SCHLUMBERGER SURVEY OF MAUI ISLAND, STATE OF HAWAII

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ABSTRACT

We present the results of 21 Schlumberger resistivity soundings made on the island of Maui. We have used the apparent resistivity data to estimate electrical resistivities of basalt saturated with seawater for different parts of the island. The values we obtained average around 20 ohm-meters, except in one area, Ukumehame canyon, on the south rift zone of West Maui. In this area, which is the site of a warm (33°C) water well, the resistivity we interpret for the seawater saturated basalt layer is close to 4 ohm-meters. Using typical Hawaiian basalt porosity values of 15 to 25% we estimate the temperature of the seawater to be 95 ± 23°C at a depth of 273 to 608 feet.

INTRODUCTION

Maui is the second youngest and second largest island in the Hawaiian chain. The island is composed of two volcanos, Haleakala, and West Maui. Haleakala volcano is considered dormant having last erupted about 210 years ago. West Maui is considered extinct; its last stage of activity produced four post-erosional cones in late Pleistocene to recent times (Macdonald & Abbott, 1970). The warmest thermal water known on Maui is in Well 12 (Fig. 1) at the mouth of Ukumehame canyon. The temperature of the water is 33°C at the bottom of the well, which is 143 feet deep (Thomas et al., 1979).

Twenty-one resistivity soundings, using the Schlumberger electrode configuration, were made on Maui as part of the Hawaii Institute of Geophysics (HIG) Direct Heat Regional Assessment Program. Eleven soundings were located between the towns of Honolua and Maalaea on West Maui and ten were located on the isthmus and around Haleakala (Fig. 1).

METHODS AND DATA INTERPRETATION

In the Schlumberger array, two closely spaced potential electrodes are centered between two current electrodes. Apparent resistivity in ohm-meters is given by:

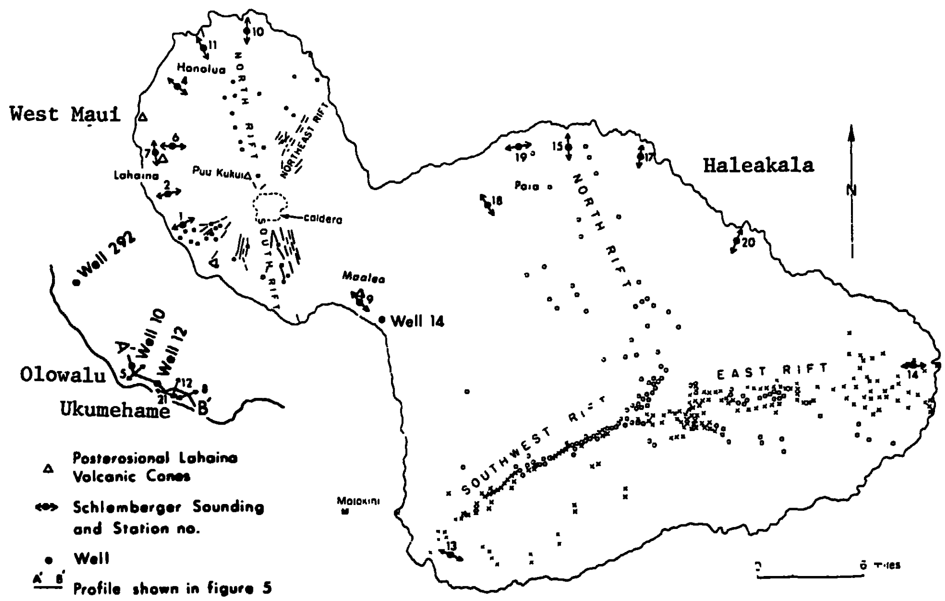

Fig. 1. Map of Maui, showing principle volcanic rift zones, dikes (short lines), vents (circles and crosses) and the Schlumberger sounding locations.

$$\rho a = \frac{\Delta V \pi}{I} \left(\frac{a^2}{b} - \frac{b}{4}\right) \quad \text{(Keller \& Fischknecht, 1966)}$$

where ΔV is the measured potential difference in volts, I is the input current in amps, a is 1/2 the current electrode separation and b is the potential electrode separation. Two nonpolarizing copper sulfate porous pots were used as potential electrodes and two stainless steel rods as current electrodes. The current transmitter was capable of providing up to 1 amp. at 1300 volts d.c. Potential differences were measured with a high input impedance (>10MΩ) digital voltmeter. Apparent resistivities versus 1/2 the current electrode separation a, were plotted bi-logarithmically in the field.

The effect of the low resistivity ocean on soundings performed close to a coastline was estimated using the model of a perfectly conducting, thin semi-infinite sheet, lying on the surface of a homogeneous earth (Mundrey & Worzyk, 1979). The corrected apparent resistivities, ρc, are then given by:

$$\rho_c = \frac{\rho_a}{\pi} \left[\tan^{-1}\left(\frac{\sqrt{y+1} + \sqrt{y-1}}{1-4y\sqrt{y^2-1}}\right) + \frac{\sqrt{1-1/y}}{2y-1} + \frac{\sqrt{1+1/y}}{2y+1}\right]$$

for soundings perpendicular to the coast and;

$$\rho_c = \frac{2\rho_a}{\pi} \left[\tan^{-1}(2y) + \frac{2y}{1+4y^2}\right]$$

for soundings parallel to the coast, where y is the ratio of the distance to the coast from the center of the array to a.

Preliminary interpretations of the sounding data were made by curve matching using two-layer master curves (Compagnie Generale de Geophysique, 1955). These initial parameters were used as input for a least-squares inversion algorithm (Anderson, 1979). The algorithm calculates best-fit resistivity and thickness parameters, their degree of correlation and their standard errors, for horizontally layered models.

RESULTS

Thirteen of the twenty-one sounding interpretations resolve a low resistivity basement which we interpret as being seawater saturated basalt. Comparison of the seawater basalt values over the area surveyed is given in Table 1.

Although some errors are large, it is apparent that the most conductive region surveyed is Ukumehame canyon, located on the southern side of West Maui. The Schlumberger data for six soundings of the south side of West Maui, with coastal corrections, best fit model curves, interpreted resistivity sections and standard errors are given in Figures 2, 3, and 4.

Except for sounding S21 the degree of correlation between the model parameters for soundings on the south side of West Maui show that the half-space resistivity is the least correlated parameter. The errors are therefore best estimated for the half-space resistivity parameter. All other resistivity parameters are highly correlated with the thickness parameter of the same layer or with the thickness parameter of the layer above it. These estimated standard errors are therefore conservative (Inmann, 1975). The interface which is most distinct in all our data is between the lowest layer and the one above it. Interpreting this interface as the bottom of the fresh water lens and taking the Ghyben-Hertzberg ratio of 40 to 1 for fresh water below sea level to fresh water above it, we can estimate the piezometric head for each sounding. The head estimates and corresponding well data are presented in Table 2.

Table 1

Location	Station Number	Resistivity and standard errors of seawater saturated basalt in Ω-m
Honolua	S10	39.0 ± 29.0
Honolua	S11	36.0 ± 34.0
Lahaina	S7	38.0 ± 27.0
Lahaina	S2	24.0 ± 3.0
Lahaina	S1	40.0 ± 185.0
Olowalu	S5	7.7 ± 2.7
Ukumehame	S21	4.1 ± 3.5
Ukumehame	S12	4.3 ± 7.7
Ukumehame	S8	3.9 ± 2.2
Maalaea	S9	13.4 ± 2.0
Paia	S18	13.1 ± 5.0
Paia	S19	9.8 ± 1.1
Paia	S15	10.5 ± 8.0

Table 2

Well or Sounding Number	Elevation (feet)	Elevation of Seawater Interface (feet)	Head (feet)
Well 292	442		1.5-2.9
S7	375	-90	2.2
S2	260	-135	3.3
Well 10	165		3.1-4.3
S5	200	-233	5.8
Well 12	79	-193	3.4-6.7
S21	79	-463	4.8
S12	145	-209	11.5
S8	80		5.2
Well 14	300		3.2
S9	65	-46	1.2

Generally, the freshwater heads estimated from all our soundings agree with well data in their area (for locations see Fig. 1). Sounding S12 was located close to Ukumehame Stream which may be causing a locally high head in that area. Also, S12 gave a large error in the depth to the seawater interface (55%). This large error may be caused in part by the effects of metal pipes associated with water reservoirs at spacings a = 500,800 and 1600 feet.

Examination of available groundwater well logs (U.S.G.S., 1980) and geologic maps (Stearns & Macdonald, 1942) suggest that resistivity layers

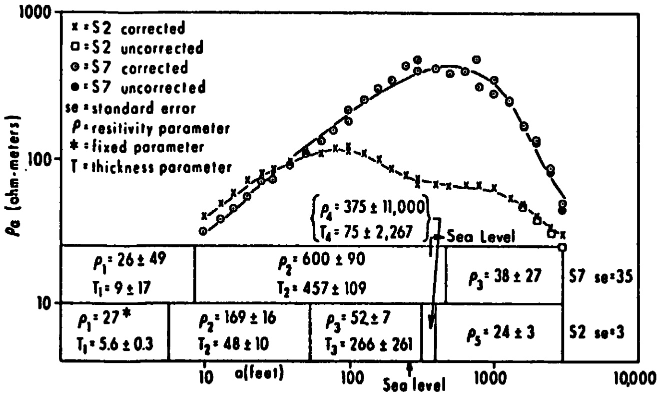

Fig. 2. Schlumberger sounding data with coastal corrections and interpretations for soundings S7 and S2 located west of Ukumehame near Lahaina Town.

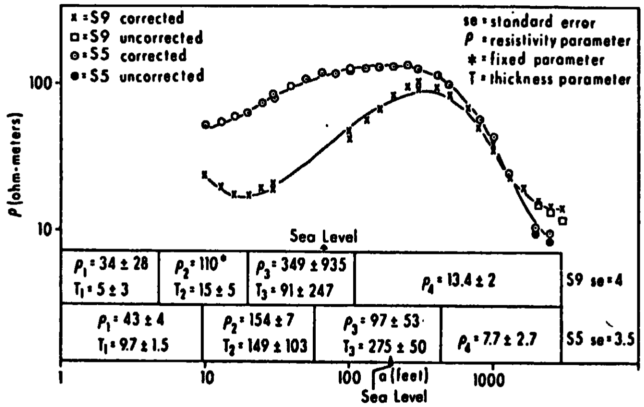

Fig. 3. Schlumberger sounding data with coastal corrections and interpretations for soundings S5 and S9 located west and east of Ukumehame respectively.

of Figures 2, 3, and 4 are distinct lithologic or hydrologic layers. The first two surface layers of soundings S8, S9, S2 and the surface layer of S7 and S5 are without question unconsolidated or consolidated alluvium deposits. Layers 3 of S8, 3 of S9, 2 of S7, 4 of S2, 1 of S12 and 3 of S5 are postulated to be fresh or weathered basalt partly to completely saturated with fresh water. The interface between partially and completely saturated cold fresh water basalt is not electrically distinct. We interpret layers 4 of S8 and 2 of S12 as being basalt, saturated with warm fresh water. We postulate that layers 3 and 4 of S2 represent weathered and fresh basalt respectively, containing fresh water (Fig. 2). Bottom layer resistivities for all soundings presented in Table 1 and Figures 2, 3, and 4 are interpreted as seawater saturated basalt. For soundings S8, S12 and S21 at the mouth of Ukumehame canyon, the bottom layers are highly conductive, ranging from 4.3 to 3.9 Ω-m and are interpreted as Wailuku basalt, saturated with hot seawater. Our interpretation is shown schematically in Figure 5.

Geologic maps show an extensive dike swarm and boss complex throughout Ukumehame canyon (Fig. 1 & 5). A large soda trachyte stock and dike exists at the head of the canyon. Although we initially suspected that the warm water observed in Ukumehame was related to the Lahaina post-erosional sequence (Fig. 1), it seems more likely that a large stock similar to the one at the head of the canyon exists not too far beneath our soundings and well 12.

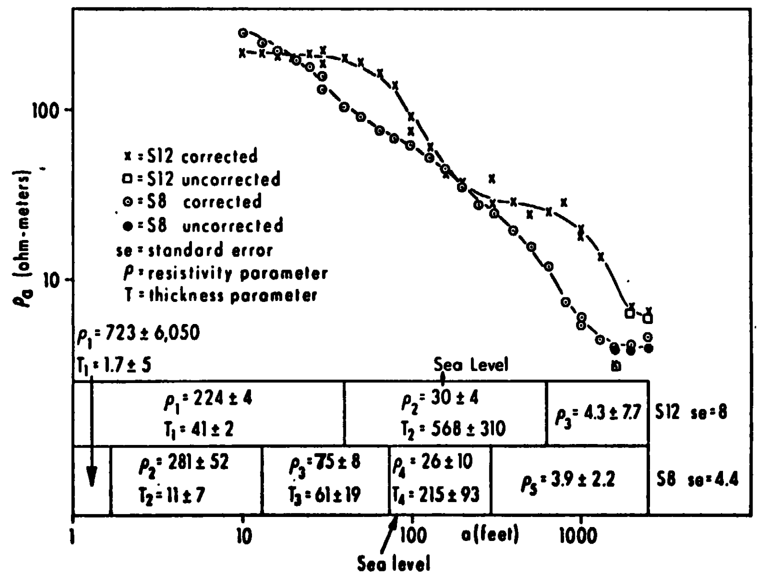

Fig. 4. Schlumberger sounding data with coastal corrections for soundings S8 and S12 in Ukumehame canyon. Interpreted models are summarized in bar form at the bottom of the figure.

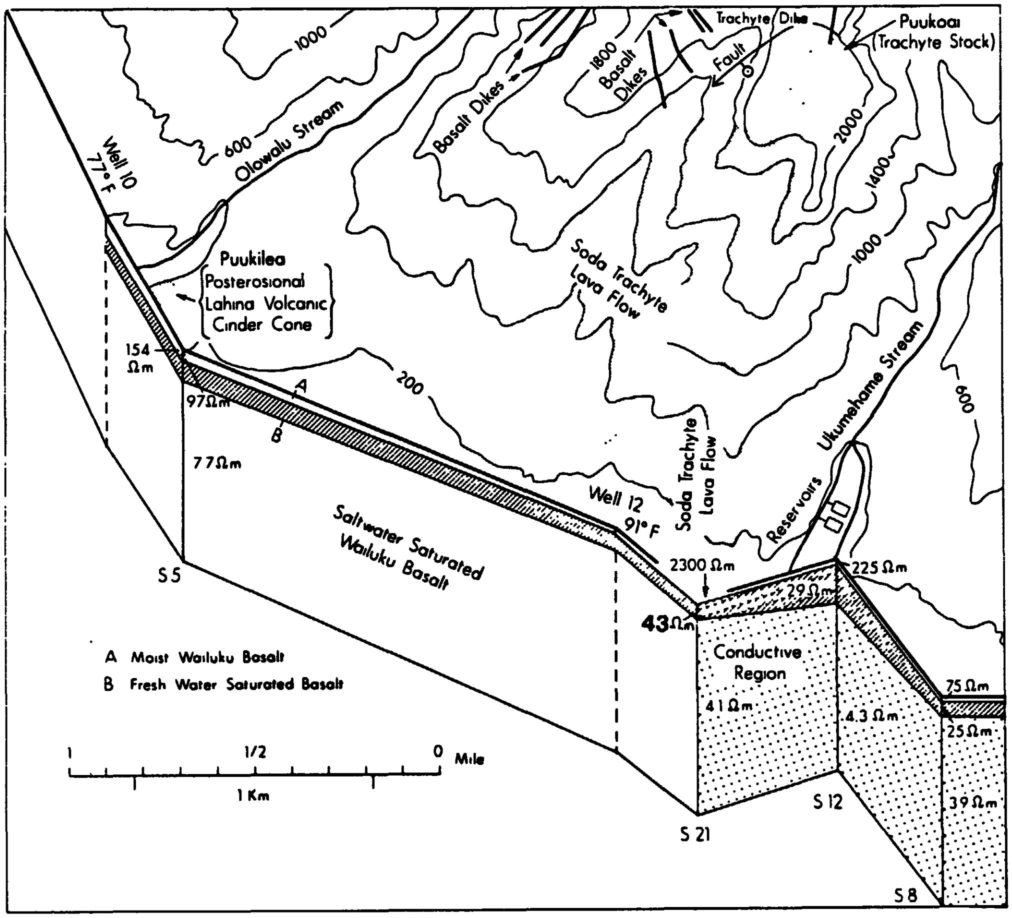

Fig. 5. Geoelectric cross section A'B' across the mouth of Ukumehame canyon (see Fig. 1). The conductive region is interpreted as hot seawater saturating Wailuku basalt.

CONCLUSION

An electrically conductive region has been located on the south rift of West Maui at the mouth of Ukumehame canyon and coincides with a known warm water well (33°C). The top of the fresh water table cannot be distinguished from partially saturated basalt unless it is warm, which appears to be the case for soundings S12, S21, and S8 at the mouth of Ukumehame canyon. The depth to the conductive seawater interface at Ukumehame ranges from 273 to 608 feet. Using the salinity-resistivity-temperature nomogram (Meidav, 1970) and typical Hawaiian basalt porosities of 15 to 25% we estimate the seawater temperature to be 73 to 120°C. Future work will concentrate toward the back of Ukumehame canyon in an attempt to locate the heat source.

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