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Record 1972/29

DOWN-HOLE INDUCED POLARIZATION LOGGING TESTS AT CURRAWANG, N.S.W. and KOWEN FOREST, A.C.T., 1971

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CONTENTS

ILLUSTRATIONS

SUMMARY

Following construction and laboratory testing, prototype down-hole induced polarization (IP) probes were used to log the BMR test hole at Kowen Forest and two diamond-drill holes on Hastings Exploration Mining Lease at Currawang, NSW.

The primary objective of the program was to establish an inexpensive IP logging system to be used with the conventional McPhar IP equipment and to evaluate the capabilities of the system.

The probes were operated in the frequency domain, and dipole-dipole electrode arrays of 3.05 metres (10 feet) and 9.14 metres (30 feet) were used.

The results were examined in relation to the geological logs of the drill holes, and this examination revealed that the method had proved successful in delineating the conductive and mineralized zones.

Further IP logging through a variety of environments would be necessary before a complete knowledge of the instrument response could be attained.

1. INTRODUCTION

The object of the program was to establish an inexpensive IP logging system and then to evaluate this system in order to determine whether further development was warranted.

Proposals for the construction of a time domain IP logging probe by the Bureau of Mineral Resources (BMR) were first put forward by J.E. Haigh (geophysicist) in September, 1969. However, development of this project did not proceed beyond 1969 and it was not until early 1971 that the project was recommenced with the intention of using existing McPhar IP Equipment and operating in the frequency domain. By this use of existing field equipment the project was put into operation rapidly and at low cost.

The electrode configuration was dipole-dipole with four electrodes of soft lead equally spaced along PVC tubing. Probes were constructed in BMR laboratory by J.W. Williams (technical officer). Dipole spacings of 3.05 m and 9.14 m were used so that the response of the instrument at different penetrations could be compared.

This Record discusses the results of IP logging in the shale-quartzite environment at Kowen Forest, ACT, and in the mineralized basic volcanic environment at Currawang, NSW. Localities of the areas are shown in Plate 1.

2. TECHNICAL ASPECTS

Construction and operation of the probes

The probes were constructed of 1.27 cm (half-inch) diameter PVC tubing with two transmitting and two receiving electrodes equally spaced along the probe in a dipole-dipole configuration.

Each electrode was 15.2 cm (six inches) long and constructed entirely of soft lead to avoid polarization of the electrodes.

The dipole-dipole configuration was chosen because of the symmetrical response of this array. Consequently the results are moere easily interpreted than those from arrays which give an asymmetrical response.

The probe was operated in the frequency domain using 5 and 0.3 Hertz with readings taken down the hole at intervals equal to the dipole spacing (i.e. 3.05 m or 9.14 m). The reading at a particular station was allocated to a depth position in the centre of the electrode array and thus profiles of apparent resistivity, percent frequency effect, and metal factor are obtained down the hole.

Sources of error in IP logging

In the first probe the cable consisted of four parallel conductors; however, this produced large coupling effects between transmitter and receiver wires. A twisted four-core cable was substituted, and this gave coupling effects which became evident only when receiver voltages were less than ten millivolts (i.e. when operating the McPhar receiver on the 1.0 and 0.5 attenuator ranges).

The excess voltage arises from capacitive and inductive coupling between the receiver and transmitter wires both inside the probe and along the length of the cable.

The square-wave frequencies of 5 and 0.3 Hertz are too low to give significant capacitive coupling; however, the high-frequency waveform which produces the square wave is a probable source of this coupling.

Laboratory measurements of the coupling effect cannot be accurately assessed because of the large number of variables involved. For example inhomogeneities in earth resistivity while traversing down the drill hole give a wide variation in the magnitude of the coupled voltage.

A complete theoretical treatment of the errors involved in IP logging is given by Dakhnov (1962). Three terms are involved:

(1) Inductive coupling error

(2) Capacitive coupling error

(3) Error due to non-symmetry of cable characteristics.

The sum of equations for each of these terms indicates that the error increases:

(a) Linearly with geometric factor K

(b) Linearly with increasing frequency for term (1) and with increasing frequency squared for terms (2) and (3).

(c) Linearly with decreasing rock resistivity

(d) Linearly with the differences in the coefficients of mutual inductance between the apairs of transmitting and receiving cables for term (°) and with the differences in impedance between the current and receiving pairs for term (3)

(e) Linearly with increasing current for terms (1) and (3) and independent of current for term (2).

In practice, coupling errors become significant only when operating in a region of very low resistivity. In an environment such as this the normal receiver signal becomes of the same order of magnitude as the inductive and capacitive coupling signals, and negative frequency effects will be observed.

Another source of error is in locating the electrodes. The error in this parameter arises from cable stretch which was found to be up to 0.3 metres per 30 metres over some lengths. This necessitates regular checking and possibly remarking of the cable.

Another major source of error is in leakage between the transmitting and receiving circuits. This is easily detected by unsteady receiver readings and can be corrected immediately. The highest probability of failure is at the probe connectors to the cable. A possible precautionary test for this leakage is to measure the isnsulation resistance between the current and receiving circuits before and after logging a hole. The resistance should be of the order of one megohm.

Calculation of geometric factor and apparent resistivity

The following includes a development of the geometric factor from first principles so that the assumptions involved are clearly illustrated.

Consider a current source of strength I located at the electrode A in a homogeneous and isotropic medium of resistivity Ra.

Since the medium is homogeneous the current density j around A depends only on the distance r from A:

$$j = \frac{I}{4\pi r^2}$$

Note that the presence of other electrodes and of the drill hole itself is not included in this formula. The potential drop is given by:

$$-dV = j \; Ra \; dr$$

$$= \frac{RaI}{4\pi r^2} dr$$

The potential at a measuring point M at a distance r_{AM} from the current source is:

$$V_M = \int_M^{\infty} - dV = \frac{RaI}{4} \int_{r_{AM}}^{\infty} \frac{dr}{r^2}$$

$$V_M = \frac{RaI}{4\pi AM}$$

Using the basic formula established above and considering a dipole-dipole electrode configuration on a probe with a dipole length L (L in metres) the following formula is obtained for the potential drop over the measuring electrodes:

$$\Delta V = \frac{Ral}{12\pi L}$$

That is, the apparent resistivity is given as below, where K is the geometric factor:

$$Ra = K \frac{\Delta V}{I}$$

where $K = 12\pi L$

Thus K equals 115 m and 345 m for the 3.05 m probe and 9.15 m probe respectively. In actual fact the electrodes are cylinders and the equipotential surfaces should be considered as ellipsoids of revolution rather than spheres as was done above. However, the large distance apart of the electrodes compared with their length enables them to be considered as point sources and the above treatment is a valid one.

Generally the medium is not homogeneous and isotropic and thus the apparent resistivity may bear little resemblance to the actual rock resistivity. The apparent resistivity is a function of the geometry and resistivity of all the formations surrounding the electrode array (including the drill hole). Thus Ra best approaches the actual resistivity when the formation thickness is greater than the probe dimensions and when the drill-hole fluid resistivity approaches that of the surrounding formation. Apparent resistivities obtained in Kowen Forest Canberra No. 3 hole with this geometric factor are compared with the resistances obtained using a single-point resistance logger commonly used by BMR (see section 4).

3. GEOLOGY

The localities of the areas involved are shown in Plate 1. A detailed map of the Currawang Prospect showing the drill-hole collars is presented in Plate 2.

The surface geology of the areas is shown in the Goulburn and Canberra 1:250 000 Geological Sheets, and the mineralization is described by McClatchie (1970).

The Currawang metalliferous deposit is of the Captains Flat type and is developed in a Silurian-Devonian volcanic sequence where the unit is cut by a fault complex. The Kowen Forest area consists of an Ordovician sequence of shale and quartzite.

4. DISCUSSION OF RESULTS

Kowen Forest - BMR Canberra No. 3

The 3.05 metre dipole IP probe was used to log this vertical hole on three separate occasions, on 1, 13, and 20 July 1971. The results of frequency effect and apparent resistivity were found to reproduce to better than one percent and seven percent respectively.

Plate 3 shows the IP log compared with a single-point resistance log. The results for the two methods show good agreement; the IP probe exhibits greater sensitivity to the conductive zones, but with a reduced resolution. This behaviour is to be expected when the theory of the two methods of measurement is considered. Correlation between the IP response and the conductive shale zones is good.

The extremely high amplitude response at the beginning of the IP curves is due to metal casing which extends from the surface to 33.5 metres down the hole. Cement casing then extends to 42.1 metres. The results indicate that the probe begins to respond to the surrounding formations when two of the electrodes have passed out of the metal casing.

Currawang

The area is 14.5 km southeast of Collector and may be reached by the Collector-Currawang-Goulburn road. The road shown (Plate 2) leads to Goulburn via Komungla.

The location of the two drill-hole collars relative to the old Currawang copper mine workings is shown in Plate 2. This mine was worked intermittently from 1865 to 1907 and is estimated to have produced over one thousand tonnes of metallic copper.

Surface geophysics in the area is adversely affected by the presence of a slag dump, which is strongly magnetic, and also by overhead power lines and underground P.M.G. cables.

The IP logging results at 3.05 metre and 9.14 metre dipole spacings for DDH.C6 and DDH.C7 are shown in Plates 4 and 5 respectively. Both holes are inclined at 45°, DDH.C6 having a total down-hole depth of 161.8 metres and DDH.C7 a depth of 55.8 metres.

The geological logs which are shown with the IP logs are not sufficiently detailed to enable correlation with all the IP anomalies. A pyrite concentration of up to 10 percent in the interval 22.3 to 23.8 metres in DDH.C7 explains the sharp-frequency effect anomaly at 22.9 metres. It is likely that the broad anomalies centred at 35.1 metres and 44.2 metres in DDH.C7 are also due to the presence of pyrite in the volcanic breccia, although of a lower concentration.

The anomaly in the IP log below 47.3 metres in DDH.C7 is due to the presence of sulphides with concentrations greater than 3 percent. Unfortunately the drill hole does not pass through the mineralized zone and consequently a complete anomaly cannot be defined.

A sharp frequency-effect anomaly with an associated resistivity low at 102.1 metres in DDH.C6 is yet to be explained. This may be due to a mineraalized shear zone.

The 9.14 metre dipole profiles for both drill holes are relatively smooth. The total length of the probe of 27.4 metres does not allow its effective use in DDH.C7; however, an anomaly is evident when the probe has reached the end of this drill hole. Comparison of the probe response to this anomaly at the two different dipole spacings is not possible because the hole was stopped while still in the mineralized zone. The 9.14 metre dipole probe has apparently been unable to detect the narrow pyrite band at 22.9 metres in DDH.C7. A weak frequency-effect high in the 9.14 metre dipole profile for DDH.C6 may be associated with the scattered pyrite mineralization over the interval 80.9 to 90.0 metres.

5. CONCLUSIONS AND RECOMMENDATIONS

The IP logging method has proved capable of indicating conductive and mineralized zones in drill holes in the environments studied.

The results have indicated that the instrument will detect an anomaly over pyrite concentrations as low as 3-4 percent and that a symmetrical anomaly will be detected on passing through formations with widths greater than the dipole spacing.

At this stage it is not possible to give accurate statements on the performance characteristics of the instrument. Further down-hole IP logging in a variety of environments and through a range of sulphide concentrations would be necessary to obtain a fuller knowledge of the instrument response.

A more comprehensive IP logging program was carried out at Tennant Creek immediately after these tests, and the results are presented in another record (Gillespie, 1972).

6. REFERENCES

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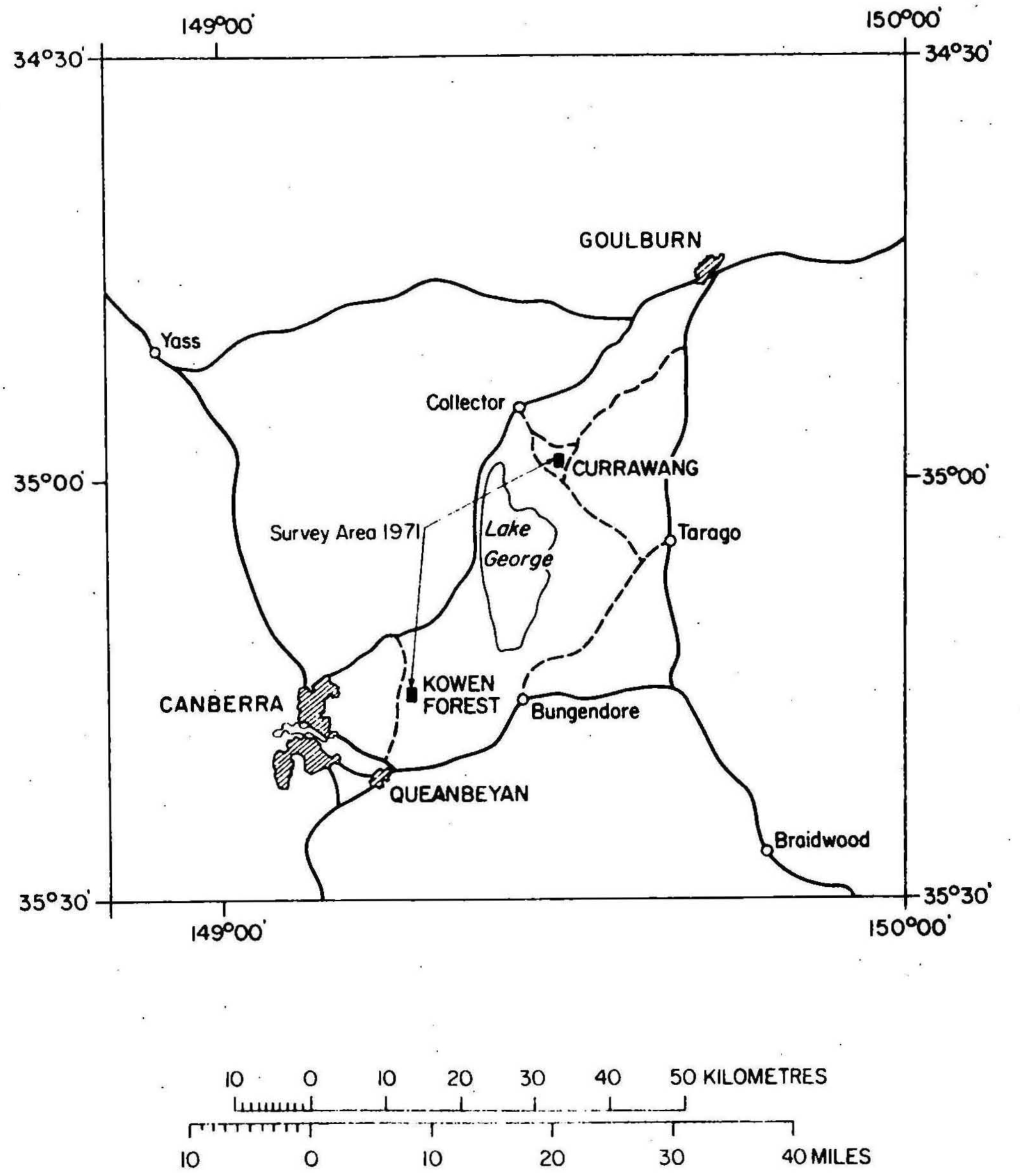
PLATE I



LOCALITY MAP

LOGGING TESTS LOCATIONS, CURRAWANG N S W AND KOWEN FOREST A.C.T.

1971

To accompany Record No. 1972/29

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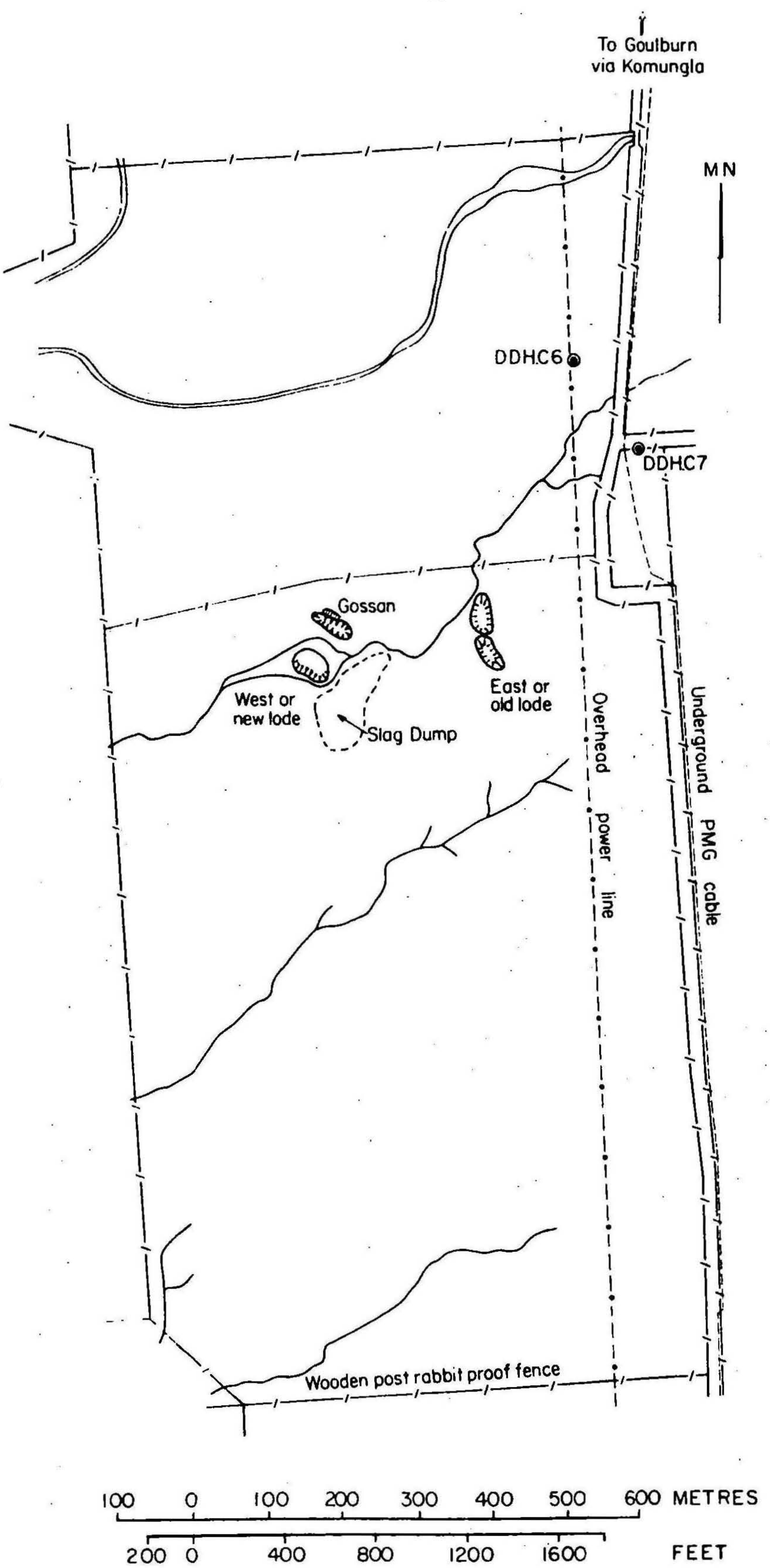
PLATE 2

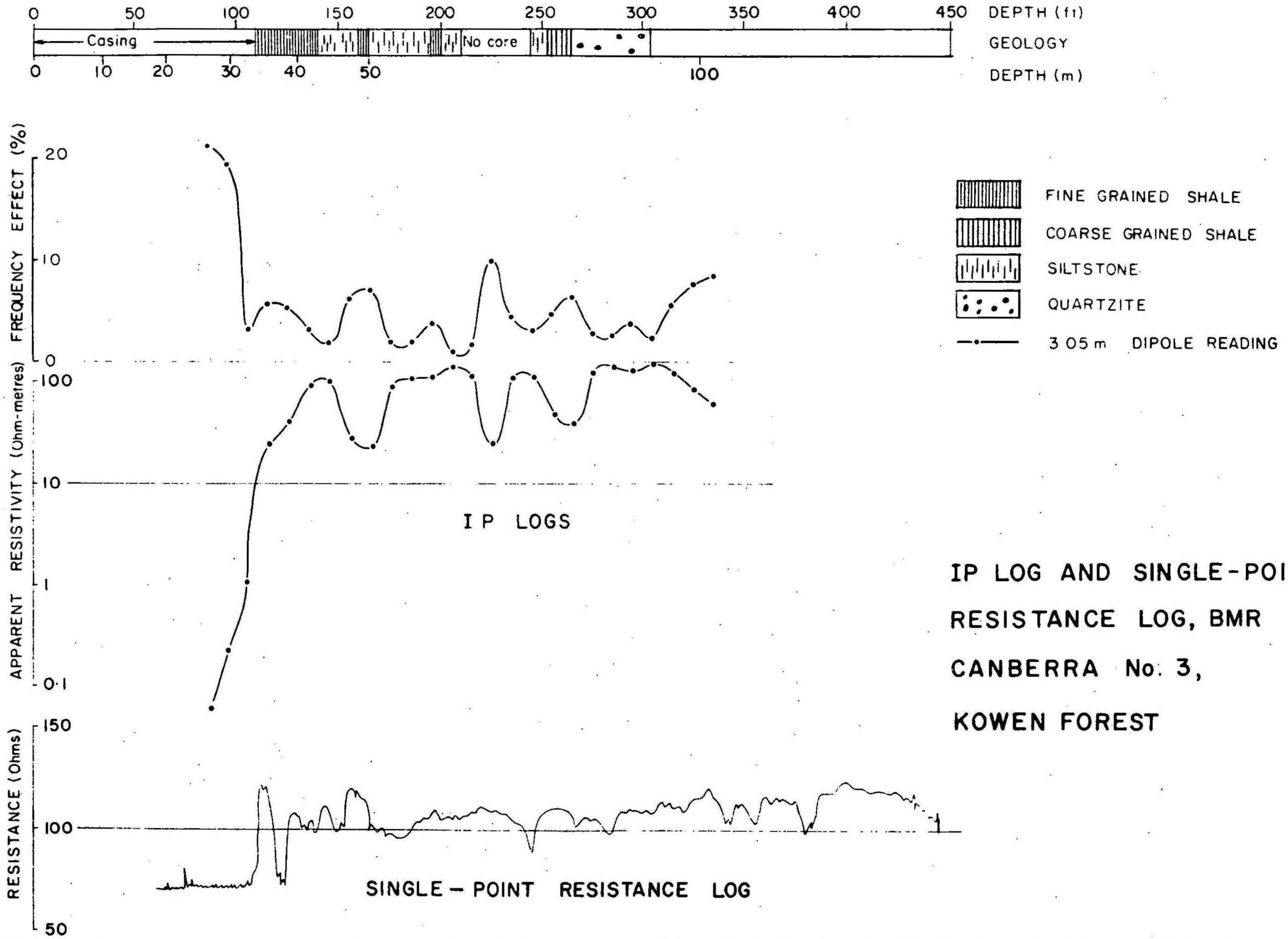


DETAILED SURFACE PLAN

CURRAWANG PROSPECT

To accompany Record No. 1972/29

I55/B7-88A



IP LOG AND SINGLE-POINT RESISTANCE LOG, BMR CANBERRA No. 3, KOWEN FOREST

PLATE 3

To accompany Record No. 1972/29

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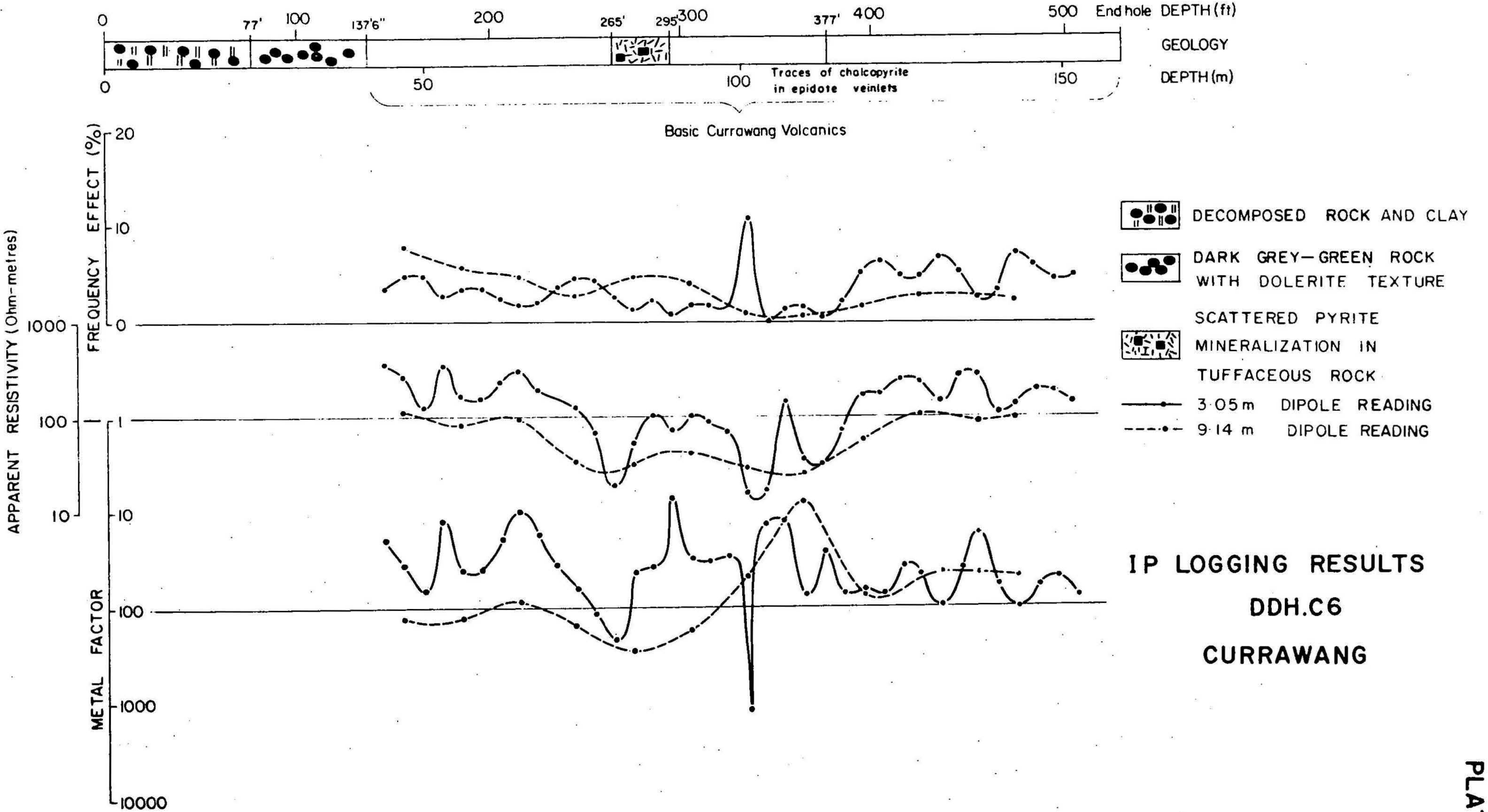

IP LOGGING RESULTS

DDH.C6

CURRAWANG

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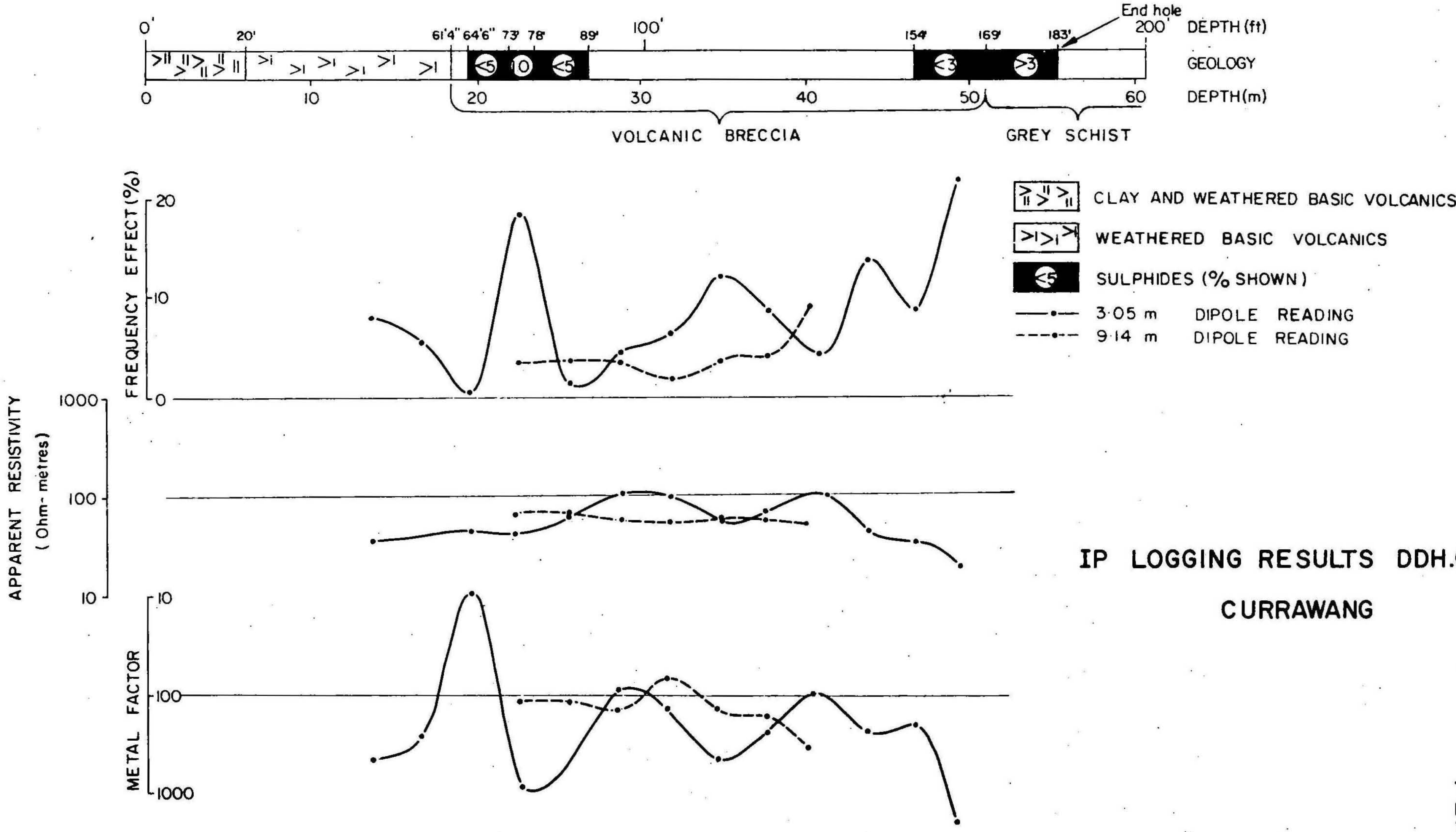

IP LOGGING RESULTS DDH.C7

CURRAWANG

PLATE 5

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