U.S. Department of the Interior
Geological Survey

Estimation of Fresh Water Abundances by Electrical Resistivity Sounding on the Kalaupapa Penninsula, Island of Moloka'i, Hawai'i

by

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At the request of the U.S. Geological Survey, Water Resources Division, Hawai'i district, 5 VES (vertical electrical-resistivity sounding) were made on the Kalaupapa penninsula, island of Moloka'i in order to estimate the amount of fresh ground-water there. The Kalaupapa penninsula is a broad, low volcano situated at the base of a huge sea cliff cut into the older and larger East Moloka'i volcano (Macdonald and Abbott, 1970). In coastal areas like the penninsula, fresh water generally floats on salt water within the porous island mass. Electrical-resistivity soundings can measure the extent to which the salt water surface is depressed below sea level by the fresh water because salt water saturated volcanic rocks have a significantly lower resistivity than do dry or fresh water saturated volcanic rocks and because a VES is capable of measuring the vertical distance from ground surface to a low resistivity rock formation. Details of VES sounding method can be found in Zohdy (1974) whereas details of the method's application in Hawai'i can be found in Kauahikaua and Jackson (1983).

Each VES was conducted using the Schlumberger electrode configuration. The location of the five soundings obtained on May 18 and 19, 1982 are shown in Fig. 1. Most of them are located on the southern base of the penninsula where hydrologists expected the most abundant fresh water. Because of the low elevation of the area, half current electrode spreads (AB/2) of less than 500 m were used. Each set of sounding data was interpreted in terms of horizontally-layered earth models by program MARQDCLAG Anderson (1979). The data and their computer interpretations are plotted in the appendix.

Two of the five VES were made along curved roads. VES3 data were corrected for a curved electrode path by computing the true, straight-line distance from the sounding center to each electrode and recomputing the apparent resistivities using the actual distances. The corrected apparent resistivities were then plotted at an electrode spacing equal to the square root of the product of the two electrode-to-center distances (Zohdy and Bisdorf, 1982). The curvature of VES1 was not severe enough to warrant correction.

Four of the five VES interpretations have one principal layer with a resistivity between 450 and 700 ohm-m, which is probably the resistivity of the Kalaupapa basalt. The value is slightly lower than the value found for volcanics in the Waimea area on the island of Hawai'i (Kauahikaua and Jackson, 1983). The variable surface layer is less than 5 m thick in all soundings. The low-resistivity layer between 9 and 50 m deep in VES3 may be valley-filling alluvium beneath 9 m of loose, rocky material similar to that exposed at the surface. All five VES indicate that a thick, low resistivity rock unit lies less than 100 m below sea level. Its resistivity is unresolvable by program MARQDCLAG except for a value of about 20 ohm-m in VES5. It is this unit that probably represents salt water saturated rock.

The vertical thickness of fresh water can be estimated from the VES interpretations (in the appendix) by subtracting the sounding elevation (at the sounding center) from the interpreted depth to salt water saturated rocks (the low resistivity basement). The derived values are collected in table I. The largest estimate is from VES3, the area where the fresh water was originally expected to be thickest.

There is another possible interpretation for VES3. Because it is known to cross several buried dikes of the main east Moloka'i volcano, the thicker estimate from that sounding may be an indirect effect of dikes. Dikes can impound great thicknesses of fresh water behind them (Macdonald and Abbott, 1970); a VES obtained over a dike-impounded water body, but which crosses the dike and extends over a thin fresh water layer may not show obvious signs of distortion by the 2D structure but would nevertheless not represent conditions on either side of the dike accurately. Using a very simple 2D model in the collection by Beyer (1977), one can show that the VES3 data are compatible with the above hypothesis if the sounding center is about 250 m from a dike on the impounded-water side (see Fig. 2).

TABLE I
Estimates of fresh ground-water thickness

VES1	14m
VES2	12m
VES3	95m
VES4	21m
VES5	6.6m

REFERENCES

Anderson, W.L., 1979, Program MARQDCLAG -- Marquardt inversion of DC- Schlumberger soundings by lagged-convolution: U.S.G.S. Open-File Report 79-1432, 58 p.

Beyer, J.H., 1977, Telluric and DC resistivity techniques applied to the geophysical investigation of Basin and Range Geothermal Systems, Part II -- A numerical Model Study of the dipole-dipole and Schlumberger resistivity methods : Lawrence Berkeley Labs technical report LBL-6325 2/3, 211 p.

Kauahikaua, J. and Jackson, D.B., 1983, Groundwater exploration in the south Kohala district, Hawai'i county, Hawai'i, using vertical electrical sounding : USGS Open File Report 83-67, 26 p.

Macdonald, G.A. and Abbott, A.T., 1970, Volcanoes in the sea: Univ. of Hawaii Press, Honolulu, 441 p.

Zohdy, A.A.R., 1974, Electrical methods in Application of surface geophysics to ground-water investigations : Tech. of Water-Resources Inv. of the U.S. Geo. Survey, ch. D1, p. 5-66.

Zohdy, A.A.R. and Bisdorf, R.J., 1982, Schlumberger soundings in the Medicine Lake area, California: U.S.G.S. Open-File Report 82-887, 162 p.

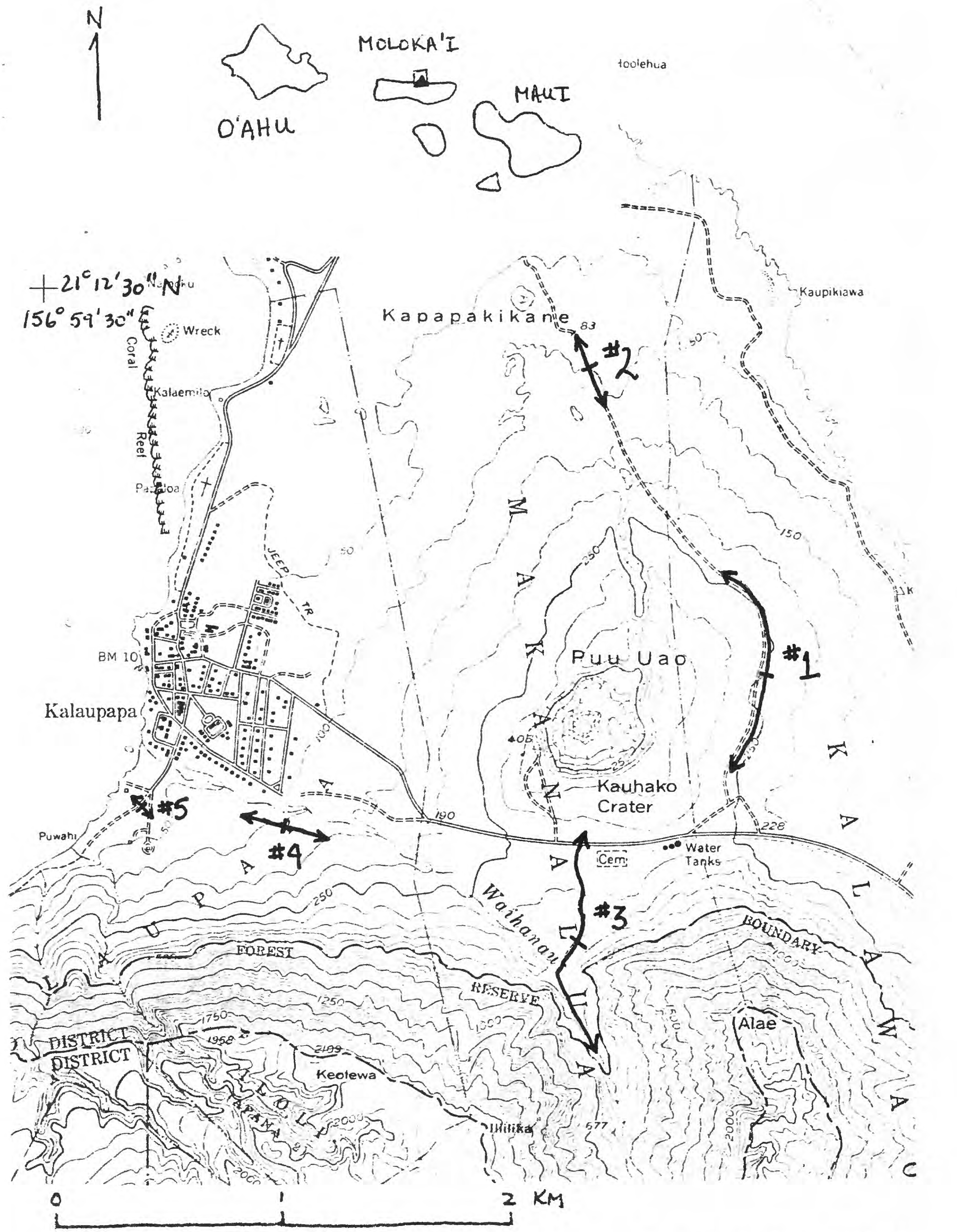
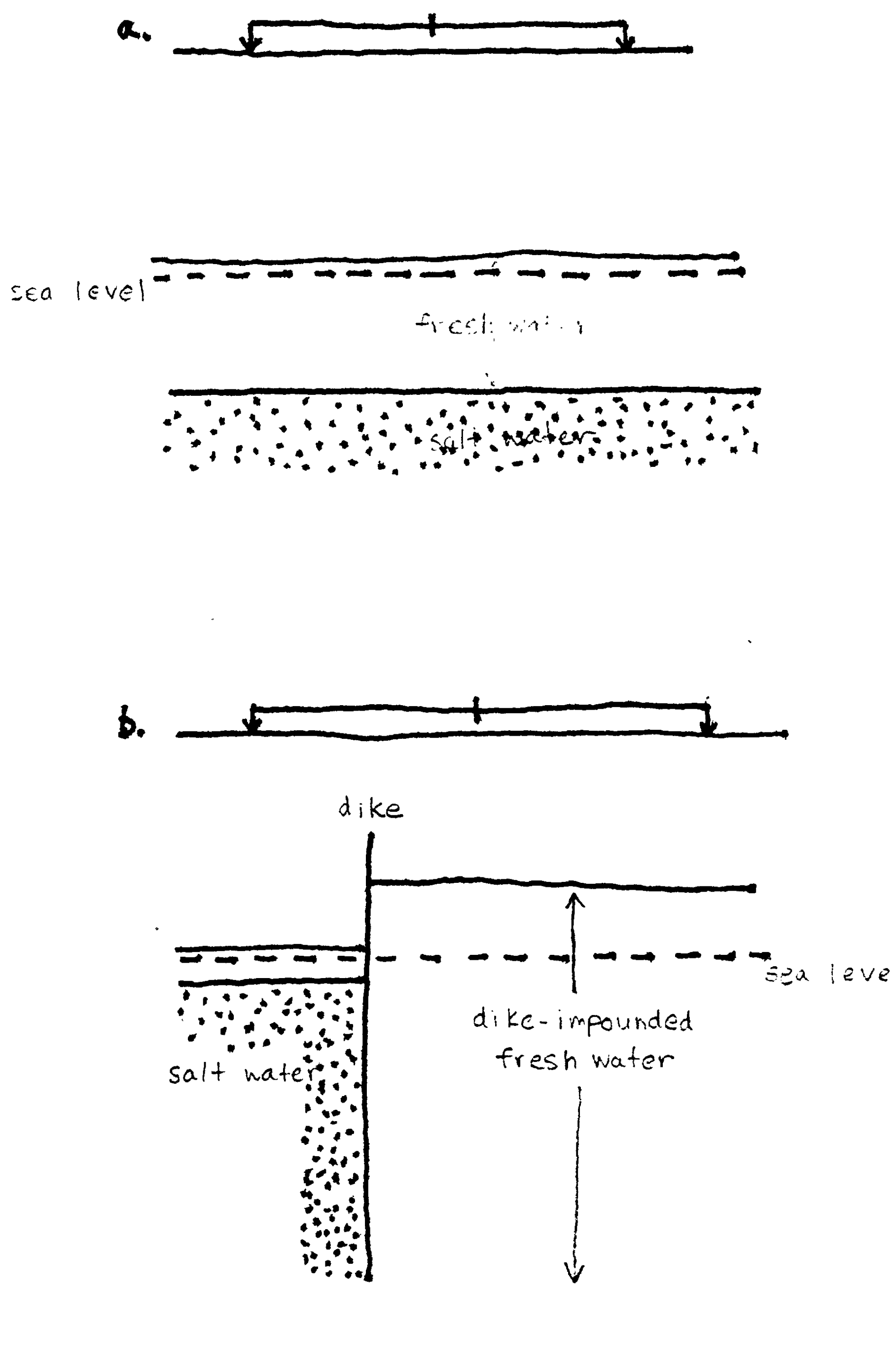


Figure 1. Map of study area showing the locations of 5 electrical-resistivity soundings. Map base from the Kaunakakai, Hawaii quadrangle (1:24,000).

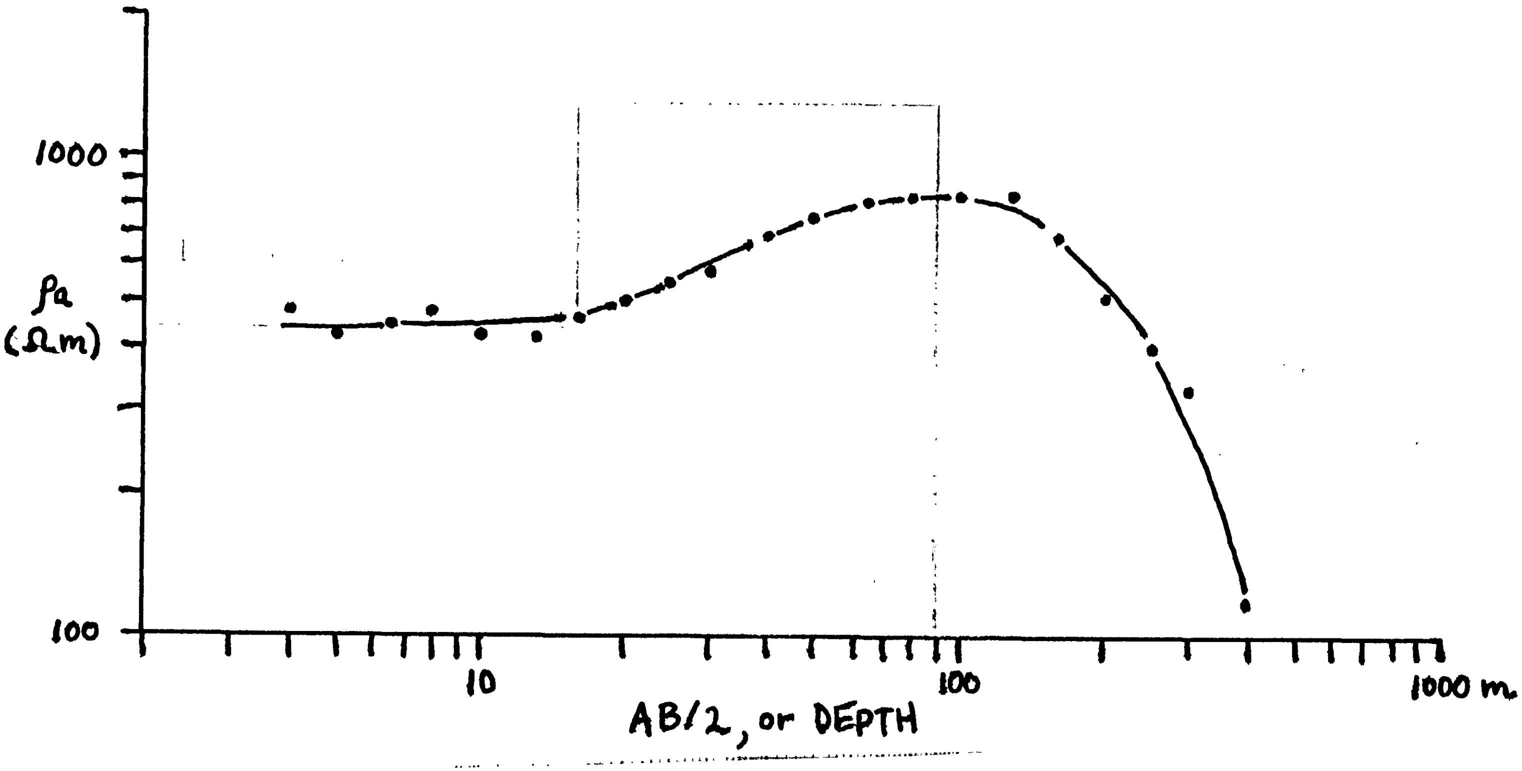
Figure 2. Alternate interpretations for VES3. a) horizontally-layered earth model with basement conductor assumed to be salt water-saturated rock, b) model where basement conductor does not extend horizontally beyond the position of a vertical dike.



APPENDIX

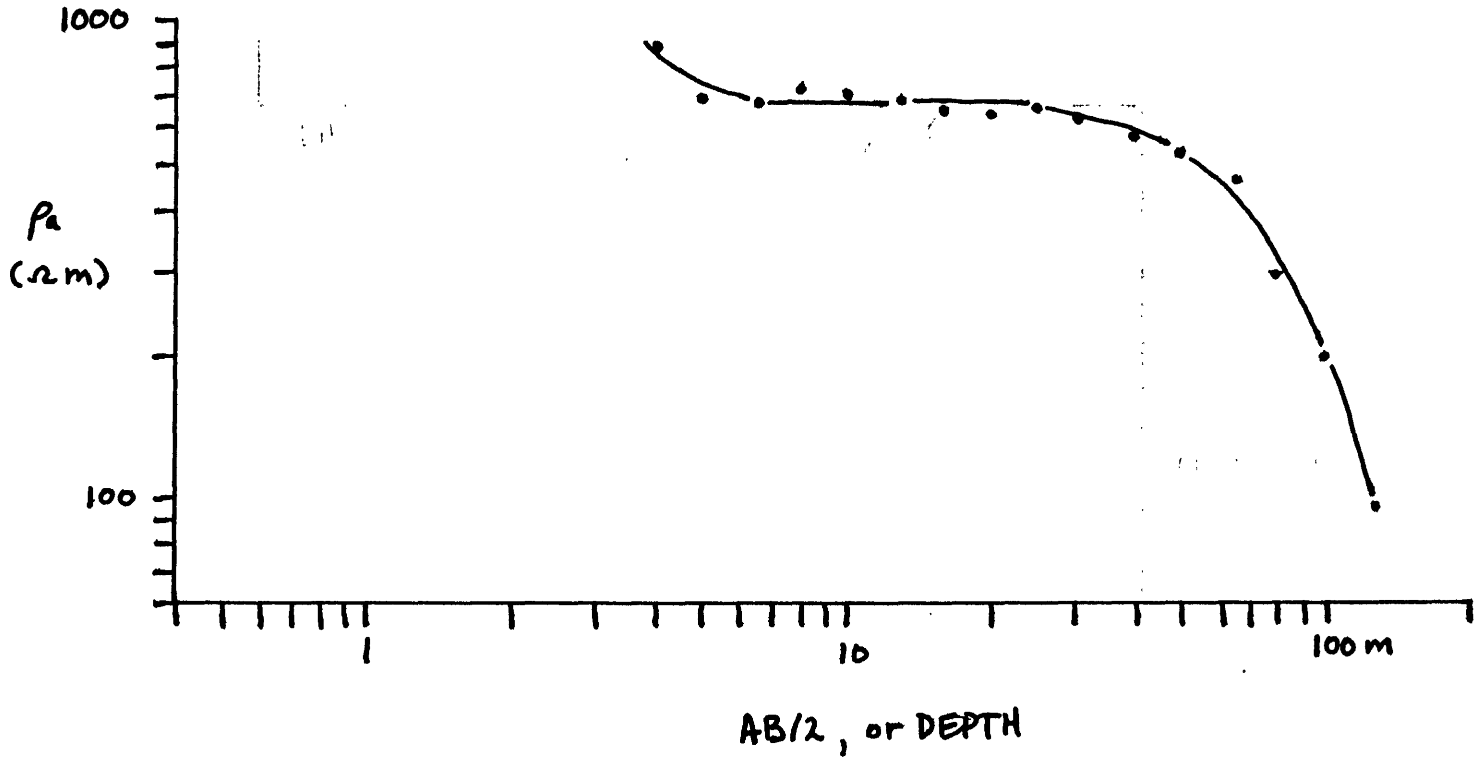
explanation of the symbols used:

Dots (labeled "OBSERVED") represent the smoothed data points and the solid, curved line (labeled "CALCULATED") is the apparent resistivities calculated for the model found by program MARQDCLAG. The model itself is listed at the bottom of the plot and is plotted with the data as a stepped line (labeled "LAYERING"). Layer resistivities and thicknesses are listed along with their estimated errors (in parentheses). Parameters with asterisks instead of errors in parentheses were not allowed to vary during computer interpretation. Parameters without asterisks or errors in parentheses had estimated errors much larger than 100% and were consequently not considered reliable; it will be sufficient to note that those parameters are very poorly resolved.



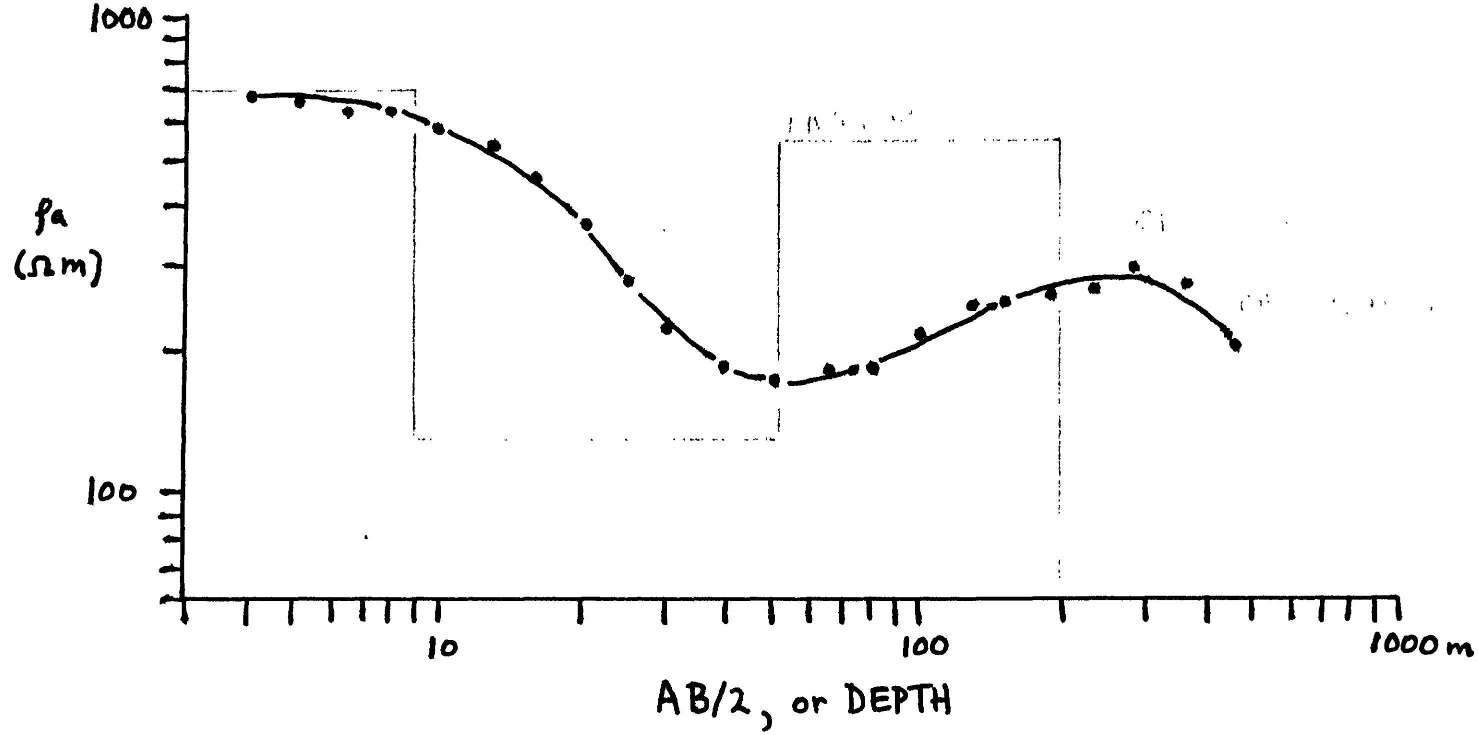
VES 1
elevation= 75 m

resistivity	thickness	depth
437 (2%)	16 (11%)	16
1291 (10%)	73 (12%)	89
20 *		



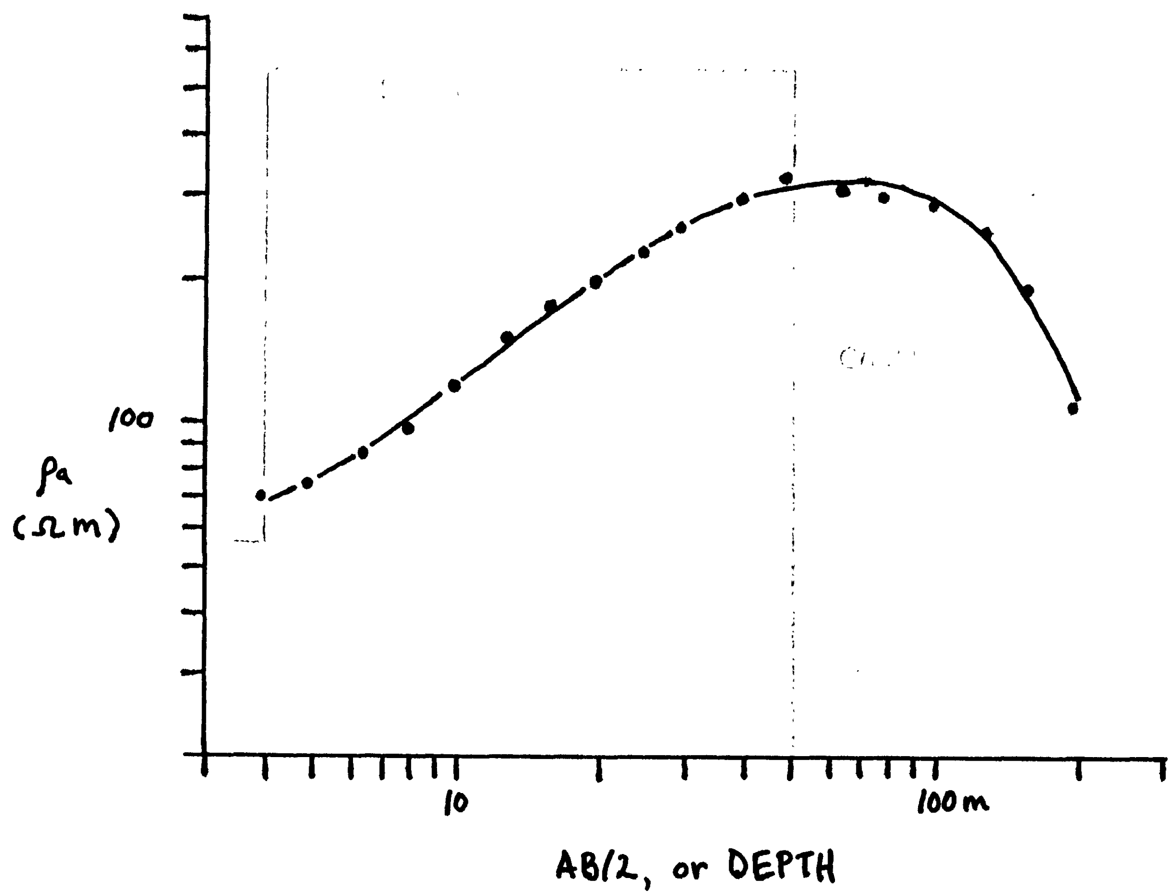
VES 2
elevation= 30 m

resistivity	thickness	depth
80,895	0.59	0.59
655 (1%)	41.8 (3%)	42
1 *		



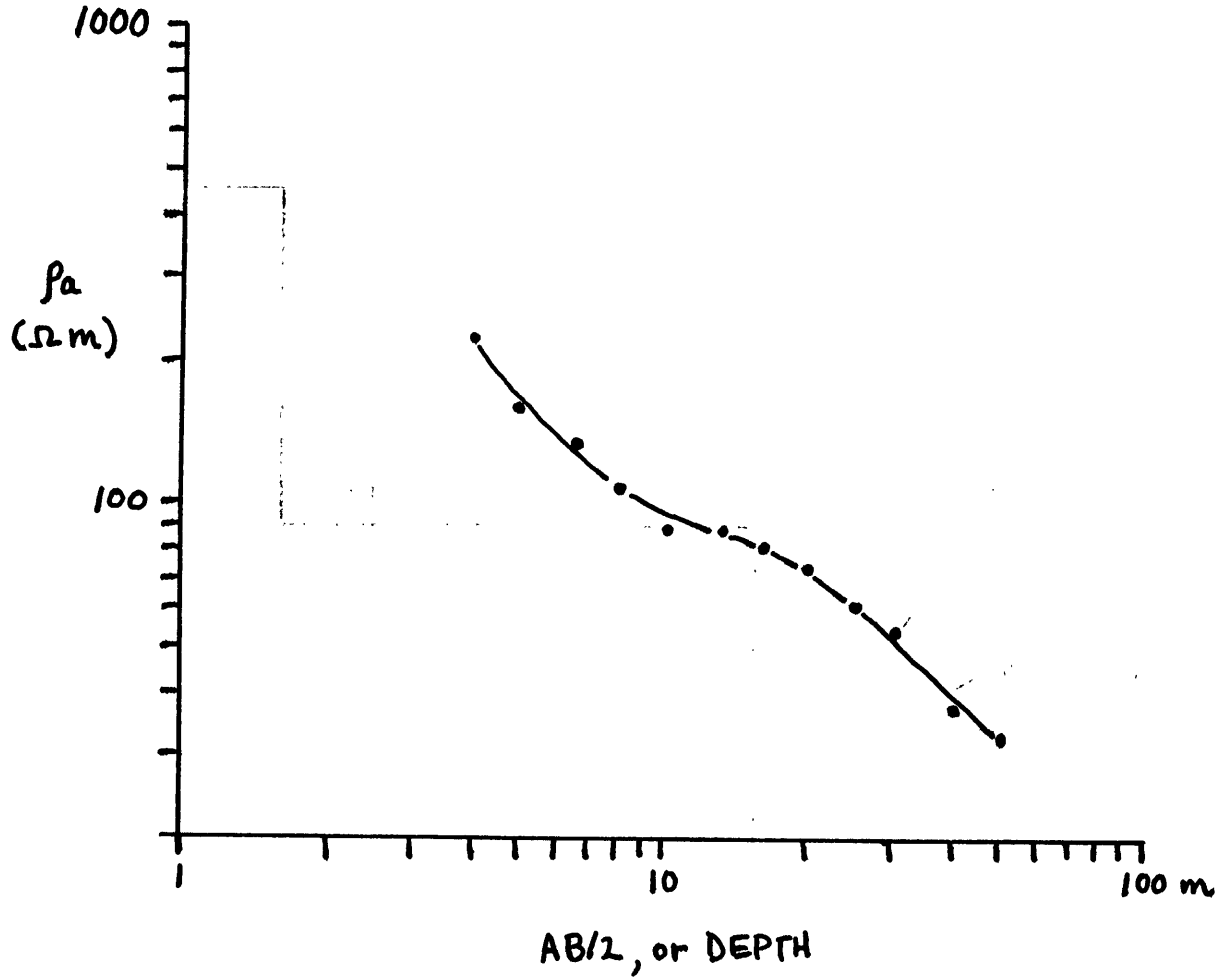
VES 3
elevation= 107 m

resistivity	thickness	depth
699 (1%)	9 (4%)	9
132 (13%)	43 (33%)	52
548 (30%)	150 (37%)	202
1 *		



VES 4
elevation= 30 m

resistivity	thickness	depth
56 (19%)	4 (23%)	4
552 (10%)	47 (12%)	51
1 *		



VES 5
elevation= 9 m

resistivity	thickness	depth
458 (18%)	1.6 (11%)	1.6
90 (7%)	14 (21%)	15.6
20 (43%)		

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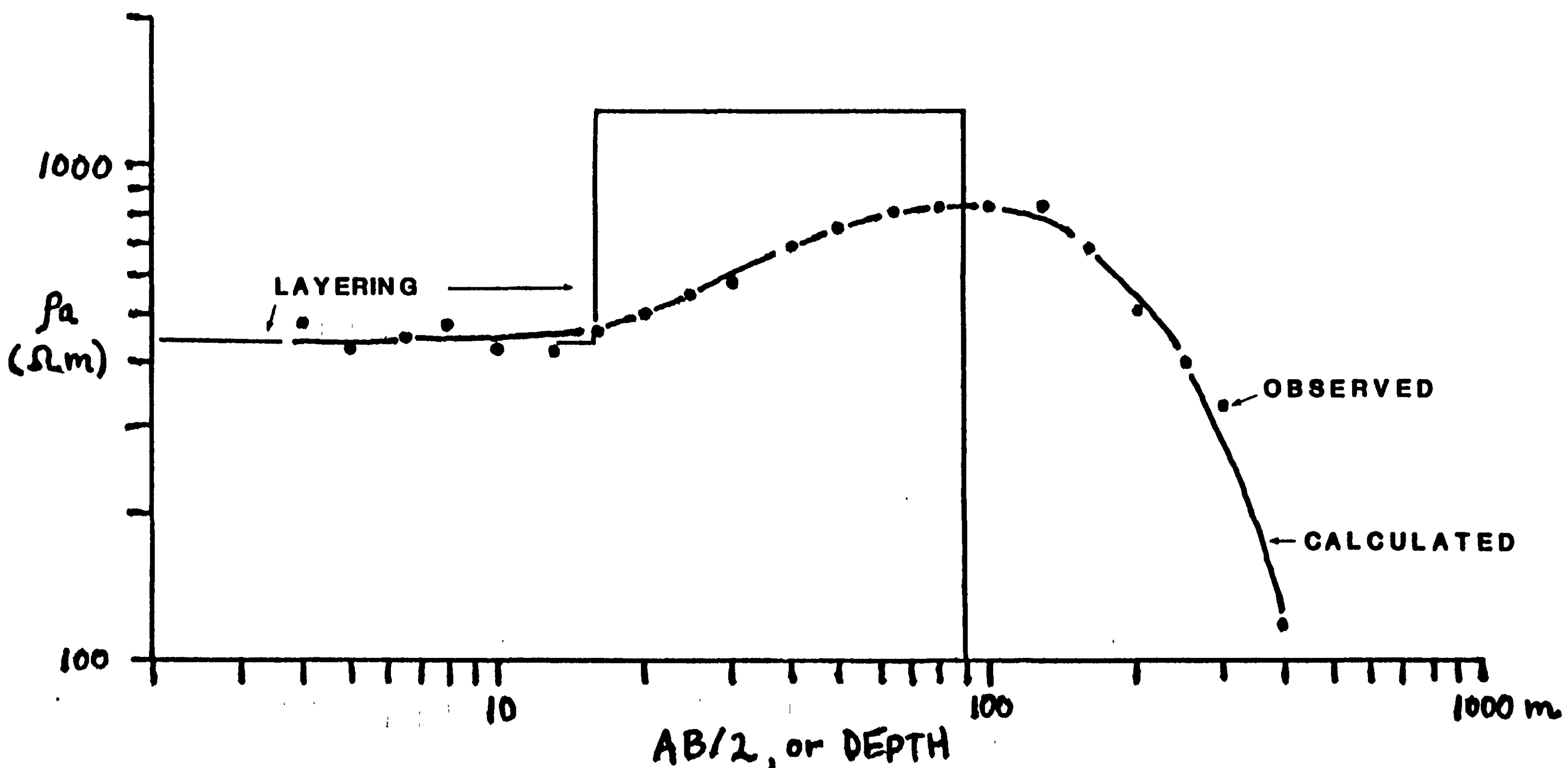

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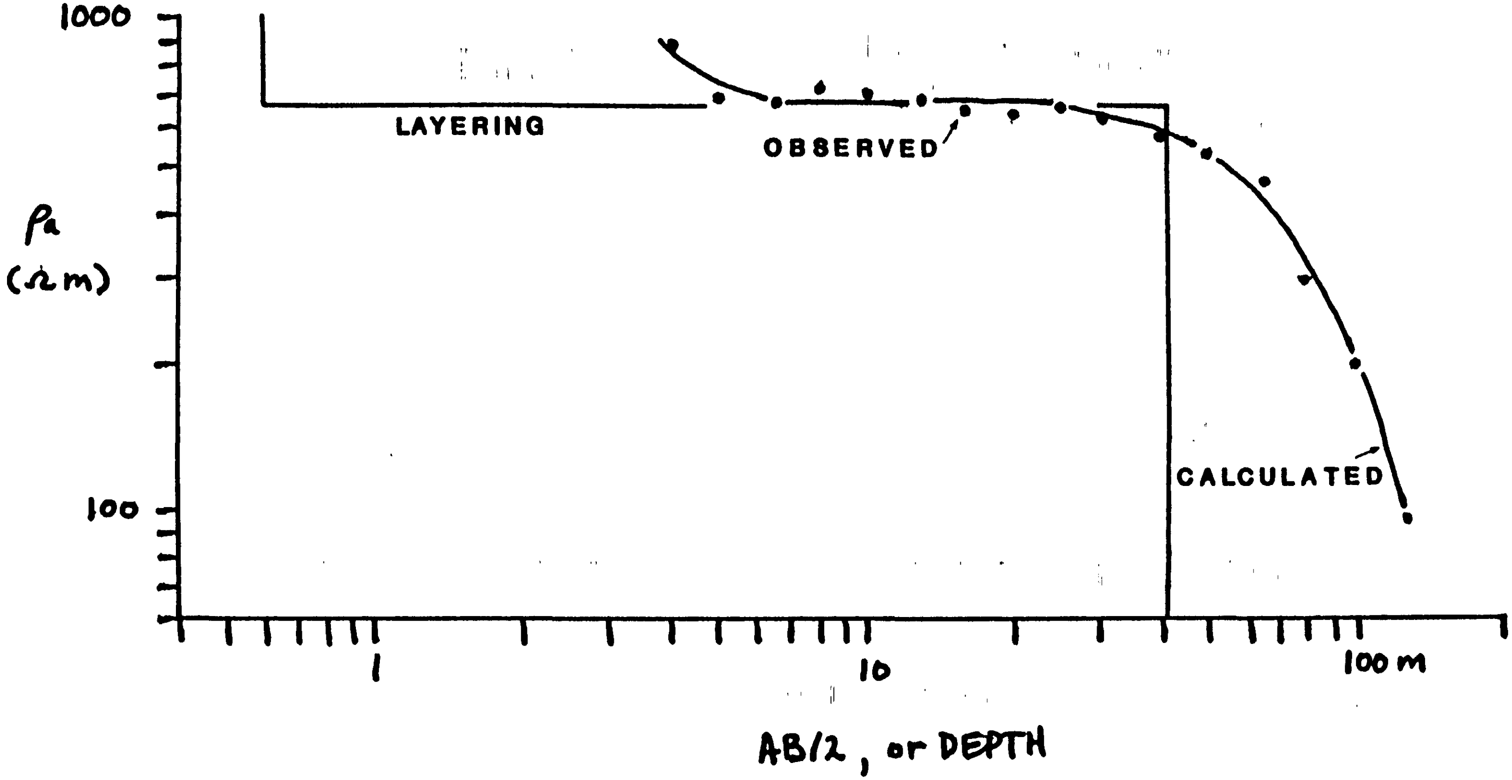

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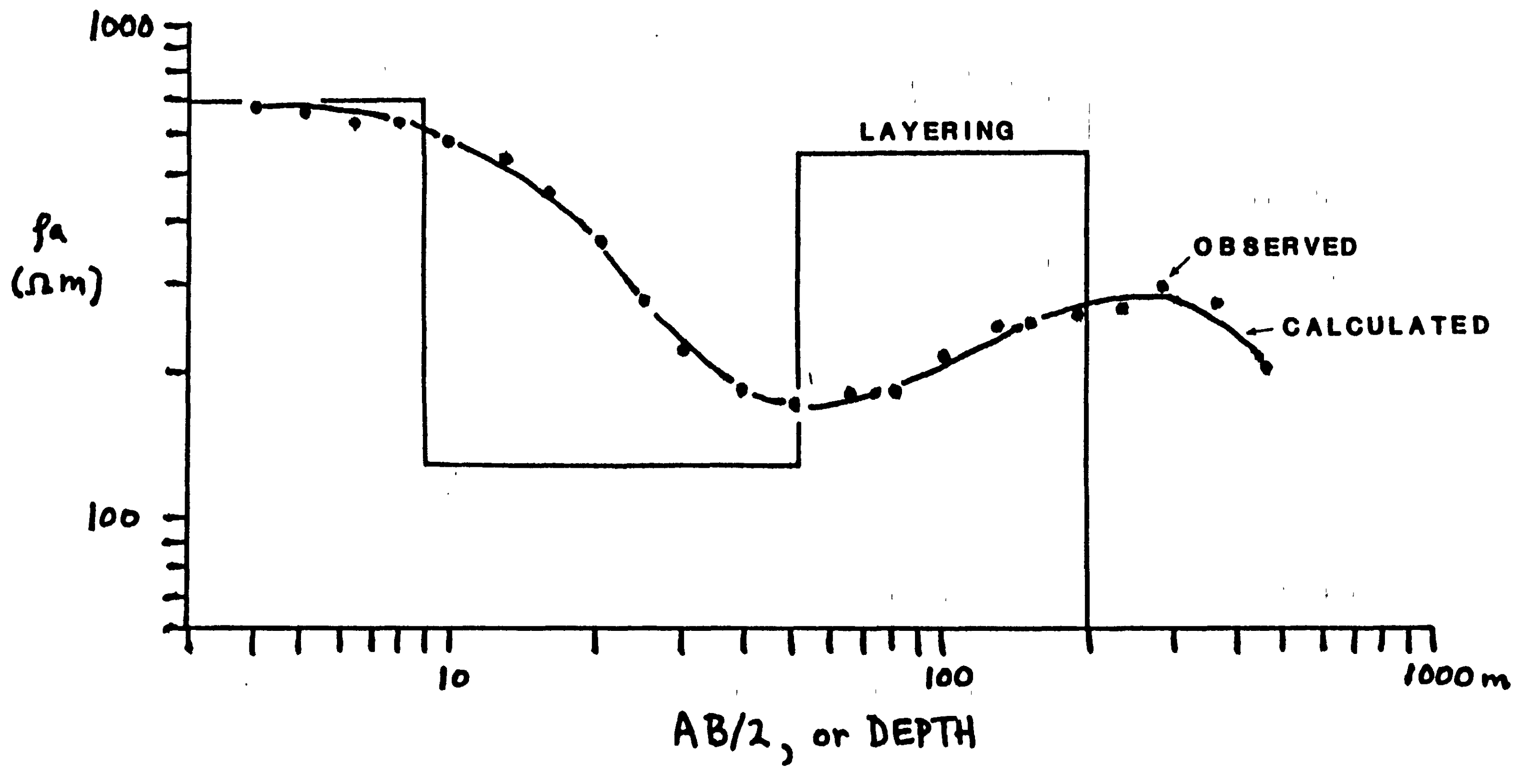

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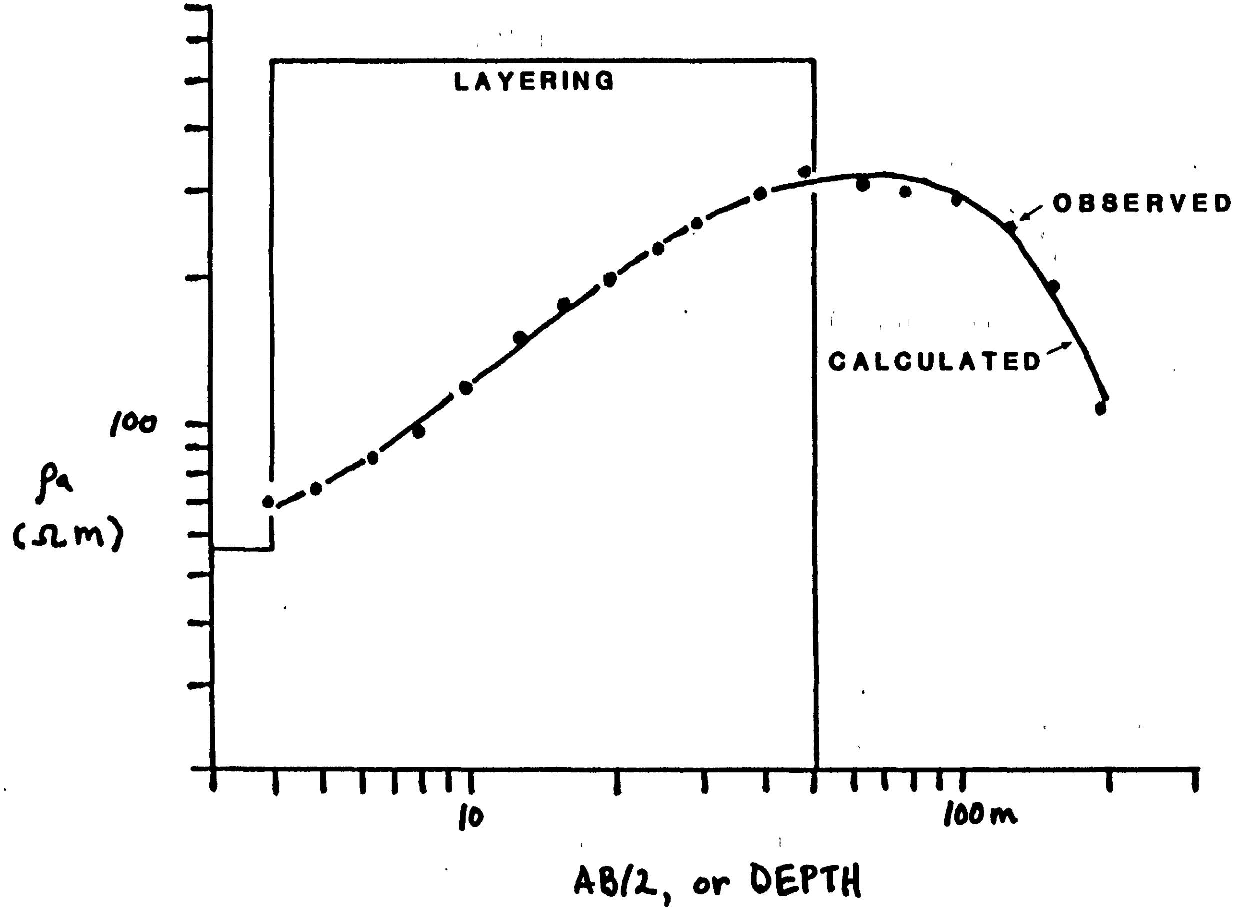

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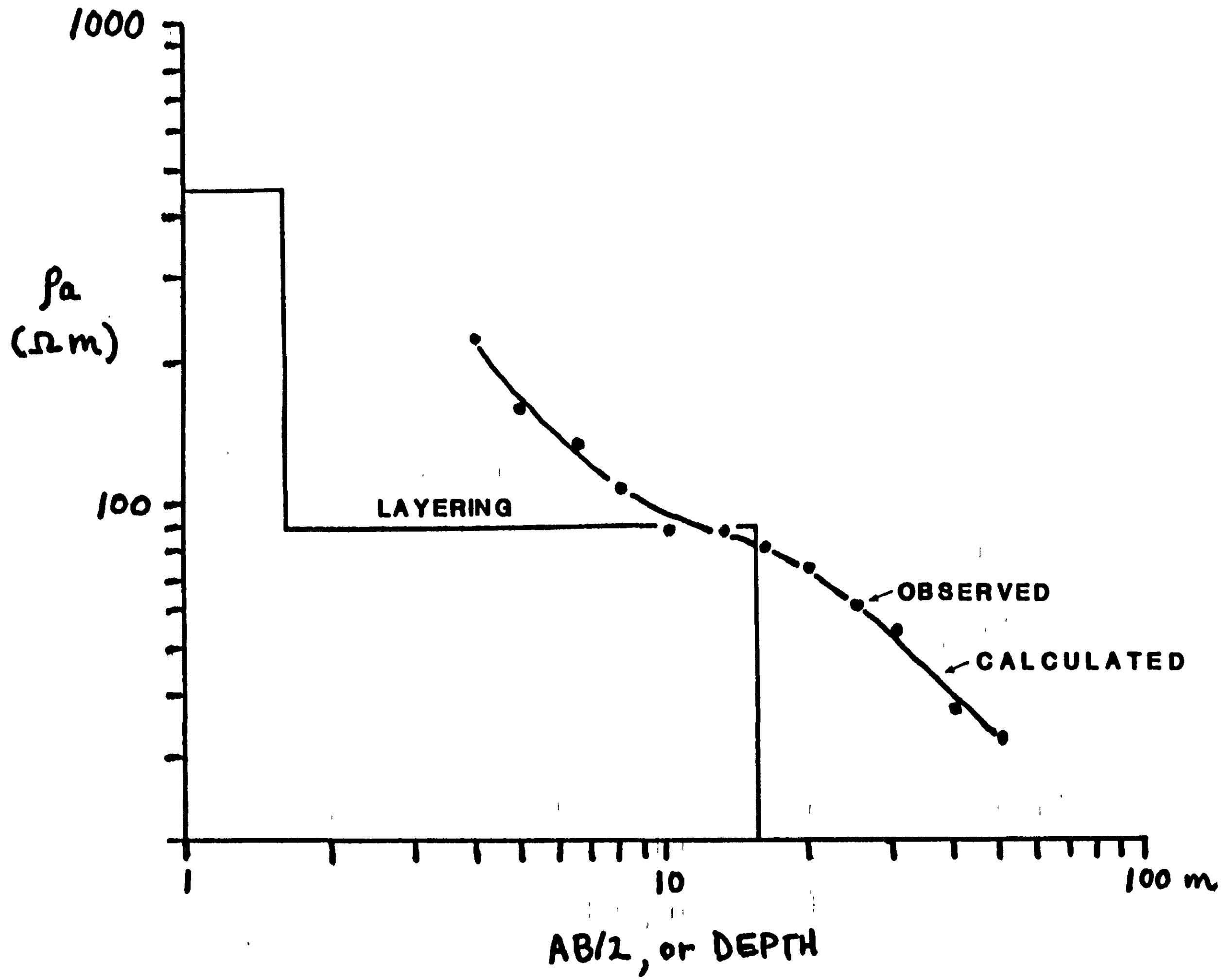

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