DEPARTMENT OF
MINERALS AND ENERGY

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1975/25

MILDURA RESISTIVITY DEPTH PROBE, VICTORIA, 1973

by

B.H. DOLAN, E.J. POLAK, and D.C. RAMSAY

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SUMMARY

Two deep resistivity depth probes at right angles were carried out near Mildura, Victoria. The survey was undertaken to provide information for proposed magnetotelluric work in the same area, and to field-test newly acquired high-power resistivity equipment.

The results were interpreted as a five-layer case with resistivities ranging from 0.5 to 58 ohm-m, and with the top of the deepest layer at 720 m. This interpretation correlates well with other geological information.

1. INTRODUCTION

Mildura is located in western Victoria on the Murray River (Plate 1). The area is flat, sparsely populated,and crossed by roads in N-S and E-W directions.

Quaternary sands and gravels overlie Tertiary and Cretaceous rocks which have been proved in several bores. Bore indications are that the beds are horizontally layered, and this evidence is supported by two seismic surveys (Branson, Moss, & Taylor, 1972; Watson, 1962).

This general area was chosen for a deep electrical investigation because the local geology was simple, there was good access, and sites could be selected which were clear of towns or houses.

The purpose of the investigation was to find the resistivities and thicknesses of the strata for correlation with proposed magnetotelluric work and to assess the capabilities of a newly obtained high-power transmitter for deep resistivity investigations.

Two resistivity depth probes at right angles were placed about five kilometres north of Pirlta, a railway station on the line from Redcliffs to Morkalla (Plate 1). The work was done by a party from the Engineering Geophysics Group, consisting of B.H. Dolan, E.J. Polak, D.C. Ramsay (geophysicists), and R.C. Watson (draftsman) during the week from 9 to 14 April 1973.

2. GEOLOGY AND PREVIOUS GEOPHYSICS

The pre-Permian basement geology of the area is not very well known, since none of the bores penetrate formations earlier than Permian. Wentworth No. 1 bore, 58 km north of the depth probe (Plate 1), proved a sequence of Quaternary, Tertiary, Cretaceous, and Permian (A.O.G., 1962), and penetrated 6 m into a pre-Permian conglomerate. Plate 2 shows the geological and electrical logs of Wentworth No. 1 bore.

Wentworth No. 1 bore was drilled on shot-point No. 30 of Traverse F of the BMR seismic survey (Watson, 1962), which showed a reflection at 275 m corresponding to the top of Eocene, and another at 381 m near the top of Cretaceous. A reflection and refraction at 564 m is close to the top of the lower Palaeozoic basement found in the bore at 626 m. Another reflection at 762 m is below the depth reached by the bore. The resistivity log of the bore shows a very high-resistivity basement overlain by medium-resistivity beds up to the top of Oligocene.

Traverse G of the BMR seismic survey is located about 8 km north of the resistivity probe. The traverse was repeated in 1972 (Branson, Moss & Taylor, 1972) in a successful attempt to obtain reflections from the mantle. Seismic refractions indicate three layers with a velocity of 1.5 km/s down to 150 m, followed by velocity of 2.15 km/s to 740 m, and a bottom refractor with a velocity of 4.9 km/s.

3. METHODS AND EQUIPMENT

The resistivity of a rock depends on the resistivity of the rock matrix and of the fluid that occupies the pore spaces within the rock. If the resistivity of the interstitial fluid is constant, the resistivity measured depends mainly on the porosity of the material. Even above the water-table there is normally sufficient moisture for the measured resistivity to be substantially lower than that of the rock matrix.

Depth probing is used to determine vertical variation in electrical resistivity. There are several arrangements of electrodes which can be used in electrical surveys (Heiland, 1946).

In the Schlumberger arrangement, which was used on the survey, four electrodes are placed in line, and the separation of potential electrodes is kept small compared with the separation of the current electrodes. The current electrodes are then advanced in stages to reach the maximum spacing, which will be roughly six times the depth of investigation. On this survey maximum spacing was six kilometres.

The apparent resistivity in ohm-metres at any spacing is calculated from a measurement of the potential drop, the current applied, and a factor depending on the geometrical arrangement of the electrodes. A graph of a depth probe is then obtained by plotting on a log-log scale the apparent resistivity value against the spacing. Generally two depth probes at right angles are taken on each location; these are considered sufficient to guard against the possibility of excessive electrical anisotropy, although ideally at least three probes in different directions should be made. The results of the depth probes are shown in Plate 4.

There are several methods of interpretation of the resistivity data, some only qualitative, others quantitative. In the interpretation of the results from Mildura the following sequence of interpretation has been adopted.

The initial interpretation was done by use of the BMR precalculated two-layer curves, superimposed on the field curves (van Nostrand & Cook, 1966). The process of interpretation was repeated for underlying resistivity layers using the Hummel (1931) equivalence principle.

The values for the thicknesses and resistivities obtained from two-layer curve interpretation were then fed into the Cyber 7600 computer. Two programs were used to check the interpretation: one developed by Cook (1969) based on the method of van Dam (1965), and one by A.A.R. Zohdy (pers. comm.).

Professor K. Vozoff's program (pers. comm.) was also used. This program does not require an initial interpretation by use of two-layer curves. The field data were fed into the Cyber 7600 and the print-out showed the resistivities and thicknesses of the layers, and the percentage deviation of the theoretical curve from the field curve at all computed points.

During the survey an induced polarization transmitter manufactured by Geotronics Pty Ltd was used. This instrument transmits a square-wave pulse of constant current amplitude. The pulse may be varied up to 20 A peak-to-peak with a maximum of 800 V potential difference between the current electrodes. The frequency is also variable: 0.3 and 0.1 Hz were used during the survey.

The layout of the receiving unit as assembled by BMR is shown in Plate 3. The receiving unit included a telluric compensator to back off the potentials due to natural earth currents.

4. RESULTS

The results of interpretation are shown in Plate 4.

The similarity of values obtained in the E-W and N-S measurements indicates that there is probably no significant resistivity anisotropy in rock layers at depth. It was therefore decided to concentrate on the interpretation of the E-W data only, as more field measurements were taken in this probe.

The best-fitting curve obtained by superposition of two-layer curves gave a three-layer interpretation as follows:

Thickness (m)	Depth to bottom (m)	Resistivity (ohm-m)
25	25	5.0
425	450	0.7
		28.0

This interpretation was then fed into the Cook modelling program, which produced the curve shown in Plate 4; the fit is good except in the middle portion.

The Vozoff program produced the following four-layer interpretation (not shown in the plate):

Thickness (m)	Depth to bottom (m)	Resistivity (ohm-m)
25	25	5.0
135	160	0.5
560	720	1.4
		58.0

An additional layer, 4 m thick with resistivity 3 ohm-m, was then introduced at the surface to account for the downturn shown in the first few field points. This five-layer interpretation was next fed into the Zohdy modelling program, and produced a curve which is a very good fit with the field data (See Plate 4). There is also a good correlation between the resistivity interpretation and the seismic refraction data (also shown in Plate 4).

An attempt was made to fit a six-layer interpretation using the Vozoff and Zohdy programs, but the results (not shown) differed considerably from the field curve.

5. CONCLUSIONS

The five-layer interpretation of the Mildura deep resistivity probe fits the vertical distribution of resistivities as shown in Plate 2 (due allowance being made for 60 km site separation) and the results of BMR seismic work at both sites.

Layer	Thickness (m)	Depth to bottom (m)	Resistivity (ohm-m)	Geological interpretation
1	4	4	3	Above the water table
2	21	25	5	"Depth of weathering". The depth of shot-holes in the seismic survey
3	135	160	0.5	Depth to top of Oligocene
4	560	720	1.4	Depth to Lower Palaeozoic basement
5			58.0	

The geological interpretation was assisted by the additional geological information available from drill logs and from the results of seismic refraction work.

Comparison of seismic and resistivity data indicates that resistivity depth probing could be used in the area to locate two resistivity horizons: the top of Oligocene and the top of the Lower Palaeozoic basement.

The Geotronics induced polarisation transmitter proved to be a suitable current source for obtaining apparent resistivity measurements with the Schlumberger arrangement, for a current electrode spacing of up to six kilometres, which was the maximum spacing tested. This permitted interpretations to a depth of the order of one kilometre.

6. REFERENCES

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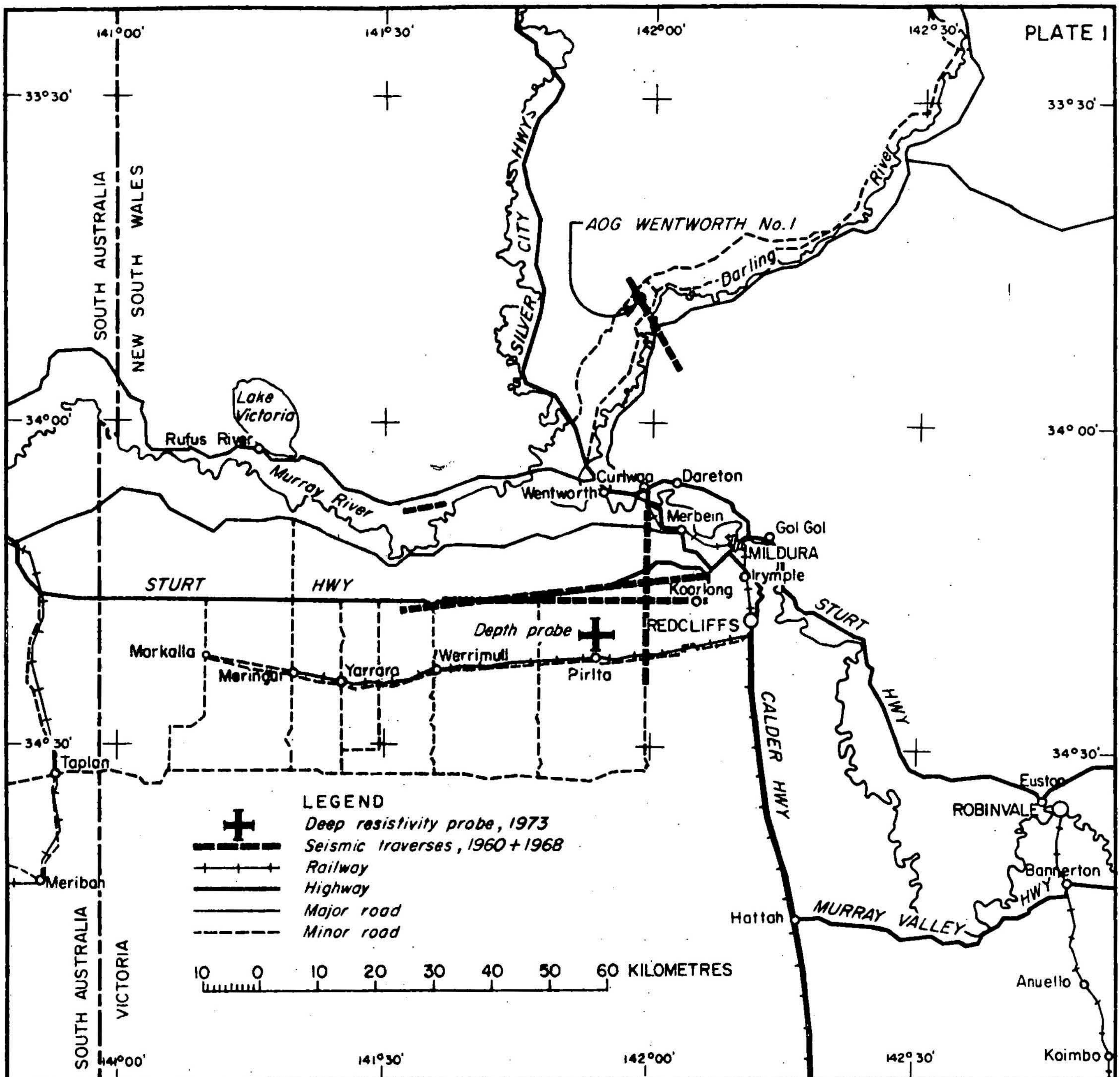
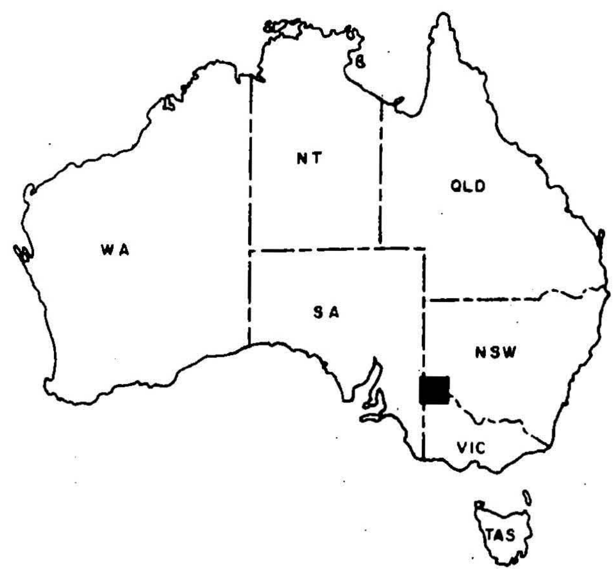
PLATE I





MILDURA DEEP RESISTIVITY SURVEY 1973

LOCALITY MAP

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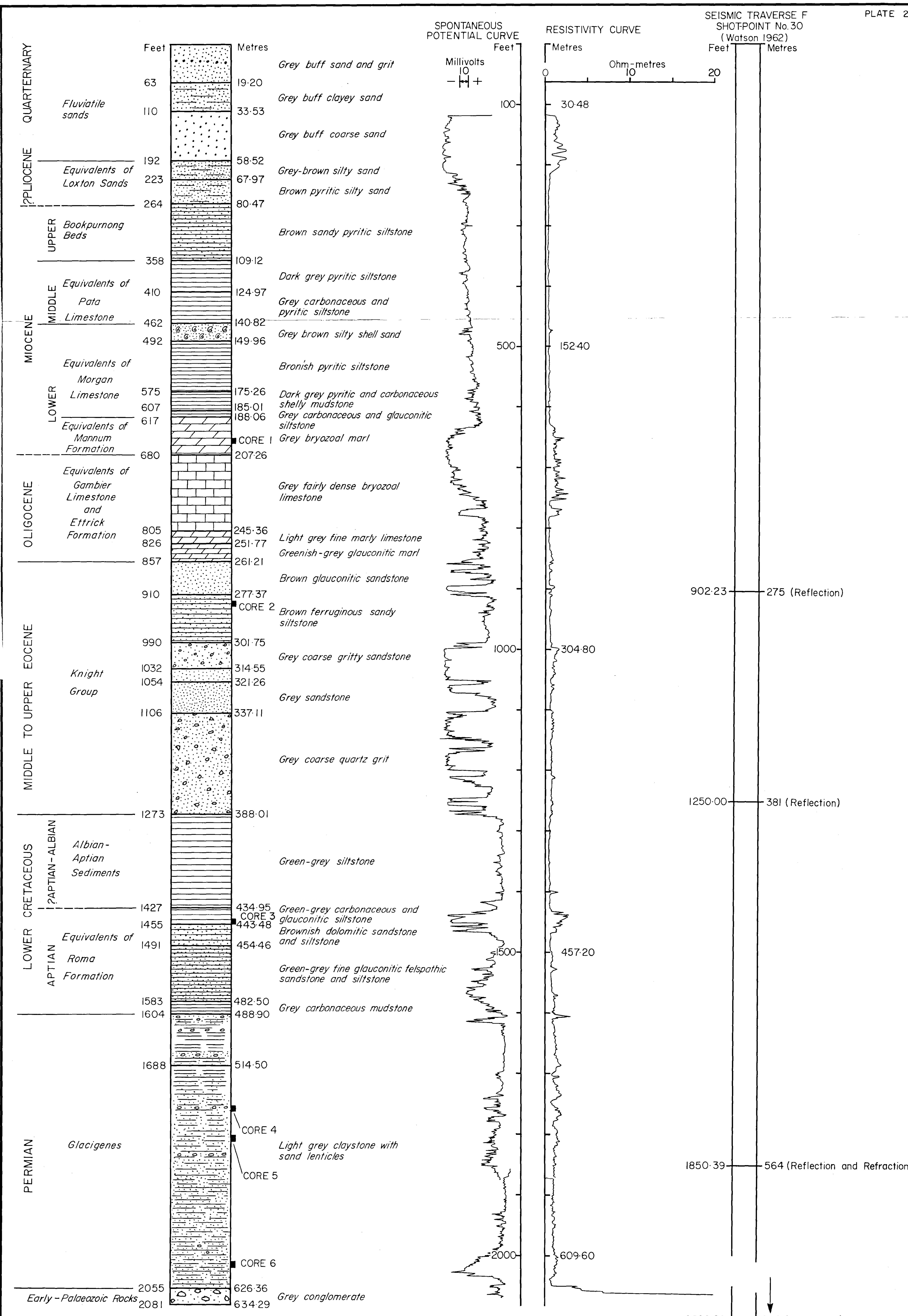

WENTWORTH NO.1 BORE LOG

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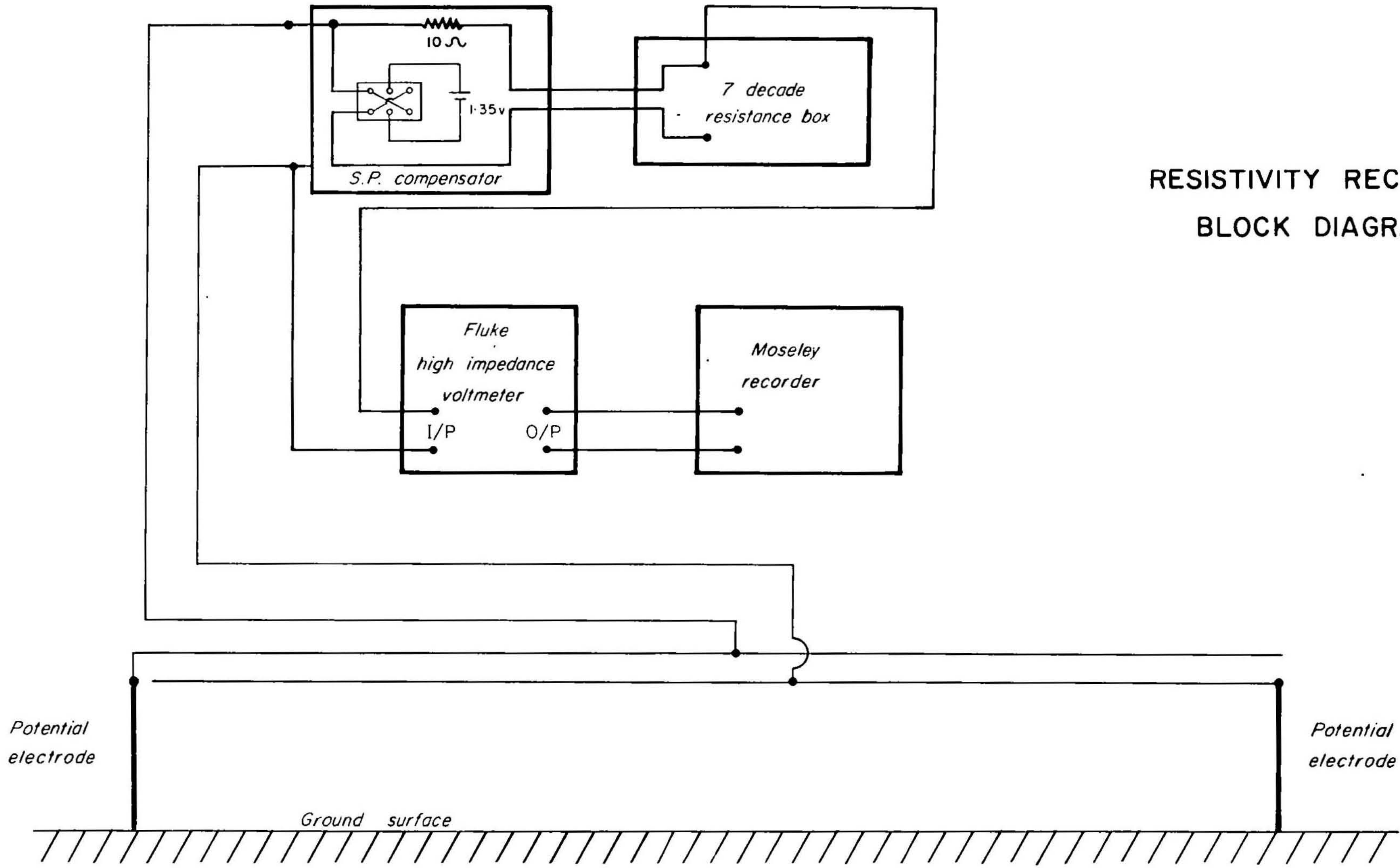
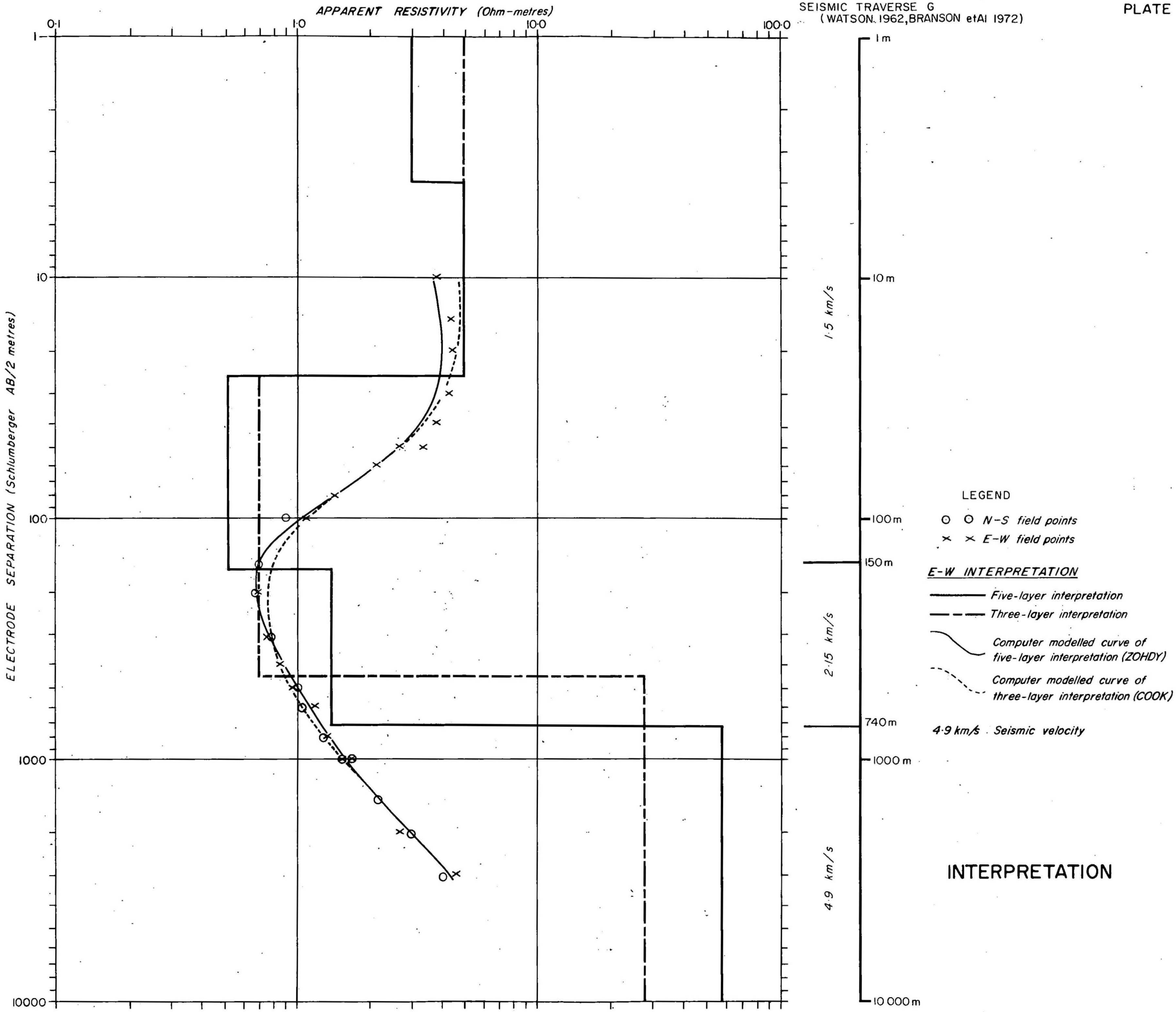


RESISTIVITY RECEIVER BLOCK DIAGRAM

G450-19A

PLATE 3

PLATE 4



INTERPRETATION

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