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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

1956, No. 121

RESISTIVITY SURVEY AT MUGGA MUGGA QUARRY, CANBERRA, A.C.T.

by

L.V. HAWKINS

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ABSTRACT

An electrical resistivity survey to determine zones of weathering in the Mugga Porphyry, was conducted at Mugga Mugga Quarry, Canberra, during August, 1956.

Continuous resistivity traverses using a standard Wenner configuration with electrode spacings of 50 and 100 feet were evaluated with the help of expanding electrode depth probes.

Generally, the depth to the unweathered porphyry is not more than 10 feet. In two places it appears to be about 10 to 20 feet, and in two additional places may be more than 20 feet. The relatively deeper weathering in these four areas may be along zones in which there has been autometamorphism of the porphyry.

1. INTRODUCTION

The Mugga Mugga quarry is situated about 200 to 800 feet south of the Mugga Mugga trig. station on the southern boundary of Canberra City, A.C.T. (Plate 1). The hill on which the quarry is situated consists of the Mugga Porphyry, which is being quarried for road making by the Commonwealth Department of Works, Canberra.

The porphyry contains zones of autometamorphism which weather more deeply than the surrounding porphyry and thus become unsuitable for road metal.

The purpose of the survey was to locate the zones of deeper weathering, as they may affect the future development of the quarry. The thickness of overburden was not required.

The electrical resistivity method of survey was selected as this was considered to be the quickest and most convenient method of obtaining the qualitative results required.

The survey was requested by the Geological Section of the Bureau of Mineral Resources and the Commonwealth Department of Works, Canberra, and was conducted by the Geophysical Section of the Bureau during August, 1956.

The topographic survey was done by the Department of Works, Canberra, which also supplied four field assistants for the geophysical survey.

The geophysical party consisted of L. V. Hawkins (party leader), geophysicist, and J. P. Pigott, field assistant.

A resistivity meter, designed and built by the Bureau, and a Megger earth tester were used in the survey.

2. GEOLOGY

The Mugga Porphyry is a dark, medium-grained, massive porphyry and forms an intrusive stock; the body forms the Mugga Mugga ridge.

The porphyry has undergone autometamorphism in places, with saussuritization of the felspars. This alteration has generally assisted the weathering of the porphyry and probably permitted weathering to extend to greater depths than elsewhere in the porphyry.

3. METHODS

As this is the first of several reports which are currently being prepared on geophysical work in the Canberra district, the resistivity method is described in some detail.

Electric current is supplied to the ground through electrodes at two points and the potential difference between electrodes at two other points is measured. The ratio of potential difference to current, multiplied by a spacing factor, gives what is known as the apparent resistivity as a function of spacing and, also, as a function of depth penetration. This application makes it possible to determine the depth to different formations, as long as formation boundaries are marked by changes of resistivity or resistivity discontinuities. The procedure is often called "depth probing" or "electrical drilling".

If the electrode spacing (and therefore the depth penetration) is kept constant and the arrangement as a whole is traversed over the area being investigated, horizontal variations in character or variations in the depth of a given formation may be determined. This technique is known as "resistivity traversing" and is particularly useful in locating variations in the thickness of a weathered layer.

The Wenner configuration of electrodes is usually used and was adopted in the present survey. The four electrodes are equally spaced in line, the two inner ones being potential electrodes. For a homogeneous medium, the following relation holds:-

$$\rho = 2\pi ab\frac{V}{I} \quad \text{................ (i)}$$

where
ρ = resistivity in ohm-centimetres
V = measured potential difference in volts
I = current in amperes
a = electrode spacing in feet
b = conversion factor (ohm-ft. to ohm-cm.)

If the subsurface is horizontally stratified, the same expression is valid, but the true resistivity, , is replaced by the apparent resistivity, ρa, i.e.

$$\rho a = 2\pi ab\frac{V}{I} \quad \text{................ (1a)}$$

In the Wenner method, the electrode separation "a" is gradually increased from 1.5 feet (log a = 0.2) by amounts which give equal increments of 0.1 in log a. For convenient interpretation, log ρ_a is plotted against log a on a scale of 1 unit in the logarithm = 2 inches. Theoretical two-layer curves have been calculated and plotted on the same logarithmic scale. The slope of the two-layer curves is controlled by the parameter K, in which

$$K = \frac{\rho 2 - \rho 1}{\rho 2 + \rho 1} \quad (2)$$

where $\rho 2$ is the resistivity of the lower layer and $\rho 1$ the resistivity of the upper layer.

The use of logarithmic plotting enables a standard curve to be applied to any section of an observed resistivity curve. For a two-layer problem, one of the type curves is fitted to the resistivity curve and the depth of the discontinuity and the resistivity of the lower layer can be estimated. The two-layer curves may also be used in the interpretation of three-layer curves by making use of Hummel's relation, which states that the apparent resistivities follow Kirchhoff's laws. For two infinite horizontal layers of resistivity ρ , and $\rho 2$ and thickness h_1 and h_2 respectively, the average resistivity (ρav) for the two layers is given by the equation:-

$$\frac{h1 + h2}{\rho\, av} = \frac{h1}{\rho 1} + \frac{h2}{\rho 2} \quad \text{.......... (3)}$$

Curves in which ρav is plotted against h_2 on a log-log scale have been constructed for several values of K. Use of these curves enables the three-layer problem to be reduced to a two-layer problem. By continuing this process, an n-layer problem can be reduced to a series of two-layer problems.

In this manner, it is possible to estimate the depths to the different layers and their resistivities. The accuracy obtained by the application of Hummel's relation to a three-layer problem increases with increased thickness of the middle layer. Further, the fitting of curves is somewhat ambiguous and consequently depth estimates sometimes range between wide limits. Generally, the accuracy of the interpretation can be improved considerably if it is known from previous measurement or experience what magnitude of resistivity can be expected in the sub-surface formations or if the resistivity results can be correlated at some point with bore hole data.

A close relationship exists between the porosity, the salinity of the water contained in the pores and the resistivity of a saturated rock (Wiebenga 1955, Appendix B). During the weathering process a rock becomes progressively more hydrated and porous, with a consequent decrease in resistivity.

Thickening of the weathered layer decreases the apparent resistivity and is shown by a minimum on the profile of a resistivity traverse.

In the present survey, resistivity traversing was used to give qualitative estimates of the thickness of weathered porphyry. Expanding electrode depth probing was carried out at two places where the resistivity traversing showed the values of apparent resistivity to be uniform and relatively low. The depth estimates and rock resistivities so obtained were used in evaluating the approximate depth of weathering.

4. RESULTS

Resistivity traversing was carried out along Traverses A, B, C and D which are shown on Plate 1. Electrode spacings of 50 feet and 100 feet were used and the results are shown on Plate 2, Fig. 1. Areas of relatively deeper weathering are indicated on the traverse plan of Plate 1 and on Plate 2, Fig. 1.

Expanding electrode depth probing was done at pegs 1150 and 1175 on Traverse A. That at 1150 was quite conclusive in its results and indicates a depth of 10 feet to unweathered porphyry. That at 1175 was marred by poor electrode contacts but indicates that the depth to unweathered porphyry may be 20 feet. The best-fitting type curve of log ρa (apparent resistivity) versus log a (electrode separation) for the depth probe at peg 1150 is shown on Plate 2, Fig. 2.

The resistivity of unweathered porphyry is shown to approach infinity, that of the weathered porphyry to be about 35,000 ohm-cm., and that of the surface of the ground to be about 105,000 ohm-cm.

A broad minimum is shown on the apparent resistivity profile along Traverse A, between pegs 900 and

1350. This minimum marks an area of relatively deeper weathering, which is shown by the depth probes to be about 10 to 20 feet deep.

A sharp resistivity minimum at peg 9 on Traverse B corresponds to the broad minimum on Traverse A. This suggests that this area of relatively deeper weathering is elongated along Traverse A.

At the south-eastern end of Traverse A, near peg 400, the apparent resistivity is approximately equal to the above minimum, and it may be inferred that the depth to unweathered porphyry at this point is also about 10 to 20 feet. No readings of apparent resistivity were taken to the south-east of peg 400.

At peg 1800 on Traverse A and between pegs 10 and 12 on Traverse D, the apparent resistivity is less than the minimum between 900 and 1350 feet on Traverse A and the thickness of weathering may therefore be a little greater than 10 to 20 feet. The resistivity minimum at peg 1800 on Traverse A coincides with a small sharp minimum near pegs 7 and 8 on Traverse D.

Elsewhere, the values of apparent resistivity are greater than the minima referred to above, and the depth to unweathered porphyry is estimated to be less than 10 to 20 feet at all points other than those previously referred to.

5. CONCLUSIONS

Between pegs 900 and 1350 on Traverse A, the depth to unweathered porphyry is about 10 to 20 feet, as indicated by the depth probes at 1150 and 1175. Near peg 11 on Traverse D and peg 1800 on Traverse A, the depth to unweathered porphyry may be slightly greater, but elsewhere in the area surveyed, it is slightly less.

The relatively deeper weathering between pegs 900 and 1350 and at pegs 1800 and 400 on Traverse A and near peg 11 on Traverse D may be along zones in which there has been autometamorphism of the porphyry.

6. REFERENCE

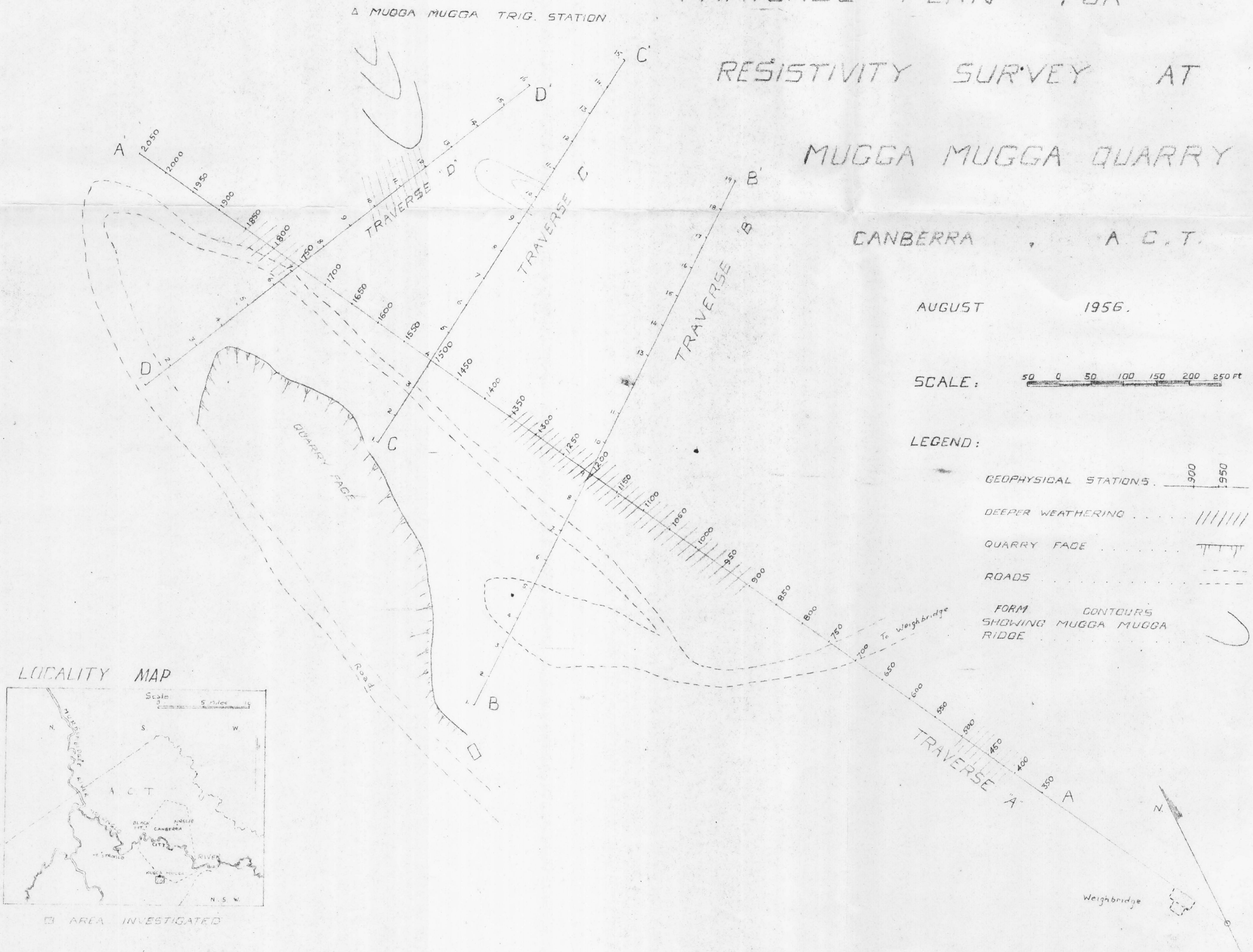
Wiebenga, W. A., 1955. - Geophysical Investigation of Water Deposits, Western Australia. Bur. Min. Res. Geol. and Geophys., Bull. 30.

PLATE 1.

TRAVERSE PLAN FOR RESISTIVITY SURVEY AT MUGGA MUGGA QUARRY

CANBERRA, A.C.T.

AUGUST 1956.



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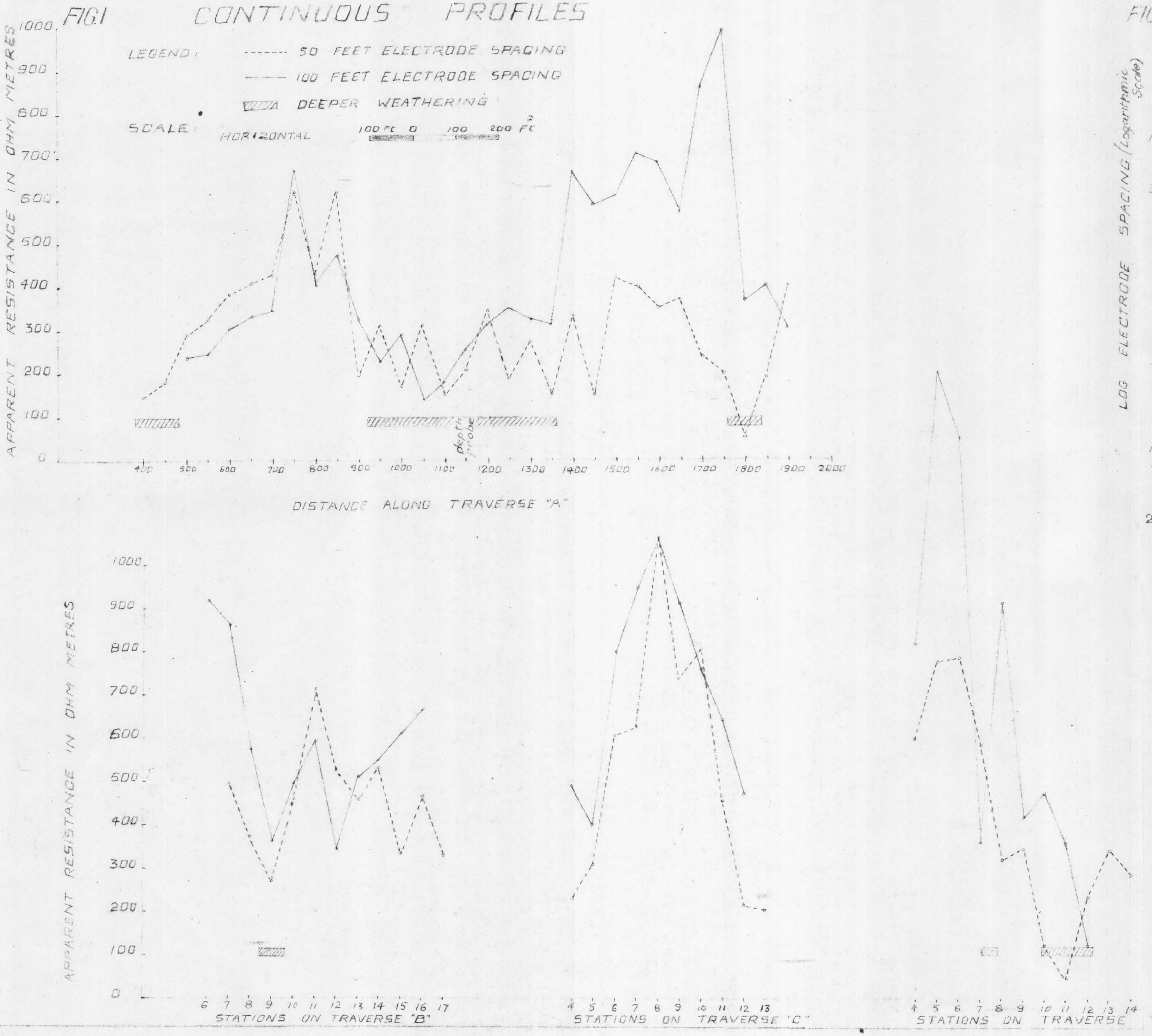

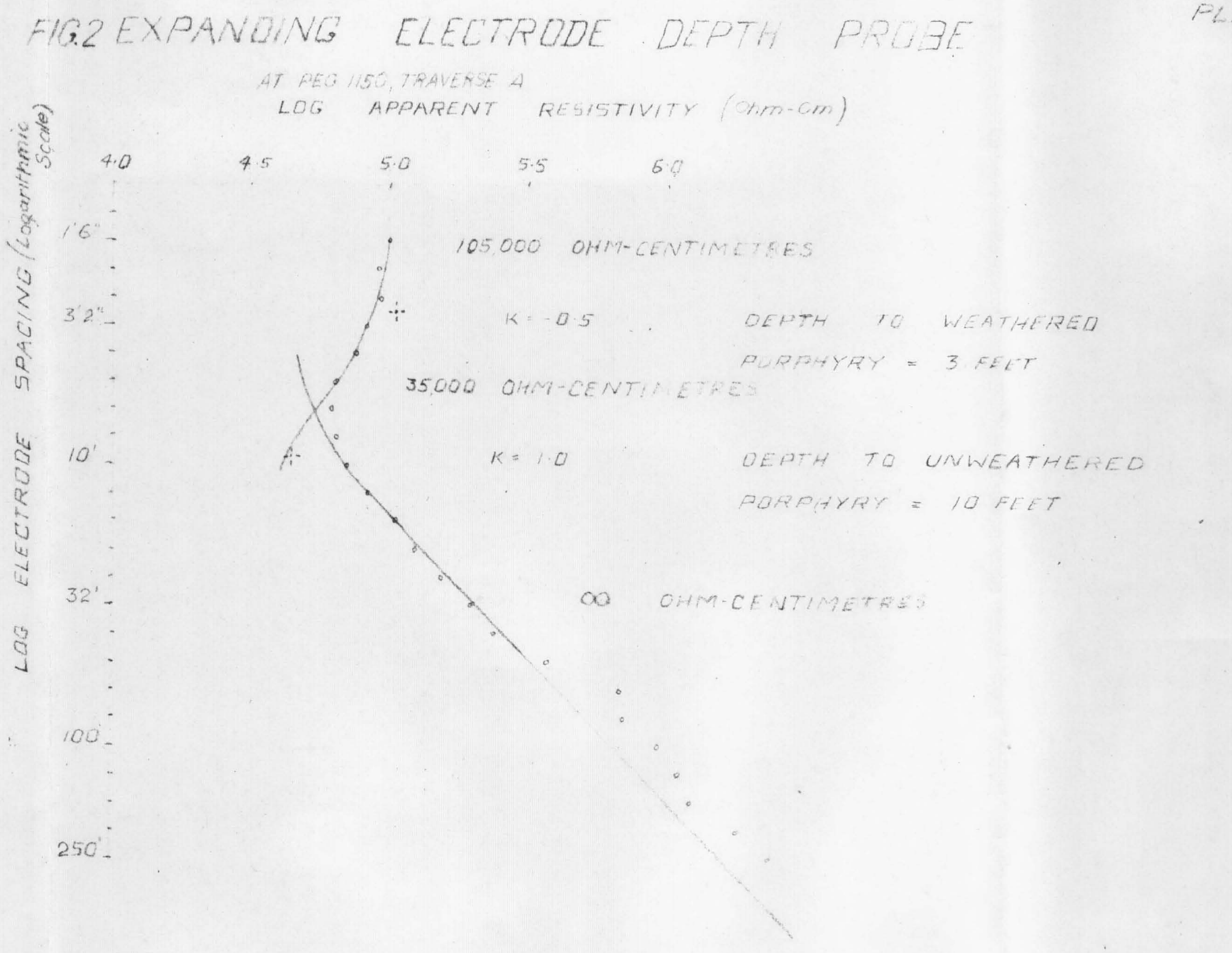

MUGGA MUGGA QUARRY

CANBERRA, A.C.T.

AUGUST. 1955.

APPARENT RESISTIVITY PROFILES AND DEPTH PROBE

GEOPHYSICAL SECTION

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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