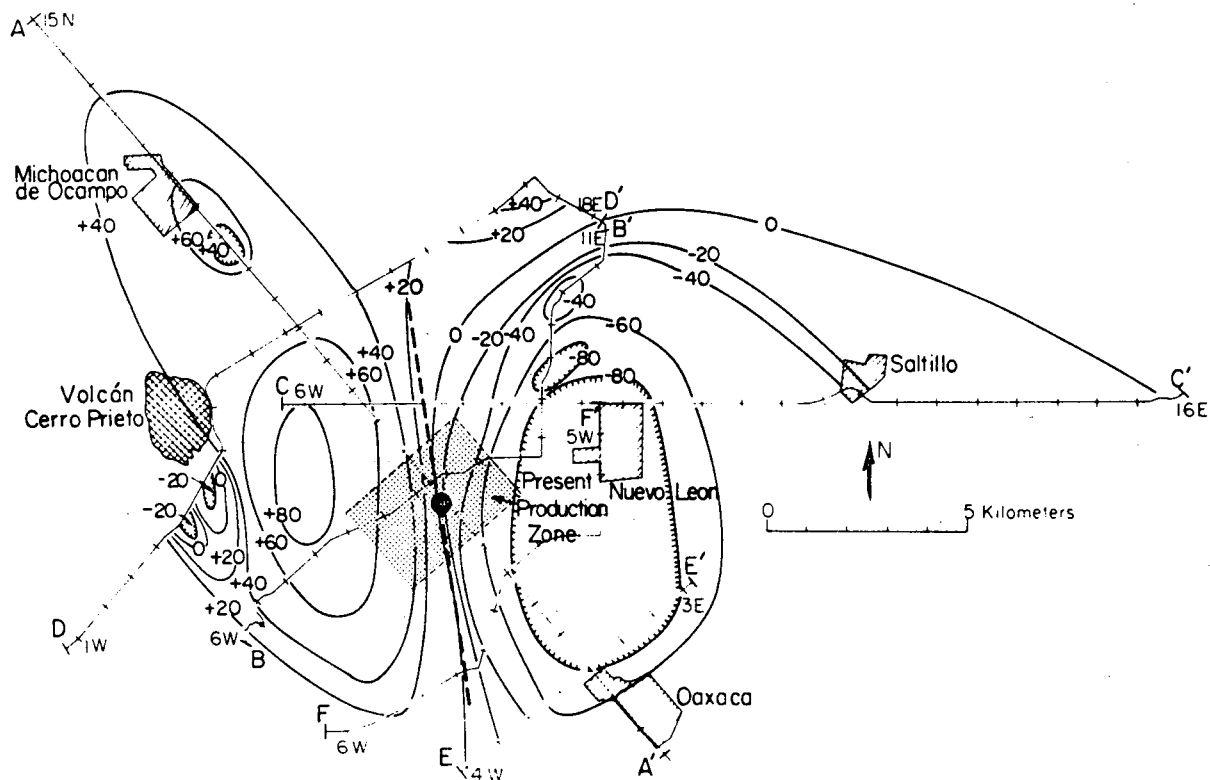
DISCUSSION

The field procedure and data analysis used to determine the self-potential anomaly at Cerro Prieto are given in Corwin et al. (1979). The relationship of the anomaly to the geography of the Cerro Prieto area is shown in Figure 1. The mechanism by which dipolar surface self-potential anomalies are generated by heat or fluid flow along a vertical fault that separates regions of differing thermoelectric or electrokinetic coupling (streaming potential) coefficients is discussed by Fitterman (1979). Briefly, the fault or fracture zone is approximated by a vertical plane of

continuous, constant dipolar charge which is maintained by the interaction of the heat or fluid flow with the coupling coefficient boundary. Given the depth and strike extent of the plane and the potential difference and conductivity contrast across the plane, the surface self-potential anomaly can be calculated. Using this approach along with a linear least-squares inversion technique, a source plane configuration giving a reasonable fit to the Cerro Prieto data was obtained (details of the inversion procedure are discussed in a paper by Fitterman and Corwin, 1980). The location of the source plane with respect to the geothermal field and the self-potential anomaly is shown by a dashed line in Figures 1 and 2. The top of the plane is at a depth of 1.3 ± 0.2 km (error estimates are one standard deviation) and its vertical extent is 11 ± 3 km. The strike length of the plane is 9.9 ± 0.4 km. The source intensity is -340 ± 40 mV, and the electrical conductivity on the east side of the plane is 80% of that to the west (the asymmetry of the anomaly could also be caused by a nonvertical dip angle of the source plane rather than a lateral conductivity contrast).

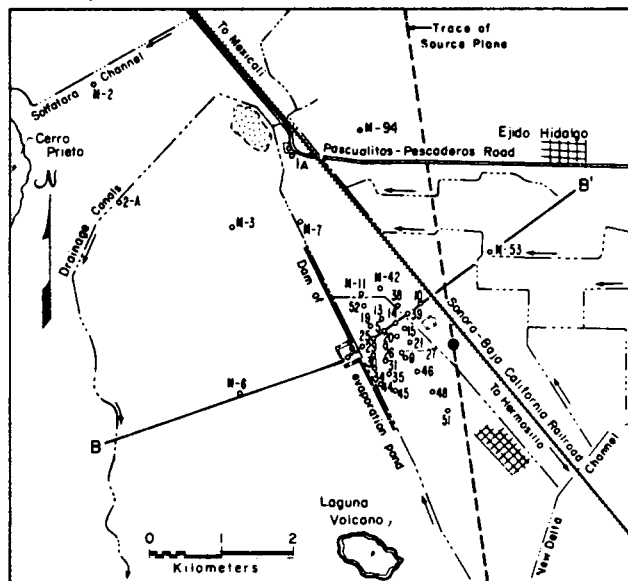
There appears to be considerable geological, mineralogical, and geophysical evidence for the existence of a north trending zone of faulting that corresponds to the inferred self-potential source plane. The depth to the top of the source plane, 1.3 ± 0.2 km, agrees well with the known depth of about 1 km to the top of the reservoir (Mañon et al., 1977). Wilt et al. (this volume) present electrical resistivity data showing a zone of high conductivity located between wells M-9 and M-53 (Fig. 2) and dipping to the east, under the trace of the source plane. Although the strike of this zone has not yet been determined, such a zone could be representative of extensive faulting. Magnetotelluric data given by Gamble et al. (this volume) also show evidence of a conductive zone in the same general area described above. Additional magnetotelluric data in the northern part of the field indicate that this conductive zone may run in a roughly northerly direction.

Vonder Haar and Puente Cruz (1979) used microseismic and well log data to infer a north-trending zone of faulting and fracturing that approximately coincides with the self-potential source plane in the central portion of the field,



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Figure 1. Self-potential contours in the Cerro Prieto area. Contour interval is 10 mV. The heavy dashed line represents the trace of the inferred self potential source plane. Lines labelled A-A' through F-F' are survey lines. • = center of the source region.



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Figure 2. Geothermal wells and the trace of the self-potential source plane in the Cerro Prieto geothermal production zone. A geologic section along line B-B' is shown in Mañon et al. (1977)
• = center of the source region.

and de la Peña and Puente (1979) infer a major north-trending fault in about the same location. Studies of density logs by Lyons and van de Kamp (1980) indicate that contours to the depth below which shale densities exceed 2.4 (indicative of hydrothermal alteration) trend roughly north-south in the central part of the field. The same authors show a zone of generally north-northeast-trending faults in the same area, which are thought to have formed at about the same time as the onset of thermal activity and the induration of sediments by hydrothermal alteration. Contours to depths of several other mineralogical changes indicative of hydrothermal alteration shown by Elders et al. (1978; this volume) follow a pattern similar to the shale alteration described above. These patterns have been used in a preliminary study by Elders et al. (1980) to infer flow patterns of hydrothermal fluids that show a north-south trending thermal plume under the central part of the field, possibly indicative of a basement fault or fracture (Elders, 1980 personal commun.).

CONCLUSIONS

Based on this self-potential study and other geological, geophysical, and mineralogical evidence, we conclude that a major geological feature runs in a north-south direction through the center of the Cerro Prieto production zone. An interpretation consistent with self-potential field data and source theory is a zone faulting or fracturing that extends from a depth of about 1.3 km to about 13 km. The -340 mV dipolar source potential is generated by heat or fluid flow within the faulted region, and the coupling coefficient discontinuity across which the source potential is generated is provided by vertical offsets along faults that bring different rock materials in contact. (The coupling coefficient contrast could also be caused by alteration of minerals, or even by the elevated temperature alone, within the zone of the most intense hydrothermal circulation.)

Until measurements of coupling coefficients under in-situ conditions are made, we do not know whether the -340 mV source potential is reasonable for the geologic materials and flows in the Cerro Prieto reservoir.

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