72/30
3

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1972/30

012529

DOWN-HOLE INDUCED POLARIZATION AND ELECTRIC APPLIED POTENTIAL SURVEYS AT TENNANT CREEK, NT, 1971

by

P.J. Gillespie

Record 1972/30

DOWN-HOLE INDUCED POLARIZATION AND ELECTRIC APPLIED POTENTIAL SURVEYS AT TENNANT CREEK, NT, 1971

by

P.J. Gillespie

CONTENTS

		Page
	SUMMARY	
1.	INTRODUCTION	1
2.	GEOLOGY	2
3.	GEOPHYSICAL METHODS	2
4.	PRESENTATION AND DISCUSSION OF RESULTS	4
5.	CONCLUSIONS AND RECOMMENDATIONS	10
6.	REFERENCES	11

ILLUSTRATIONS

Plate 1 IP Results, DH1
Plate 2 IP and magnetic susceptibility results, DH3
Plate 3 IP Results, DH4
Plate 4 IP Results, DH5
Plate 5 IP Results, DH6
Plate 6 IP Results, DH7
Plate 7 IP Results, DH8
Plate 8 IP Results, DH9
Plate 9 IP Results, DH10
Plate 10 IP Results, DH11
Plate 11 Spatial relation between DH10 and DH11
Plate 12 IP Results, DH12
Plate 13 IP Results, DH13
Plate 14 Surface equipotentials, electrode geometry, and surface geology for Applied Potential survey.

SUMMARY

Down-hole induced polarization (IP) logging was carried out in thirteen drill holes in the Tennant Creek area in 1971 by the Bureau of Mineral Resources (BMR) to gain information on the characteristics of the down-hole IP probe and also to assist in exploration on the field.

In addition an electric Applied Potential or mise-à-la-masse survey was made, to determine the value of this method in delineating subsurface conductive zones.

The IP logging method gave an anomalous response over magnetite and/or sulphide zones. The Applied Potential method met with only limited success because of the low surface resistivities, which reduced the amplitude of the anomaly, and also because of the excitation of a large near-surface zone, which complicated the results. However, the method appears to have indicated the trend of a mineralized shear zone.

Further work is required in directional drill hole logging to determine the spatial distribution of conductive zones, and the Applied Potential method should be tested in a higher-resistivity environment than that found at Tennant Creek.

1. INTRODUCTION

In 1971 the Bureau of Mineral Resources (BMR) built an IP probe for use with McHPhar IP frequency-domain prospecting equipment. The probe was successfully tested early in 1971 in localities near Canberra (Gillespie, 1972) using a dipole-dipole electrode configuration with 3.05 m (10 feet) and 9.14 m (30 feet) dipoles. The equipment was used to log thirteen drill holes in the Tennant Creek area between 31 August and 20 October 1971.

The work was undertaken to gain information on the instrument response in the mineral environment of Tennant Creek and also to assist in exploration in the area. The IP logging results were compared with geological logs and, wherever possible, withmagnetic susceptibility logs derived from susceptibility measurements on powered core samples.

A test electric Applied Potential survey was carried out during the IP logging program in an attempt to delineate subsurface vnductive zones. The method involves introducing direct current into a conductive zone and mapping the resultant surface distribution of potentials.

Details of the history of mining and production in the Tennant Creek field, which is mainly a copper and gold producer, are discussed by Ivanac (1954) and Crohn & Oldershaw (1965). At the request of the companies co-operating in the project only the geological logs for the drill holes are shown; drill hole identification and localities have been omitted.

Grateful acknowledgement is given to the following for their assistance during the survey:

Australian Development Ltd

Geopeko Ltd

The Northern Territory Administration and particularly the Mines Branch.

The survey was made by the author with assistance from members of a BMR metalliferous geophysical survey party which was operating in the Tennant Creek area at the time.

2. GEOLOGY

A comprehensive account of the geology of the Tennant Creek area is given by Crohn & Oldershaw (1965). Gold and copper orebodies occur at Tennant Creek in close association with tabular and pipe-like quartz-hematite and quartz-magnetite bodies and in major shear zones cutting through rocks of the Warramunga Group. The Warramunga Group is a Lower Proterozoic sequence of sediments; graded bedding is common with the thickness of individual beds averaging between 30 and 60 cm and rarely exceeding 4.5 to 6 m The drill holes all pass through rocks of the Warramunga Group.

The water-table level, which is the effective upper limit for IP logging, was generally about 60 m down the hole. The base of complete oxidation was often deeper than the water-table and could be up to 90 m down the hole.

3. GEOPHYSICAL METHODS

IP logging methods

A description of the development and technical aspects of the IP probe is given in another Record (Gillespie, 1972). The probe was operated with the McPhar frequency-domain IP equipment normally used for surface IP work.

The field procedure was firstly to determine the maximum current which could be used along the hole. This was done so that a current of constant magnitude could be used for the entire log, and thus there would be no possibility of variation of frequency effect due to changes in current density. During this determination a non-anomalous zone is located for calibration. The hole is then logged in one direction and readings checked when returning to the calibration point. The calibration at this point was checked at the end of every run.

Readings were taken at intervals equal to the dipole spacing and results plotted at a depth coordinate equal to the centre of the electrode array. In irregular or highly anomalous zones readings were taken at closer intervals.

Logging was limited by the depth to the water-table and the occurrence of down-hole obstructions. In some holes (DH2, 3, 4, and 5) water was added to extend the range of logging.

The original PVC probe described in the preceding Record (Gillespie, 1972) was rejected in favour of a flexible probe. A discussion of the reasons for this change together with a comparison of the performance of these probes is given in Section 4.

Applied Potential method

In the Applied Potential or mise-à-la-masse method one electrode is placed in a conductive zone and the other electrode is placed effectively at infinity. Direct currentis passed between the two electrodes and the distribution of potentials is mapped. The departure of the distribution from that expected for a homogeneous medium gives an indication of the geometry of the conductive zone. A detailed description of the method is given in a report by Parasnis (1967) on a survey incorporating both surface and down-hole potential measurements.

In the Tennant Creek survey one electrode was placed at the resistivity low at 132.6 m in DH10 and the remote electrode was placed 730 m south of the drill hole. The down-hole electrode consisted of 1.2 m of copper tubing and the remote electrode consisted of over 10 square m of aluminium foil in a watered and salted pit.

The McPhar IP transmitter was used to place the down-hole electrode at a positive potential with respect to the remote electrode, and surface potential measurements were made at 30.48 m (100 feet) intervals on a grid surrounding DH10 amd DH11. The McPhar IP receiver was used for the potential measurements because it has provision for self-potential (S-P) bucking. Porous pots filled with copper sulphate solution were used for the receiving electrodes.

The field procedure involved measurement of the potential of points on the grid relative to an arbitrary reference point which was designated as zero. This point was placed on the northern end of Traverse T3 in an undisturbed region. With the advance and reference receiver electrodes set up on the grid the procedure was as follows:

(1) Self-potential between advance and reference electrodes was cancelled using the S-P bucking switch.

(2) DC+ transmission between the down-hole and remote electrodes was commenced and the magnitude and polarity of the potential between the receiver electrodes was measured.

(3) DC+ transmission was stopped and S-P cancellation checked. If the S-P drift after transmission was greater than 0.5 mV the procedure was repeated. Any drift of magnitude greater than 0.5 mV was not tolerable because of the low voltage levels being measured.

(4) The advance receiver electrode was moved forward to the next station on the traverse and the procedure was repeated.

Traverses were tied in on their northern extremities, where the potential distribution was relatively undisturbed.

At the commencement of the survey a further step was added between (2) and (3) above. This involved switching transmission from DC+ to 0.3 Hertz and thus obtaining a percent frequency effect reading at each station. However, the S-P drift and low voltage levels prevented the reading being taken with the desired accuracy, and this step was soon omitted.

4. PRESENTATION AND DISCUSSION OF RESULTS.

IP Logging

The results are shown in a standard form with depth down the hole and geology on a horizontal scale. The frequency effect is showwn in percent on a linear vertical scale, and the apparent resistivity and metal factor are shown on logarithmic vertical scales.

DH1

Plate 1 shows the IP results for DH1. The drill hole consisted almost entirely of schistose porphyry except for some chloritized and sheared metasediments from 128 m to 142.5 m.

The hole was logged at the 3.05 m dipole spacing with the original PVC probe (as described by Gillespie 1972); after passing several obstructions, this probe became jammed during return to the surface and was lost at 183 m. This loss of the PVC probe together with a knowledge of the obstructions encountered in testing other drill holes led to a decision to construct a new flexible probe of reduced diameter. The new probe was constructed with the soft lead electrodes built around the cable itself and consequently the electrode diameter was only slightly greater than the cable diameter. The flexibility of the probe aalso allowed easy storage and transport.

The new probe was used to log DH1 so that a comparison of the logging results with those of the original PVC probe could be made. The comparison test ended when water seeped into the probe at 128 m; however, it is obvious that the two curves fit closely. This is to be expected as the only change in the probe geometry was a reduction in the diameter of the cylindrical electrodes.

The new probes (3.05 m and 9.14 m dipole spacings) were used to log all the subsequent drill holes.

The IP log for DH1 has only a background variation and shows no significant anomalies that can be ascribed to mineralization.

DH2

The results for this drill hole are not shown. The hole was originally 58 m deep and consisted predominantly of hematite with some magnetite and a little quartz. The entire hole was above the water-table, and over four thousand gallons of water were put in the hole in an attempt to log it. However, only 15 m of hole could be logged owing to a cave-in which occurred at 41.2 m while water was being added.

The IP profile is too short to allow meaningful interpretation and serves only to give an indication of the near-surface resistivites in the area. These were of the order of 20 to 100 ohm-metres. Frequency-effect values were less than 5 percent.

DH3

The IP logs for 3.05 m and 9.14 m dipole spacings together with the geology and magnetic susceptibility results are shown in Plate 2. There is an exact correlation between the 3.05 m dipole IP anomaly and the zone of magnetite, whereas the 9.14 m dipole profile is shifted slightly deeper.

The small IP anomaly at 105.2 m, which corresponds with a 2-5 percent pyrite zone, is interesting because the mineralization occurs in chlorite schist and is not associated with magnetite. Thus the anomaly gives an illustration of the instrument response over sulphides alonee without any interference from magnetite. Other such anomalies are present in DH8 (Plate 7) and DH11 (Plate 10).

The small high in magnetic susceptibility at 39.6 m has been resolved on the IP log as being distinct from the main peak. The two small magnetic susceptibility highs at the extreme end of the hole have not been detected on the 3.05 m dipole probe but there is a small high in frequency effect and low in apparent resistivity on the 9.14 metre dipole profile as the susceptibility anomaly is approached.

The resistivity low for the magnetite zone is superimposed on a general increase from the near-surface values of the order of 30 ohm-metres to values of the order of 1 000 ohm-metres below the magnetite zone. Thus the resistivity low is not well defined. This behaviour is also mirrored in the metal-factor profiles.

DH4 and DH5

Both these drill holes investigate the same magnetite-chlorite zone that was intersected by DH3. The IP logs are shown in Plates 3 and 4.

Although the anomalies are not completely defined they show a response which is similar to that of DH3. That is, the magnetite zone is indicated by a marked rise in frequency effect, but there is no well defined resistivity low. Both drill holes are too shallow to illustrate the higher resistivity below the magnetite zone as found in DH3.

The 9.14 m dipole profiles have anomalies of similar amplitude to those of the 3.05 m dipole profiles, which would indicate that there is no reduction in the volume or grade of the magnetite zone within a radial distance from the drill hole of the order of 9 m.

The sharp minimum in ferequency effect at 100 m in DH5 may be due to the oxidation of the magnetite-chlorite rock at this depth.

DH6

Plate 5 shows the IP logging results in a drill hole which was entirely barren of mineralization. No significant IP anomalies are evident.

The geological log indicates that the core consists entirely of sandstone, siltstone, and shale; however, the magnetic susceptibility measurements indicate a uniform susceptibility of 0.003 cgs units extending along the entire hole from 76.2 m. This is probably due to a very small percentage of disseminated magnetite throughout the core. The base of complete oxidation is at 50.6 m.

The IP log for the 9.14 m dipole probe is flat above 180 m whereas the 3.05 m dipole profile shows small amplitude fluctuations, some of which could be correlated with small shears at 99.1 m, 16.5 m, and 127.4 m.

There is no explanation for the broad resistivity low over 183 m to 198 m on the 9.14 m dipole profile. Considerable difficulty was encountered in raising the 9.14 m dipole probe through this region and it was decided not to risk the 3.05 m dipole probe.

DH7

This drill hole intersected ore-grade mineralization, and the IP logs (Plate 6) are very significant in that they illustrate the instrument response in a very low-resistivity environment. Metal-factor values are not shown because the frequency-effect readings over the region of interest could not be determined. This is because in a low-resistivity environment of less than 10 ohm-metres, the magnitude of the conductivity coupled or normal receiver signal approaches that due to inductive and capacitive coupling, and negative frequency effects are observed when coupling becomes dominant. For ease of interpretation the large negative frequency effects due to the coupling error are not shown and instead the upward trends evident before the coupling becomes dominant are continued.

The magnitude of the coupling term is linearly proportional to the geometric factor of the probe and inversely proportional to the resistivity. This is discussed in the preceding Record (Gillespie, 1972). Thus in logging through an environment of steadily decreasing resistivity the 9.14 m dipole probe will fail to give reliable frequency-effect readings before the 3.05 m dipole probe. This fact is evident here (Plate 6) and also in the results for DH9 (Plate 8).

The lode zone appears as an extremely low-resistivity region below a background resistivity of 3 000 ohm-metres. Two of the sediment bands 1.5 m thick between the zones of mineralization at 190.5 m and 196.6 m appear to have been resolved at the 3.05 m dipole spacing. The other magnetite and/or sulphide zones have been resolved as smaller anomalies.

DH8

This drill hole intersected minor pyrite and chalcopyrite mineralization over the interval 207.6 m to 211.2 m. The 3.05 m dipole IP anomaly (Plate 7) is centred on 206.4 m and is thus displaced slightly above the mineralized zone. This discrepancy in location is due to cable stretch, which was corrected before 9.14 m dipole logging commenced.

An obstruction in the hole prevented logging past some mineralization which was present below 274 m; however, the 9.14 m dipole profile shows some indications of approaching an anomalous zone.

DH9

The IP results for this drill hole are shown in Plate 8. The magnetite zone from 137 to 196 m appears as a general resistivity low associated with high but irregular frequency-effect values. The irregular frequency-effect values are related to the distribution of magnetite and the small widths of the formations.

The most interesting correlation evident in the results is between the shear zone and the sharp resistivity low centred at 187.8 m. A frequency-effect high is associated with the resistivity low which indicates that the shear zone may be mineralized.

DH10

The results for this drill hole (Plate 9) show three distinct resistivity zones and a sharp IP anomaly associated with the mineralized magnetite-quartz and chlorite-magnetite zone.

A zone of low resistivity of the order of 100 ohm-metres exists above the shear zone at 87.2 m. Between this shear zone and the mineralized zone the background resistivity is 1 000 ohm-metres and below the mineralized zone it is approximately 8 000 ohm-metres. This resistivity trend is also evident on the 9.14 m dipole profile although the mineralized zone appears as a very distinct but broader resistivity low.

The IP anomaly at 152 m is not explained by the geological log, but would appear to indicate the presence of minor sulphide mineralization. This statement is based on a comparison of the anomaly with the IP anomalies in DH3 (Plate 2) and DH8 (Plate 7).

Both these anomalies are due to sulphide mineralization in sediments. Further support is given by the fact that minor chalcopyrite mineralization occurs in DH11 from 141.3 m to 142.5 m. The relative positions of the drill holes are shown in Plate 11. The distance between the mineralization found in DH11 and the anomaly is DH10 is approximately 15 m. Unfortunately the anomaly was too close to the end of the hole to be covered by the 9.14 m dipole probe.

DH11

A small frequency-effect anomaly in the IP results for DH11 (Plate 10) corresponds with the disseminated chalcopyrite zone over the interval 141.3 m to 142.5 m.

The resistivity profile above 113 m in DH11 is almost identical with the resistivity profile above 98 m in DH10. It seems likely therefore that a shear zone may be associated with the resistivity low at 104 m in DH11 and the accompanying frequency-effect high indicates that the shear zone may be mineralized.

There is no indication that the magnetite zone intersected by DH10 has been detected on the IP log of DH11. The two drill holes are separated by approximately 24 m in this region.

DH12

The IP results for this drill hole are shown in Plate 12. Two chlorite-magnetite zones separated by massive siltstone with quartz chlorite veining appear on the IP results as one broad frequency-effect high centred at 119 m. A similar pattern in frequency-effect and apparent resistivity at 152 m may indicate the presence of similar mineralization in the vicinity of the drill hole. The 9.14 m dipole profile has a very low amplitude response with a small frequency-effect high and resistivity low over the mineralized zone.

DH13

The IP results for this drill hole are presented in Plate 13. There is good correlation between the frequency-effect anomalies and the zones of magnetite. A sharp resistivity low occurs over the magnetite zone from 101.8 m to 106.7 m and another resistivity low occurs over the deeper magnetite zone at 130.2 m. The high level of frequency-effect values between the deeper magnetite zones is due to minor magnetite concentrations in the siltstone.

The drill hole was logged after the removal of the B casing and before the remova of the N casing because of the soft ground. No 9.14 m dipole log was obtained.

APPLIED POTENTIAL

Plate 14 shows the distribution of surface potentials, the electrode geometry, and the surface geology.

The object of this survey was to energize the mineralized zone which was intersected at 129 m in DH10 and then to determine its spatial distribution by mapping the surface distribution of potentials.

The placing of the surface electrode at a remote position allows the earthed electrode to be considered as a point source. The resulting surface equipotentials would then be circular for a homogeneous medium.

A nearly circular distribution of contours north of the cross traverse indicates that there is no continuation of the conductive zone in this direction. A local high occurs directly over the current electrode and this high has a southwest trend corresponding with the trend of the projected shear zone shown on the surface geological map (Plate 14). This zone represents a surface projection of the mineralized zone between 129 m and 137 m in DH10 which contains the energizing electrode.

Higher potential values to the south may indicate that an electrical connexion exists between the mineralized zone and a conductive zone closer to the surface in this region.

The contour pattern isseverely disrupted by the potential low entering from the east. The intensity of the low could indicate that it is a surface or near-surface effect, and it may be due to non-uniformity in the overburden resistivity. The potential low corresponds to a gravel excavation site.

5. CONCLUSIONS AND RECOMMENDATIONS

The response of the down-hole IP logging probe to magnetite and/or sulphides has been demonstrated. The actual penetration distance of the measurement is variable under different conditions of resistivity and geometry and cannot be accurately stated except for particular situations. As a general estimate, the major part of the probe response would come from a radial distance of up to the dipole spacing from the drill hole. The 9.14 m dipole profiles show the same general trends as the 3.05 m dipole profiles, with changes in detail of the position and shape of the anomalies.

The Applied Potential method was only partly successful in delineating subsurface conductive zone. The method was adversely affected by extremely low surface resistivity and consequently all measured voltage levels were very low. In addition, near-surface effects complicated the results. The method would give improved results if used in a higher resistivity environment or if a higher-powered transmitter was used.

Further work is required in directional drill hole logging so that the spatial distribution of the conductive zone around the drill hole can be determined. This could be carried out as in the Applied Potential method used here or by the comparison of data from downhole-remote and surface-remote sending dipoles as outlined by Hawk (1970).

6. REFERENCES

CROHN, P.W., $ OLDERSHAW, W., 1965 - The geology of the Tennant Creek one-mile sheet area, NT. Bur. Miner. Resour. Aust. Rep. 83.

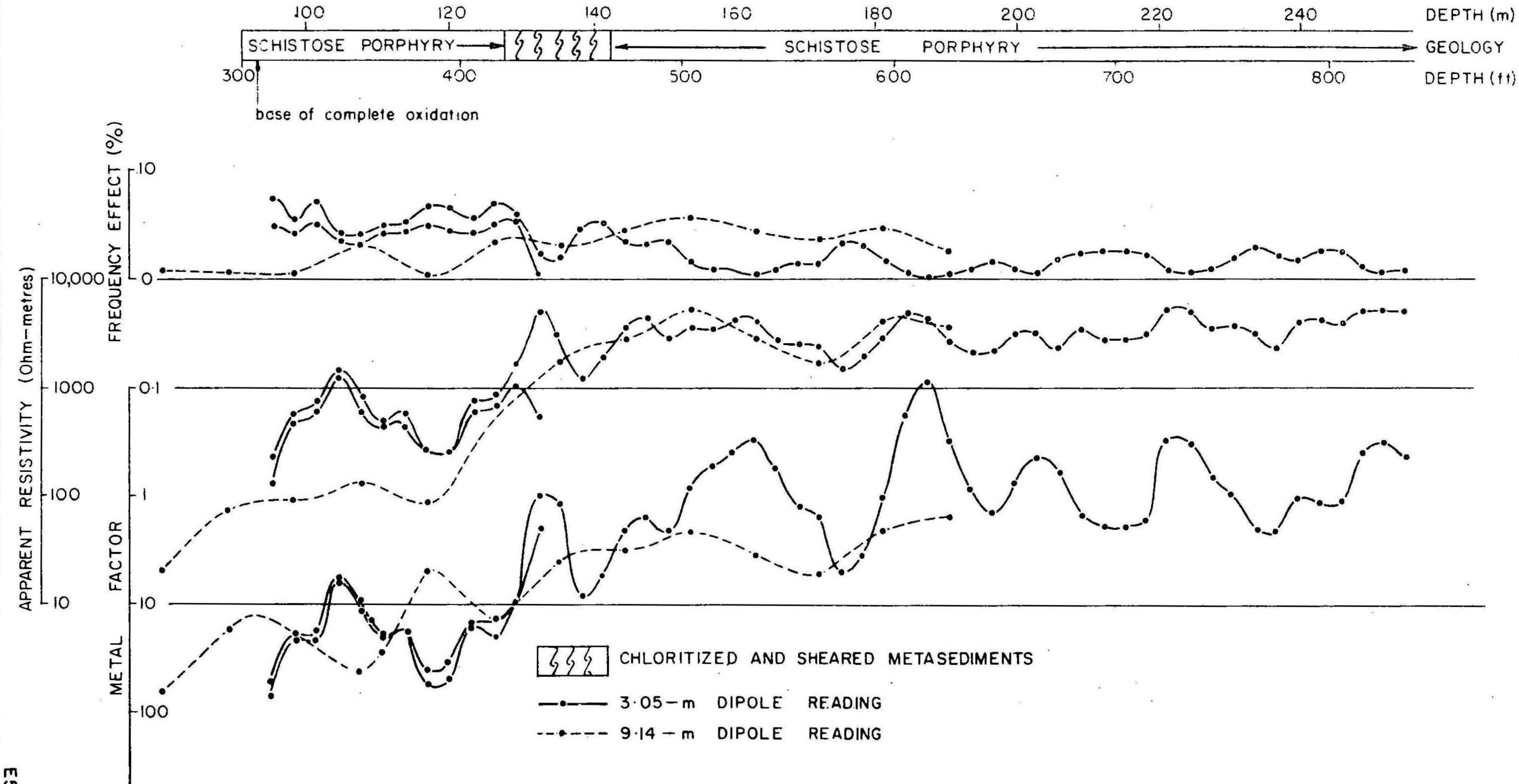
GILLESPIE, P.J., 1972 - Down-hole induced polarization logging tests at Currawang, NSW and Kowen Forest, ACT, 1971. Bur. Miner. Resour. Aust. Rec. 1972/29 (unpubl.).

HAWK, A. M., 1970 - A reconnaissance down-hole induced polarization and resistivity survey method McPhar Geophysics Ltd publication.

IVANAC, J.F., 1954 - Geology and mineral deposits of the Tennant Creek goldfield, NT. Bur. Miner. Resour. Aust. Bull. 22.

PARASNIS, D.S., 1967 - Three dimensional electric mise-à-la-masse survey of an irregular lead-zinc-copper deposit in central Sweden. Geophysical Prospecting 15, 3.

To Accompany Record No. 1972/30



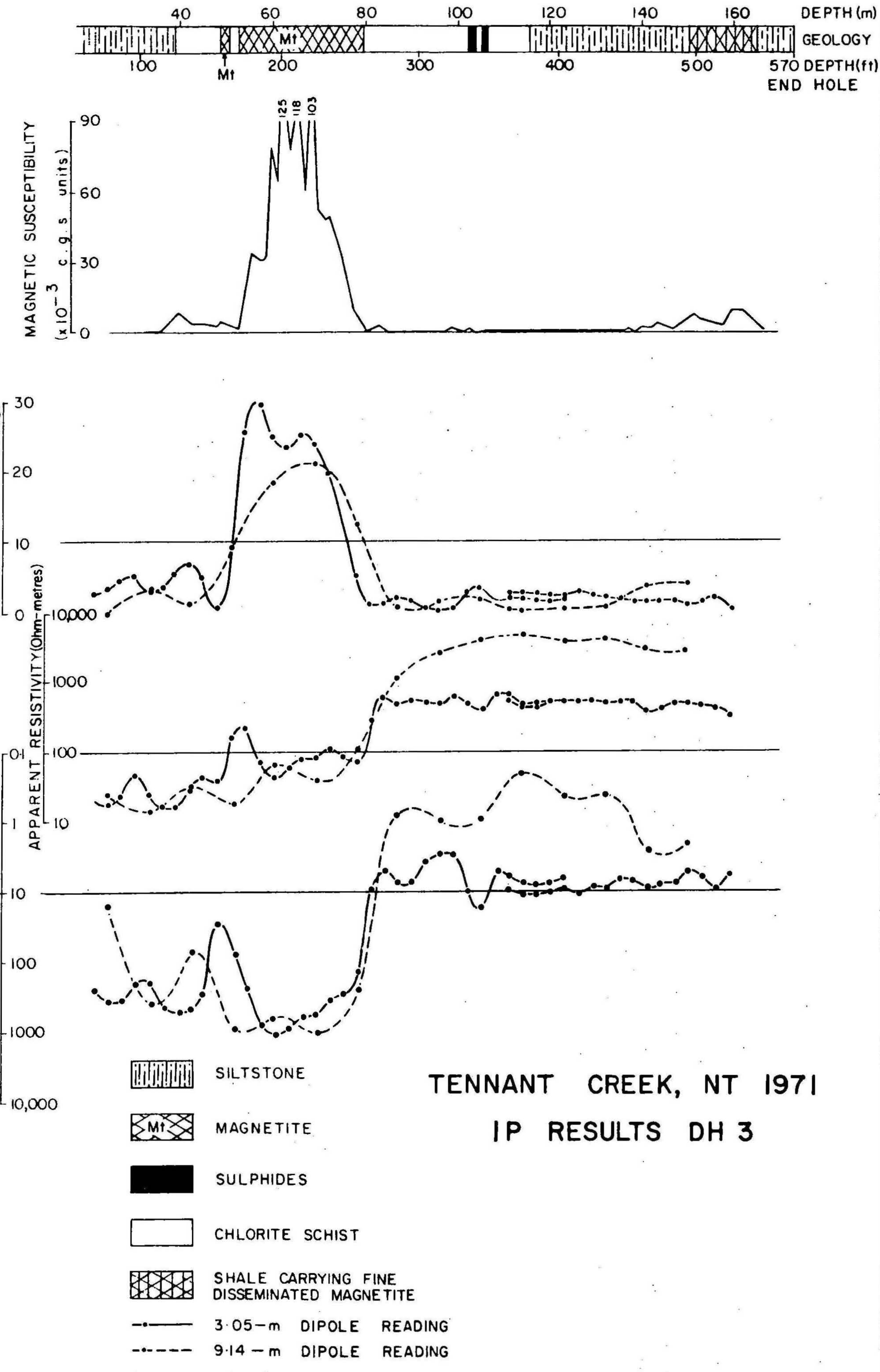
TENNANT CREEK, NT 1971

IP RESULTS DH 1

PLATE 1

E53/B7-118A

PLATE 2

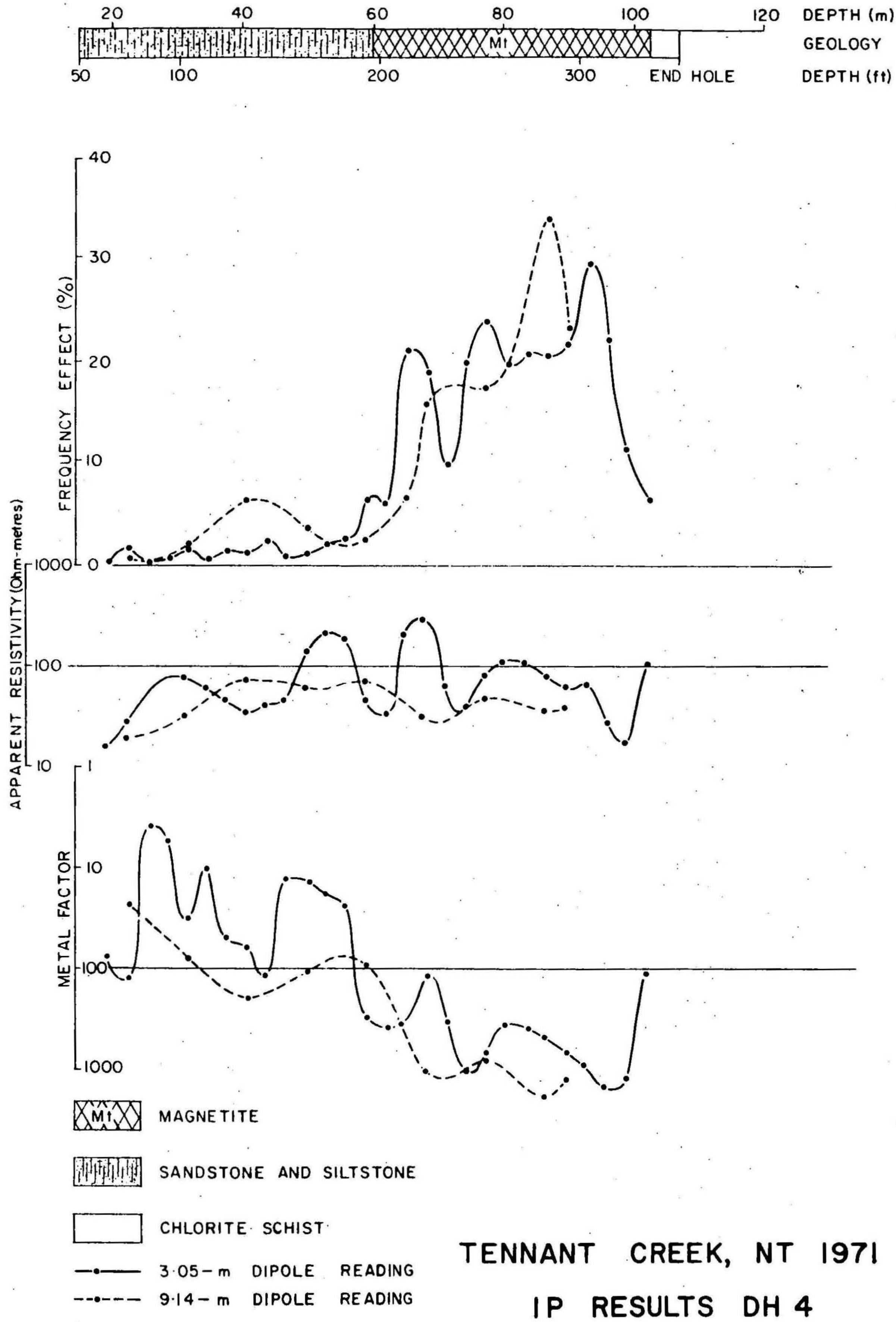


TENNANT CREEK, NT 1971
IP RESULTS DH 3

To Accompany Record No. 1972/30

E 53/B7-119 A

PLATE 3



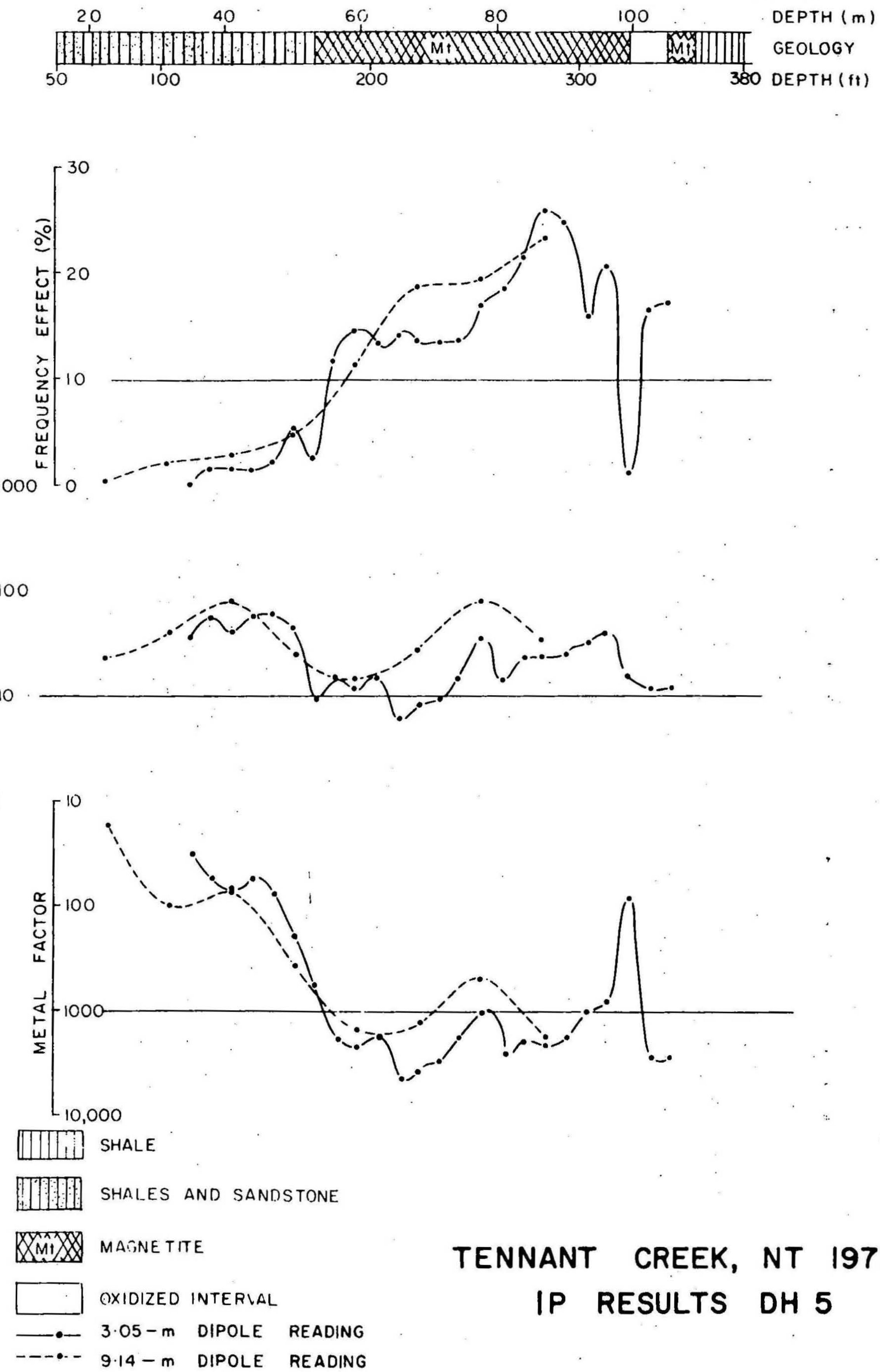
TENNANT CREEK, NT 1971

IP RESULTS DH 4

To Accompany Record No. 1972/30

E53/B7–120A

PLATE 4

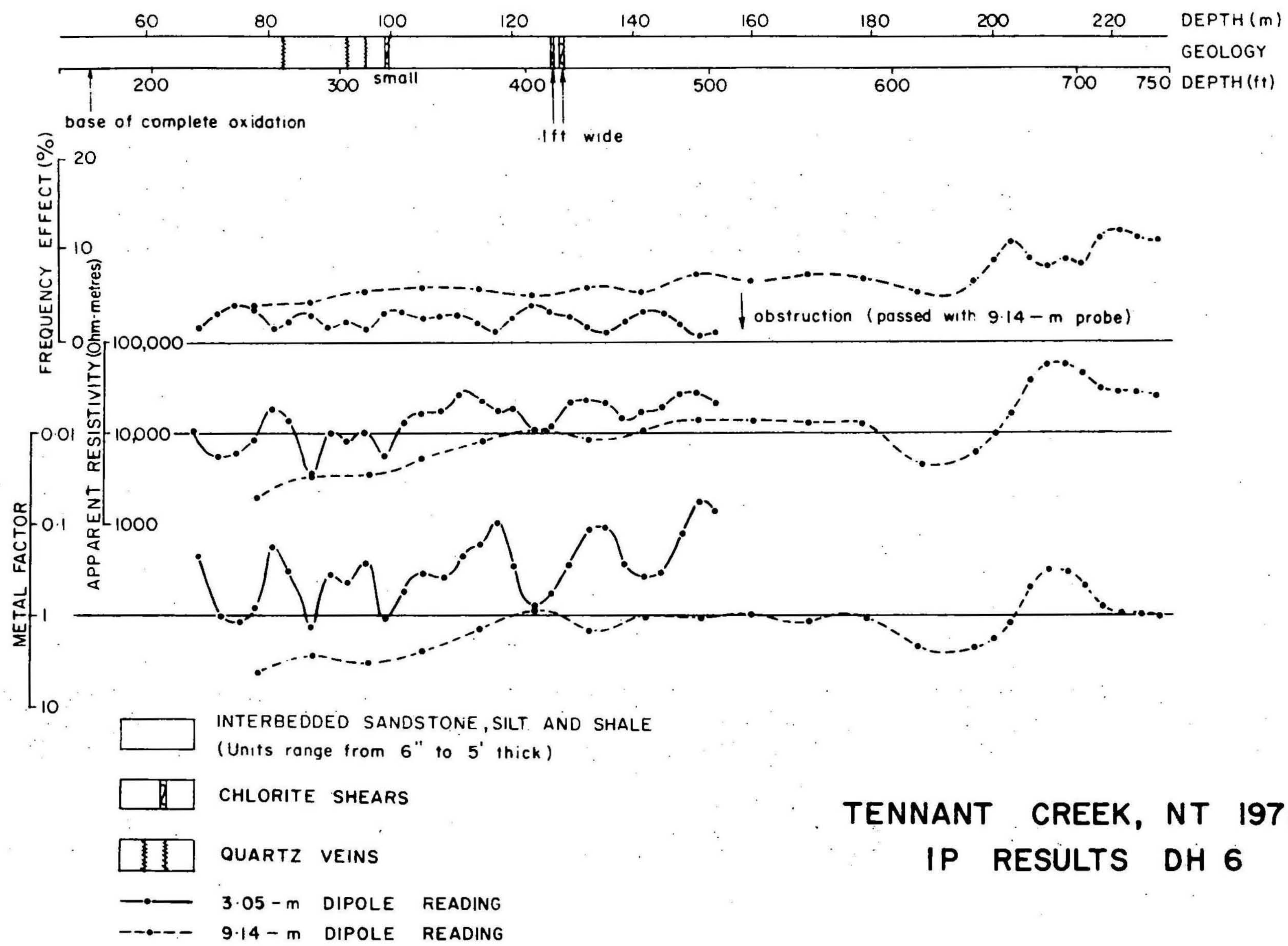


TENNANT CREEK, NT 1971
IP RESULTS DH 5

To Accompany Record No. 1972/30

E53/B7-121A

To Accompany Record No. 1972/30

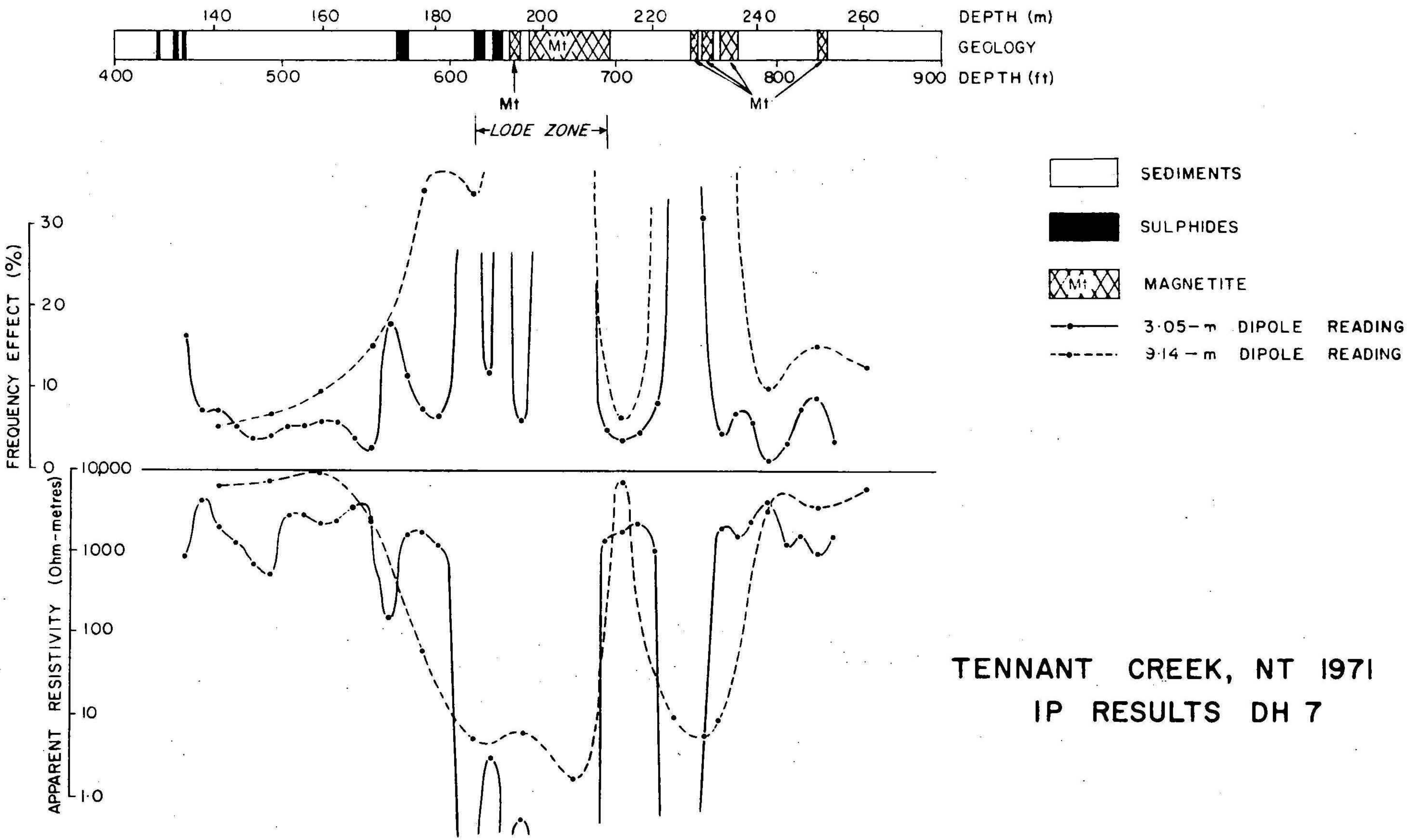


TENNANT CREEK, NT 1971
IP RESULTS DH 6

E53/B7-122A

PLATE 5

To Accompany Record No. 1972/30

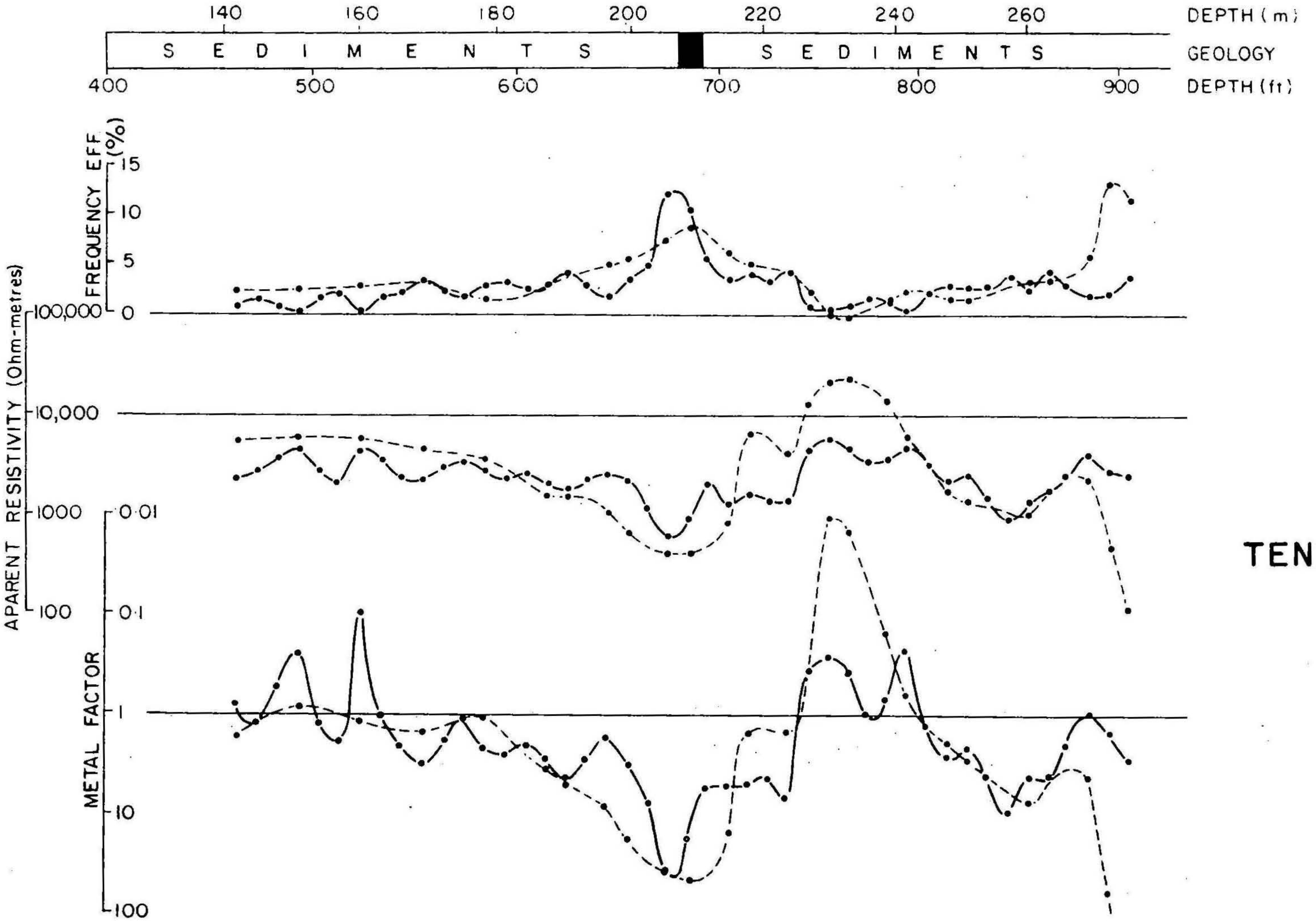


TENNANT CREEK, NT 1971
IP RESULTS DH 7

E53/B7-123A

PLATE 6

To Accompany Record No. 1972/30

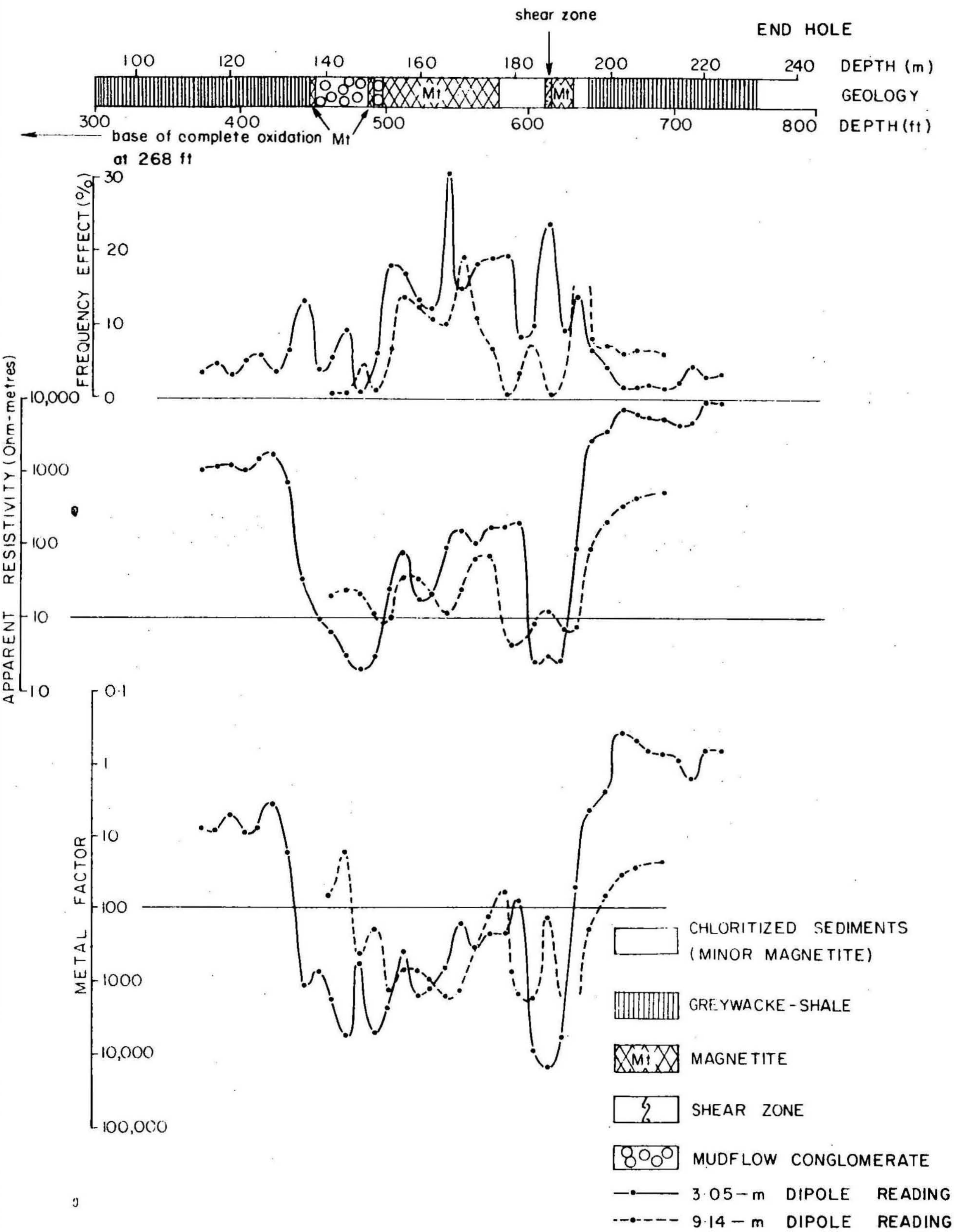


TENNANT CREEK, NT 1971
IP RESULTS DH 8

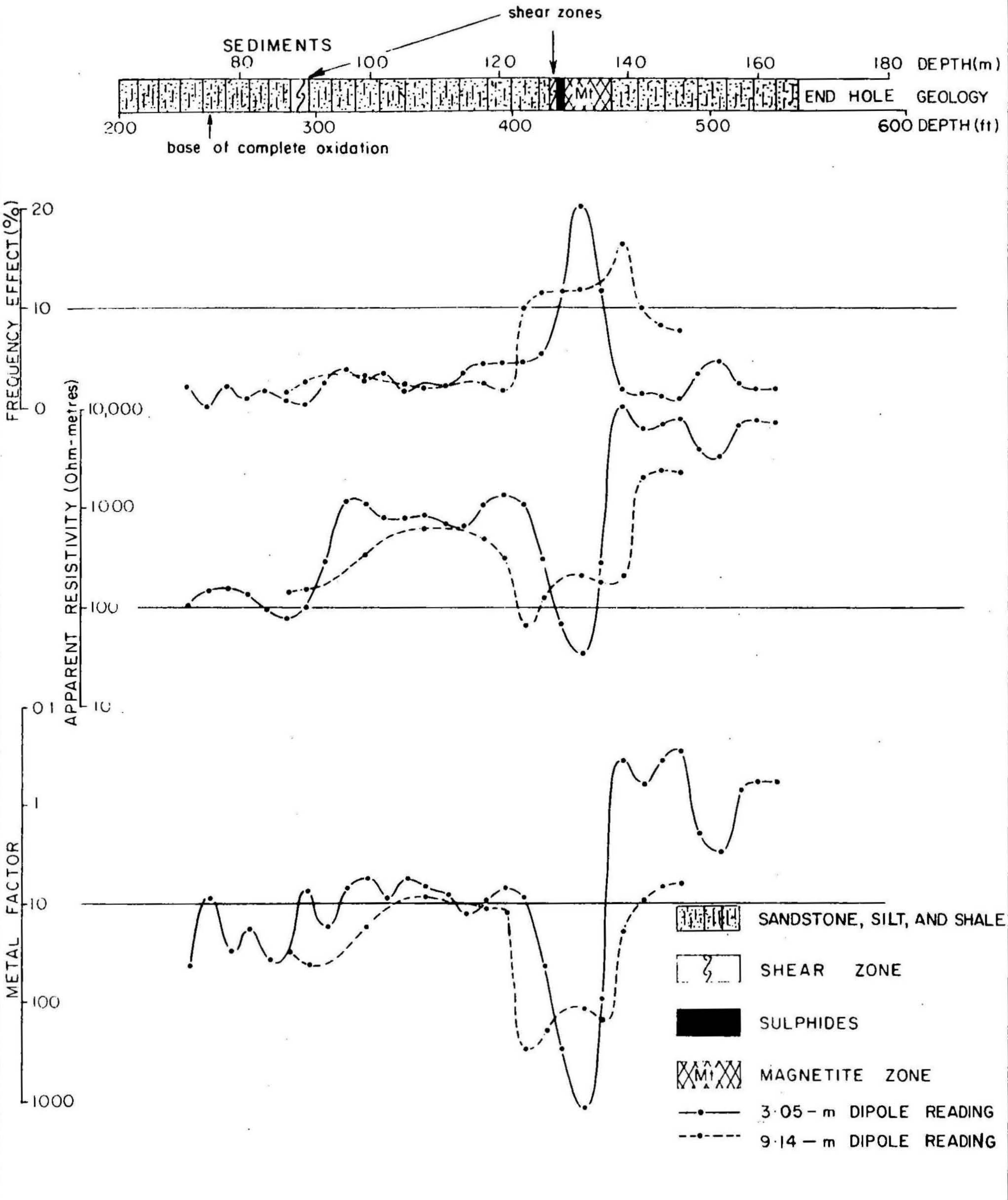
PLATE 7

E53/B7-124A

PLATE 8



TENNANT CREEK, NT 1971
IP RESULTS DH 9

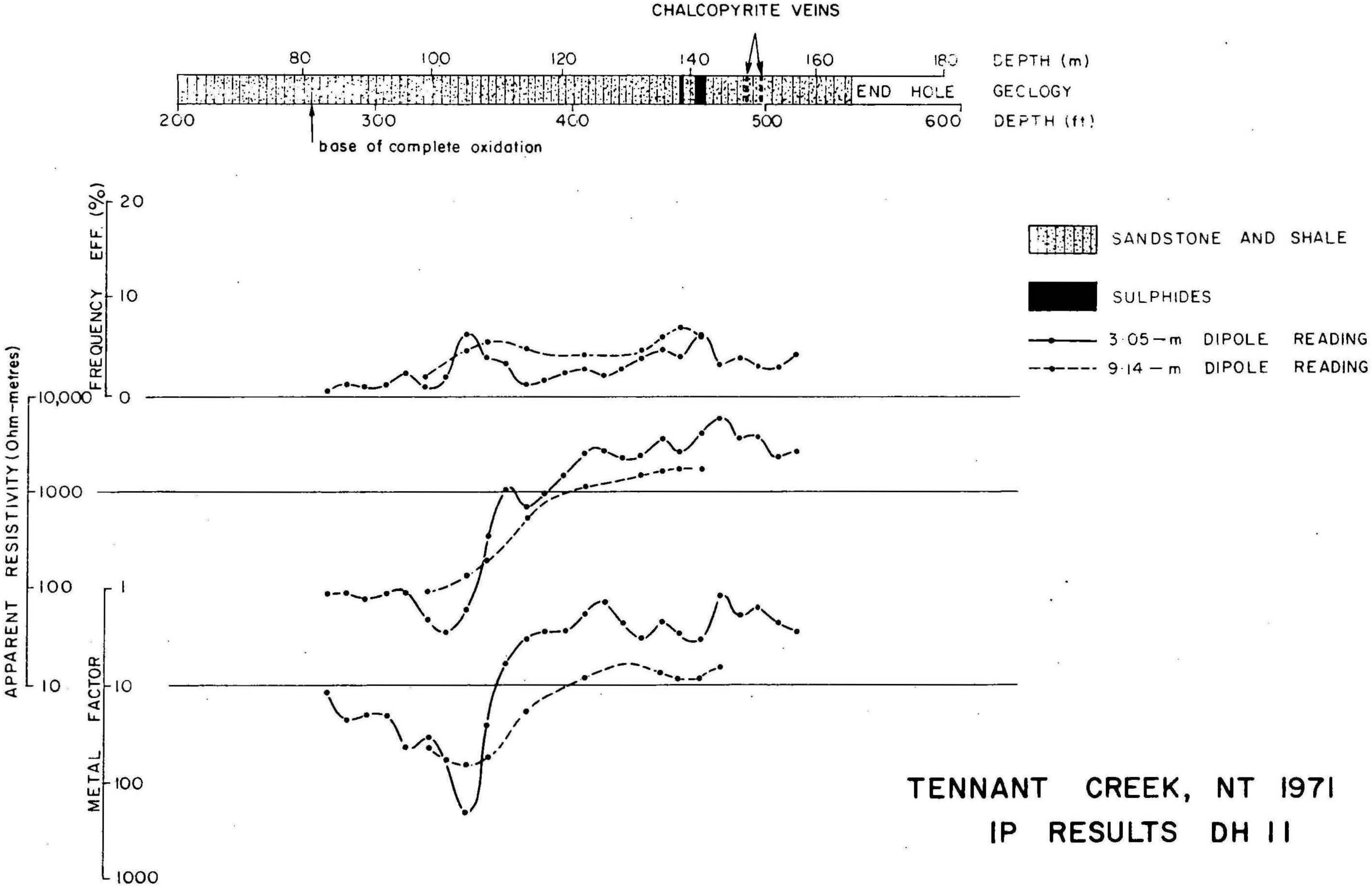


TENNANT CREEK, NT 1971
IP RESULTS DH 10

To Accompany Record No. 1972/30

E53/B7-126A

To Accompany Record No. 1972/30

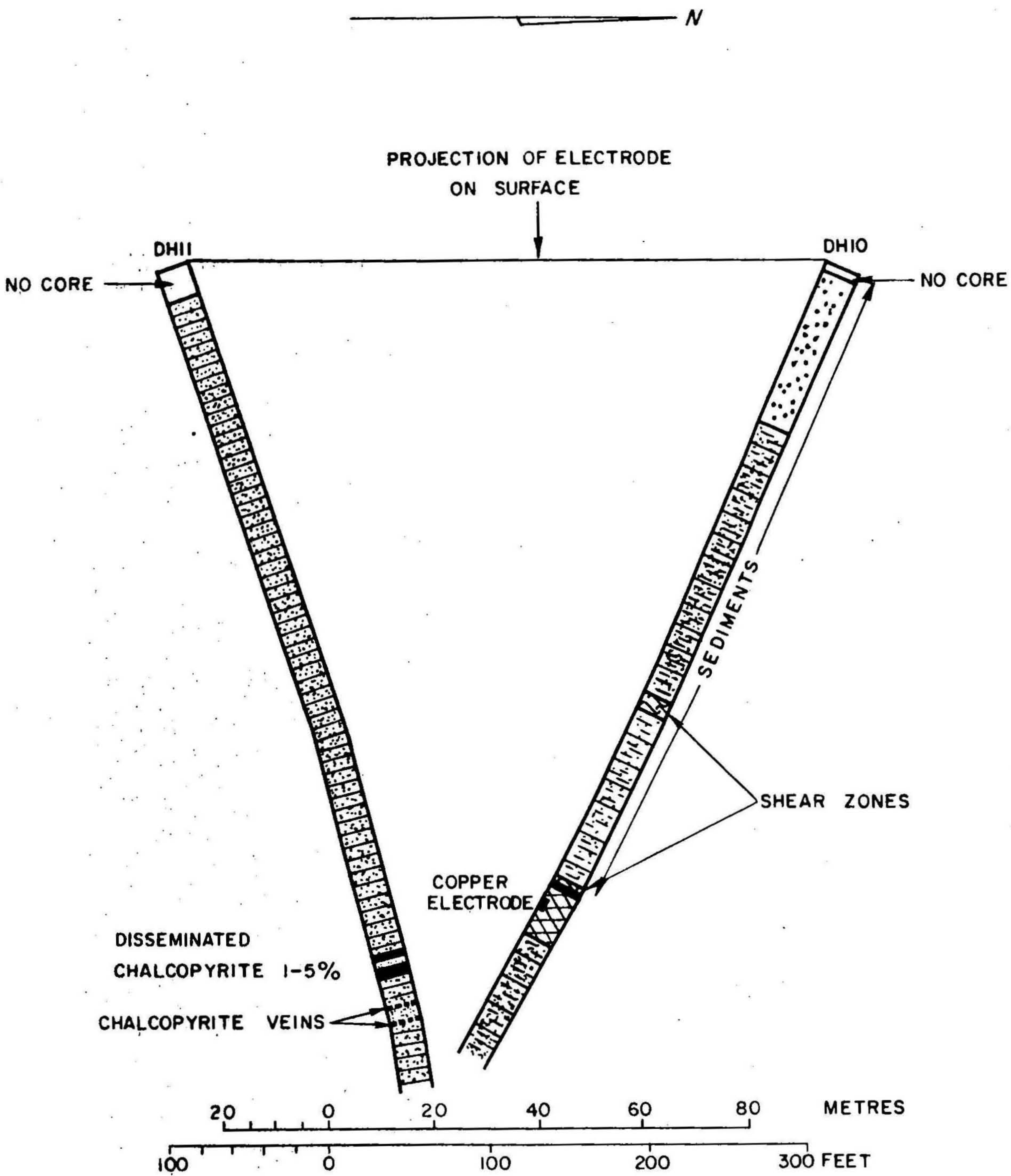


TENNANT CREEK, NT 1971
IP RESULTS DH 11

PLATE 10

E53/B7-127A

PLATE II



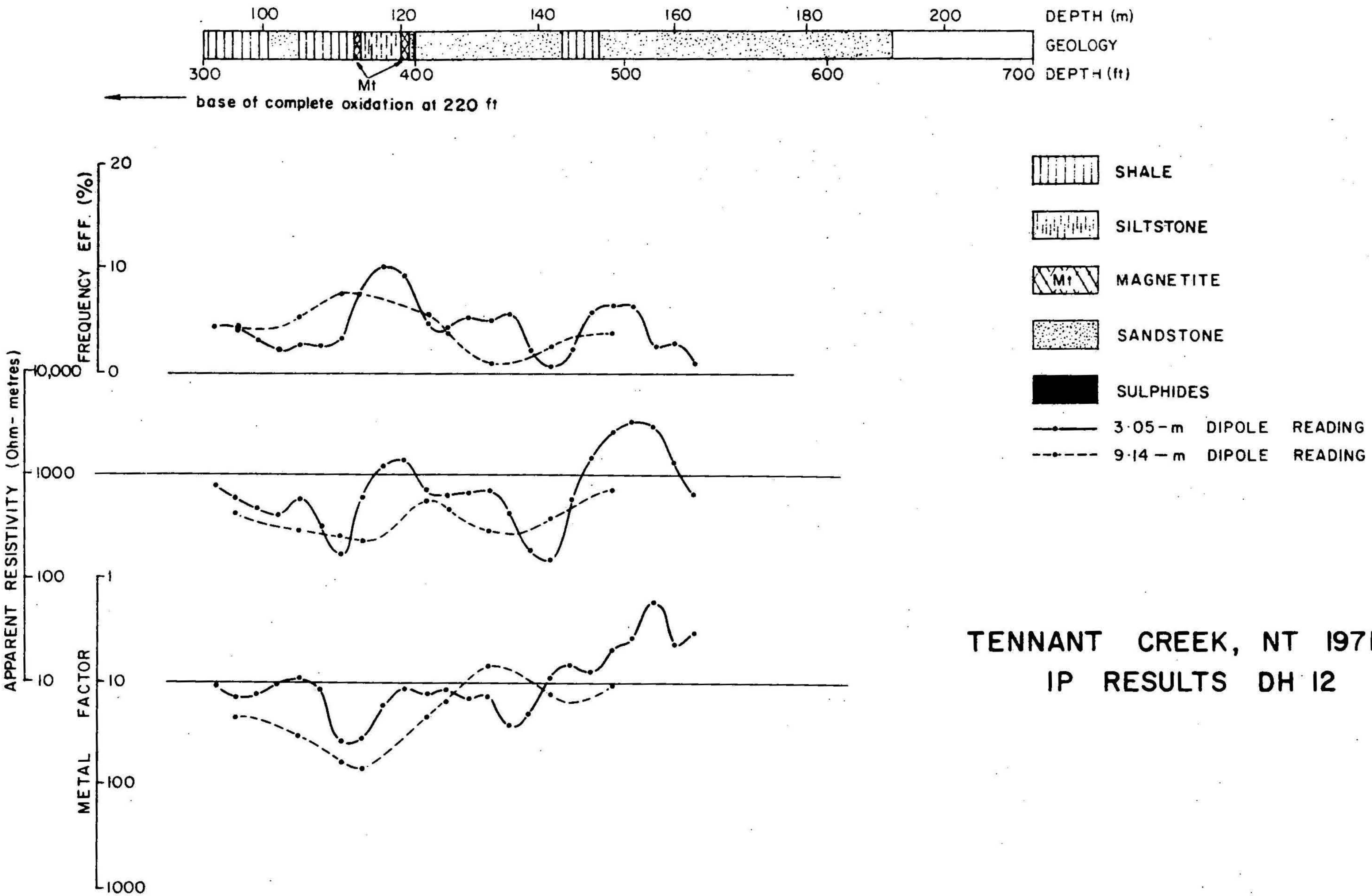
- SANDSTONE AND SHALE
- MEDIUM TO COARSE-GRAINED SANDSTONE
- Mt MAGNETITE
- SULPHIDES
- SANDSTONE, SILT, AND SHALE

TENNANT CREEK, NT 1971
SPATIAL RELATION BETWEEN DH 10 AND DH 11

To Accompany Record No. 1972/30

E53/B7-128A

To Accompany Record No. 1972/30



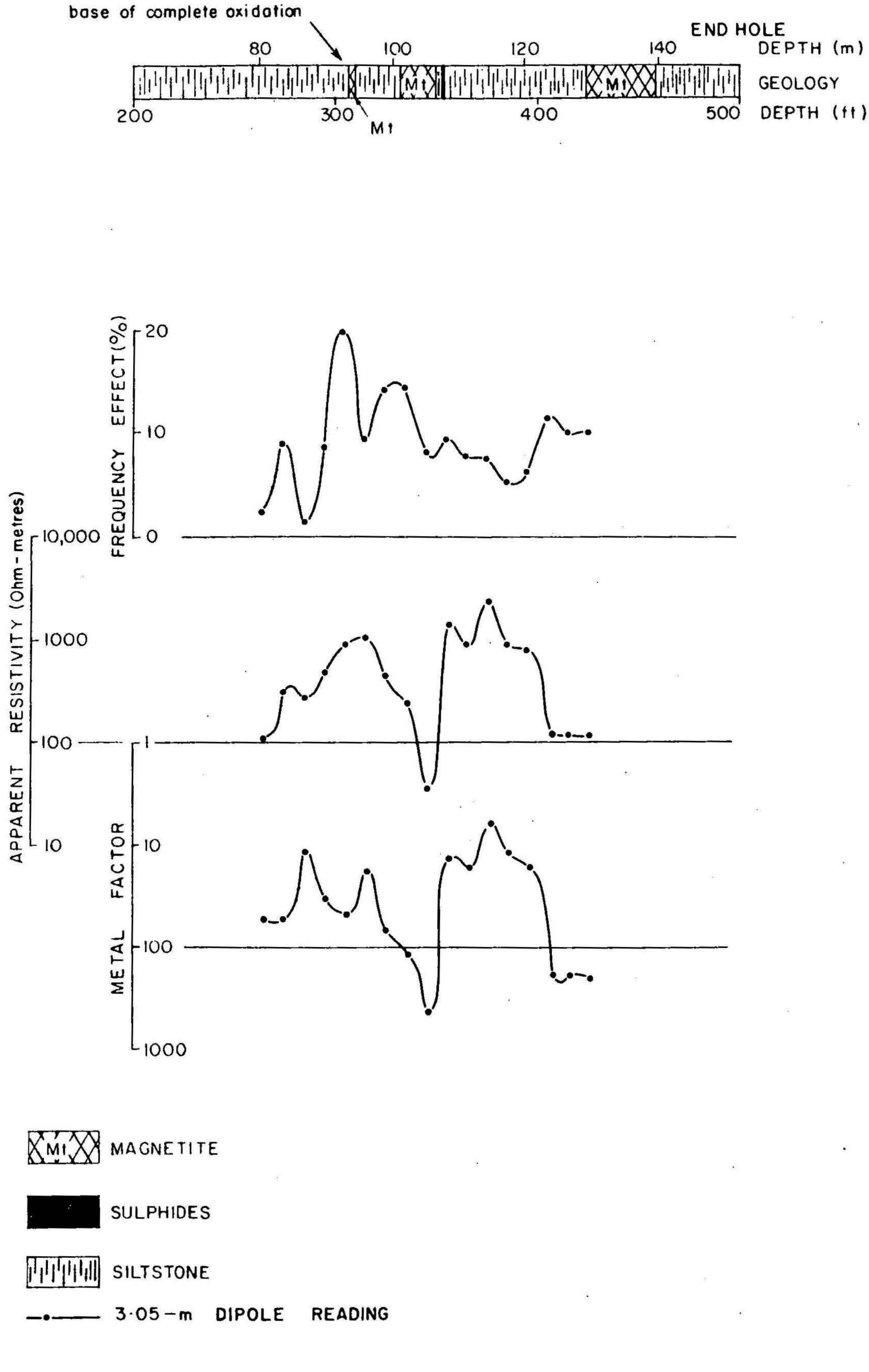
TENNANT CREEK, NT 1971

IP RESULTS DH 12

PLATE 12

E53/B7-129A

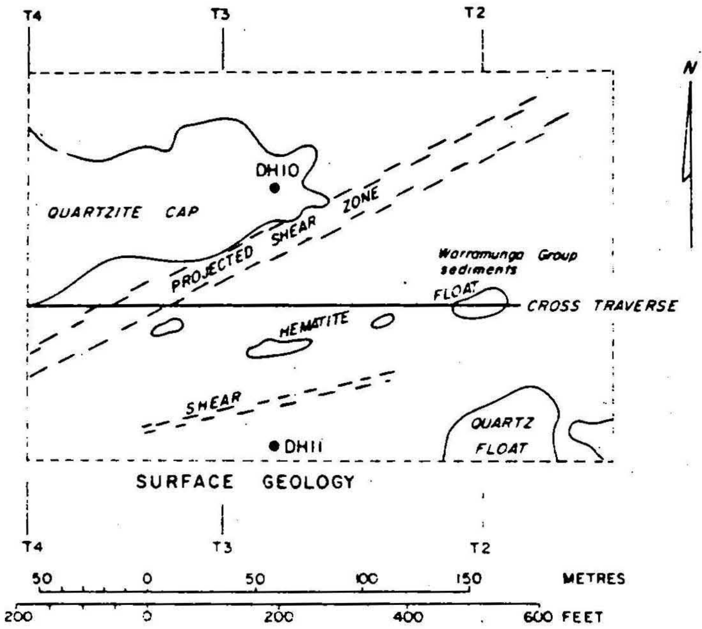
PLATE 13

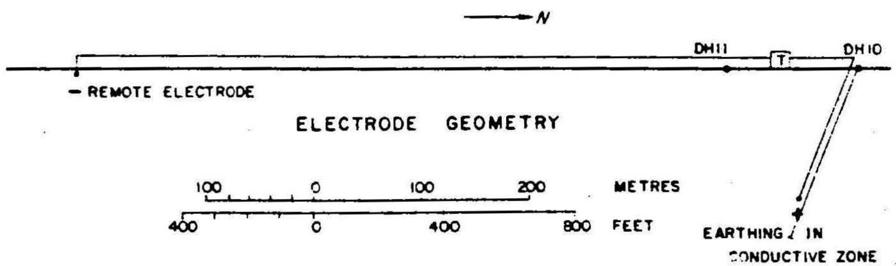


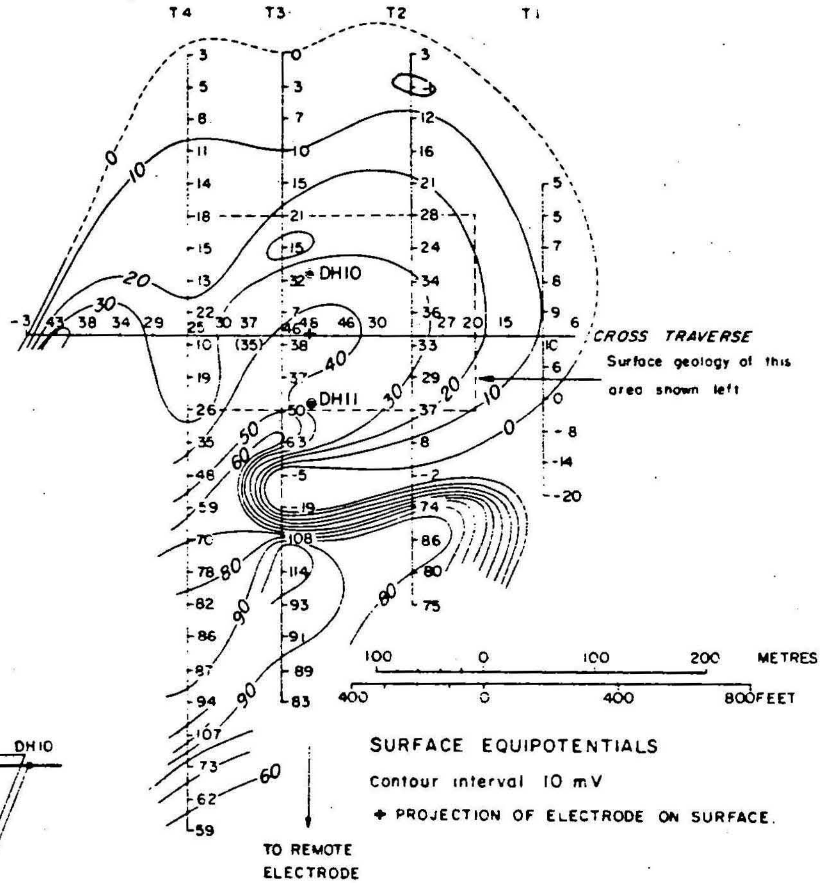
TENNANT CREEK, NT 1971
IP RESULTS DH 13

To Accompany Record No. 1972/30

E 53/B 7-130A







TENNANT CREEK, NT 1971

SURFACE GEOLOGY, EQUIPOTENTIALS, AND ELECTRODE GEOMETRY FOR APPLIED POTENTIAL TECHNIQUE

To Accompany Record No 1972/30

E53/B7-13