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RESULTS OF ELECTRIC SURVEY IN THE AREA OF HAWAII GEOTHERMAL TEST WELL HGP-A

James Kauahikaua (1) and Douglas Klein (2)

U.S. Geological Survey, Denver, Colorado 80225 (1)
Hawaii Institute of Geophysics, Honolulu, Hawaii 96822 (2)

Between 1973 and 1976, the Hawaii Institute of Geophysics made five Schlumberger-type soundings, two bipole mapping surveys, a dipole-dipole pseudo-cross section, and fifteen line-loop transient soundings in the Puna district on the Island of Hawaii (Kauahikaua and Klein, 1977a and b). The Schlumberger and transient sounding data were inverted for a best-fitting layered-earth model to define resistivity variations with depth. The soundings allow qualitative separation of the effects of lateral resistivity variations from those of vertical variations in the bipole mapping data. The accumulated data suggest that all the near-surface lavas are highly resistive (6000 to 8000 ohm-m), but that the lavas below sea level are fairly conductive. However, a distinct lateral resistivity variation exists in the substratum. Resistivities range from 100 to 300 ohm-m along Kilauea volcano's rift zone and from 6 to 10 ohm-m between the rift and the coast. Superimposed on this pattern are an anomalous, low-resistivity area within the rift zone and one within the coastal area that may be related to geothermal activity. A successful test hole, drilled to nearly 2000 m in depth, is situated within one of these anomalies.

Electromagnetic transient sounding (time-domain) measurements were made using a straight grounded wire of a kilometer or less in length that was energized with a square wave of electric current having a period of about 13 seconds. The time derivative of the vertical magnetic field was measured as a function of time by recording the induced voltage in a coil of wire laid horizontally on the ground. The received voltage was digitized at 4-millisecond intervals and stacked to reduce noise. Final data reduction required deconvolution of the response of the measurement system from the measured earth response to yield the true earth response.

Interpretation of the fifteen transient soundings made in this area was based solely on the results of a nonlinear, multilayer, time-domain, inversion computer program that was developed from a similar frequency-domain inversion program (Anderson, 1977) and a time-domain, multilayer, modelling program (Kauahikaua and Anderson, 1977). In order to achieve a self-consistent interpretation, the magnitude of the primary magnetic field was estimated directly from the data rather than computed from theoretical formula. Convergence of the inversion proceeds more smoothly and yields more stable results with this modification.

Five Schlumberger soundings were interpreted (localities shown on Figure 1) using standard techniques (Keller and Frischknecht, 1966). The data were also interpreted using a nonlinear, multilayer, inversion program similar to the one discussed by Inman et al. (1973). Finally, apparent resistivities were mapped around two bipole sources according to the method of Keller et al. (1975). A dipole-dipole pseudo-cross section was also constructed from the reduced data.

The Schlumberger data showed that the resistivity of the upper few tens of meters is highly variable, ranging from 3000 ohm-m to 34,000 ohm-m. The bulk of material below this surface layer, but still above sea level, has a rather uniform resistivity of 6000 to 7800 ohm-m. Below sea level, the resistivities decrease to less than 70 ohm-m with one exception: A resistivity layer of 600 ohm-m at 70 m above sea-level was noted from sounding G3 (Figure 1).

A clearer determination of the sub-sea-level resistivity structure comes from the transient-sounding results, because the use of a more powerful electric current source made larger source-to-field point separations possible and because the technique is insensitive to the resistive overburden. Below sea level, resistivities are about 10 ohm-m along the rift-zone trace and decrease to

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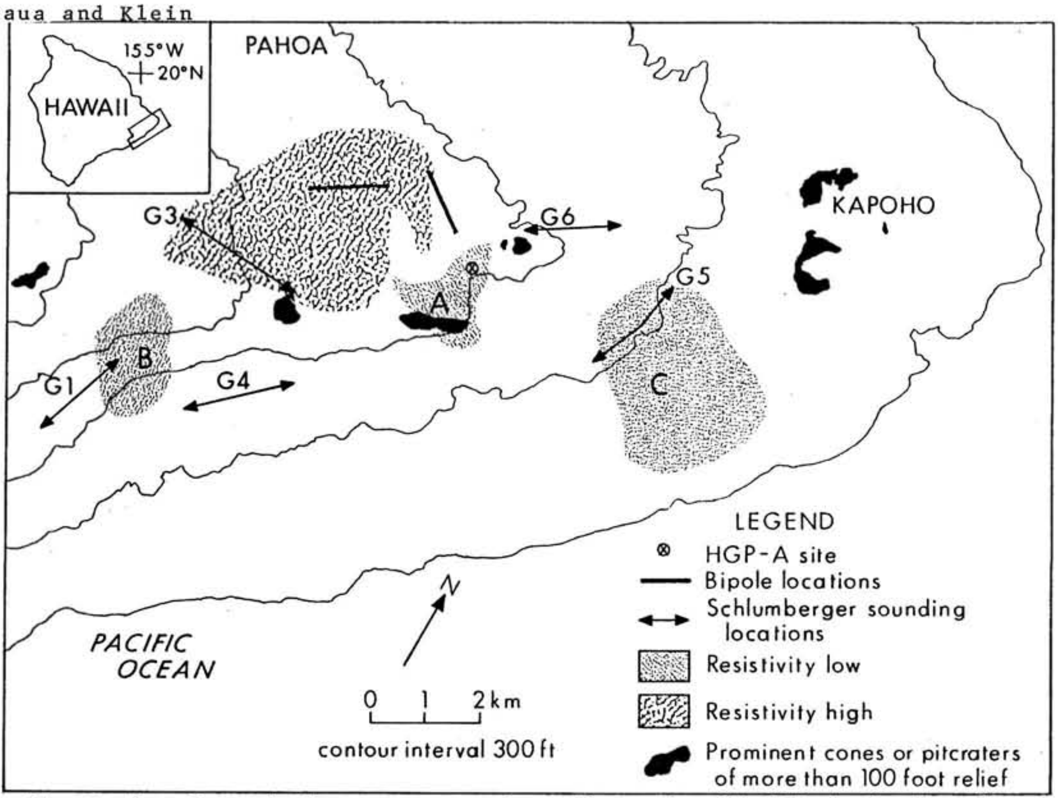

Figure 1. Map of the area around geothermal well HGP-A showing the localities of the test well, five Schlumberger soundings (G1 through G6), a dipole-dipole pseudo-cross section, and areas of abnormally high and abnormally low resistivities.

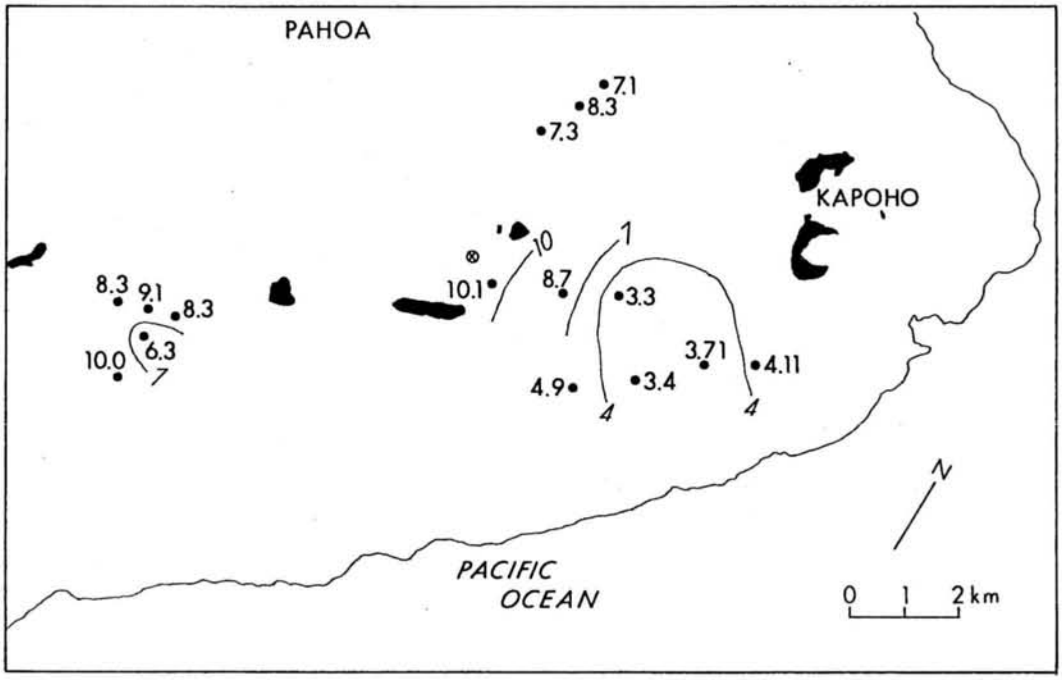

Figure 2. The deepest resistivities interpreted from the transient-sounding measurements. Each value is plotted at the midpoint between source and field point. Resistivities are in ohm-meters.

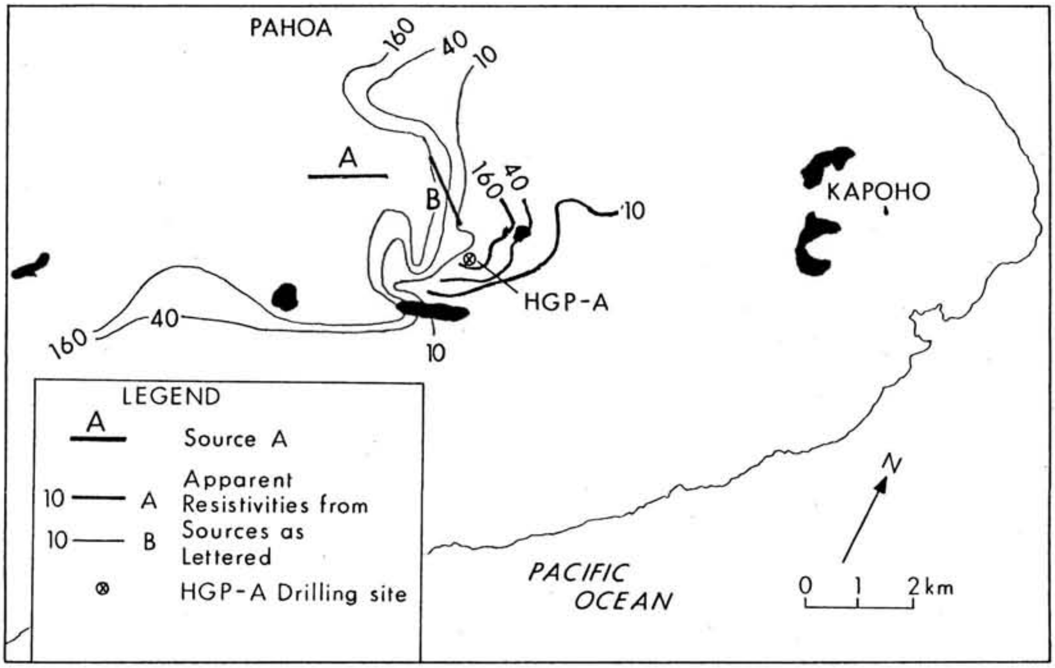

Figure 3. Compilation of apparent-resistivity data in the Puna district from bipole-dipole galvanic mapping studies.

7 ohm-m on either side of the rift. Abnormally low resistivities were mapped in the area south of Kapoho. The resistivities there are 4 to 5 ohm-m and are overlain by a thin layer whose resistivity is as low as 1 ohm-m. This vertical structure reflects the known shallow hydrothermal structure in the local water table (Epp and Halunen, 1976) and suggests that this anomaly is caused by seepage of heated groundwater from the rift. The deepest resistivity layered sensed with each transient sounding is plotted in Figure 2 at a point midway between source and field point.

Comparison of these results with those of bipole mapping and the dipole-dipole cross sectioning shows that distinct, and rather abrupt, lateral variations in resistivity occur near the test-hole location. A resistivity map around the southeast end of the bipole B (Figure 3) and the dipole-dipole cross section indicate that the electrical structure directly east of the test hole is essentially horizontally layered with a surficial layer of about 6000 ohm-m overlying a layer of 5 to 10 ohm-m material. The overburden is thicker to the northwest. In contrast, the apparent resistivities plotted around bipole A (Figure 3) display a broad zone of apparent resistivity about 300 ohm-m that coincides directly with the rift-zone trace and which cannot be interpreted as being due to the same layered structure as the area to the east. The apparent resistivities decrease abruptly to about 5 to 10 ohm-m to the south and east in a manner that suggests buried vertical contacts rather than horizontal layering. In the immediate vicinity of the test hole and farther to the southwest, there are areas of anomalously low resistivity (labeled A and B in Figure 3).

The resistivity structure derived from these electrical surveys is summarized in Figure 1. The large dark-stippled area in the center of the figure is a block of 300- to 600-ohm-m material that extends from about 70 m above sea level to an unknown depth. On the basis of Schlumberger soundings made on the islands of Oahu and Hawaii (Zohdy and Jackson, 1969), these resistivities indicate that the area is saturated with relatively fresh water. If the groundwater is supported at depth by more dense saline water, as is common in Hawaii, then the fresh water could extend to 2800 m below sea level (based on a hydraulic head of 70 m). The light-stippled areas labeled A and B are low-resistivity anomalies within the rift, which coincide with two prominent self-potential (SP) anomalies mapped by Zablocki (1977). Test well HGP-A was drilled into the SP anomaly associated with area A to a depth of nearly 2000 m and encountered bottom temperatures of about 300°C. Water samples recovered from the well indicated that the water is fairly fresh. The stippled area labeled C is a low-resistivity anomaly probably caused by seepage of heated water from the rift zone.

REFERENCES

Anderson, W. L., 1977, Marquardt Inversion of Vertical Magnetic Field Measurements from a Grounded Wire Source, U.S.G.S. report USGS-GD-77-033, 76 p., available from U.S. Dept. Commerce Natl. Tech. Inf. Service, Springfield, Va. 22161 as Rept. PB-263 924/AS.

Epp, D. and J. Halunen, 1976, Well Temperature Surveys, in Initial Phase II Progress Report, Hawaii Geothermal Project, p. 39-44.

Inman, J. R. Jr., J. Ryu, and S. H. Ward, 1973, Resistivity Inversion: Geophysics, v. 38, p. 1088-1108.

Kauahikaua, J. and W. L. Anderson, 1977, Calculation of Standard Transient and Frequency Sounding Curves for a Horizontal Wire Source of Arbitrary Length, U.S. Geological Survey Report USGS-GD-77-007, 63 p., available from U.S. Dept. Commerce Natl. Tech. Inf. Service, Springfield, Va. 22161 as Rept. PB-274 119/7WC.

Kauahikaua, J. and D. P. Klein, 1977a, Electromagnetic Induction Sounding Measurements in the Puna District, Hawaii, in Geoelectric Studies on the East Rift, Kilauea Volcano, Hawaii Island, Hawaii Inst. Geophys. Tech. Rept. HIG-77-15, p. 91-119.

__________, 1977b, Interpretation of Electromagnetic Transient Soundings Made On the East Rift of Kilauea Volcano, Hawaii, in Geoelectric Studies on the East Rift, Kilauea Volcano, Hawaii Island, Hawaii Inst. Geophys. Tech. Rept. HIG-77-15, p. 121-173.

Keller, G. V. and F. C. Frischknecht, 1966, Electrical Methods in Geophysical Prospecting, Oxford, Pergamon Press, 519 p.

Keller, G. V., R. Furgerson, C. Y. Lee, N. Harthill, and J. J. Jacobsen, 1975, The Dipole Mapping Method: Geophysics, v. 40, p. 451-472.

Zablocki, C., 1977, Self Potential Studies in East Puna, Hawaii, in Geoelectric Studies on the East Rift, Kilauea Volcano, Hawaii Island, Hawaii Inst. Geophys. Tech. Rept. HIG-77-15, p. 175-195.

Zohdy, A. D. R., and D. B. Jackson, 1969, Applications of Deep Electrical Soundings for Groundwater Exploration in Hawaii: Geophysics, v. 34, p. 584-600.