DEPARTMENT OF
NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/62

FIELD TESTS WITH THE SCINTREX DHP-4 DOWN-HOLE EM PROSPECTING SYSTEM NSW, 1975

by

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SUMMARY

Between January and March 1975, the Bureau of Mineral Resources made a series of field tests with the Scintrex DHP-4 electromagnetic borehole prospecting system. The tests were designed to evaluate the detection capabilities of the DHP-4 equipment and to develop guidelines for its use in mineral exploration.

Field trials were made over the Woodlawn ore deposit, NSW (Jododex Australia Pty Ltd) and over the Basin Creek No. 1 and Snowball prospects, NSW (AOG Minerals Pty Ltd). The field trials indicate that detectability depends upon the mutual EM coupling relationship between the transmitter, conductor, and down-hole receiver, and varies significantly for differing geometrical situations. For optimum EM coupling the detection limit was shown to be roughly 30 m for the conductive Woodlawn orebody. No significant response to the mineralisation at the Basin Creek and Snowball prospects was observed because of the poor electrical conductivity and size of the mineralisation.

Results indicate that a free-space approximation cannot be used to normalise down-hole amplitude data. Free-space calculations can however assist in survey design and interpretation.

Although a response to the Woodlawn orebody was obtained, the tests showed that the DHP-4 has only limited applications in its present form. However, several factors favour the continued development of fixed-source, down-hole methods. Inherent advantages include the insensitivity of the method to small targets, and the possibility of directional information. Detectability could be improved by measuring orthogonal components of the subsurface magnetic field.

1. INTRODUCTION

Between January and March 1975, the Bureau of Mineral Resources (BMR) carried out field tests with the Scintrex DHP-4 down-hole electromagnetic (DHEM) prospecting system.

The tests were designed to evaluate the detection capabilities of the DHP-4 equipment and to develop guidelines for its use in mineral exploration. The possibilities of using EM techniques for off-hole mineral exploration have long been recognised (Veksler & Plyusnin, 1957) but relatively little has been published concerning their effectiveness, and only in recent years has commercial borehole equipment become available.

Field trials were made at the Woodlawn ore deposit, NSW (Jododex Australia Pty Ltd) and at the Basin Creek No. 1 and Snowball mineral prospects, NSW (AOG Minerals Pty Ltd). The test site locations are shown in Figure 1.

The field data were acquired by R. Almond and Dr N. Sampath. The data processing, interpretation, and report were completed by R.D. Ogilvy.

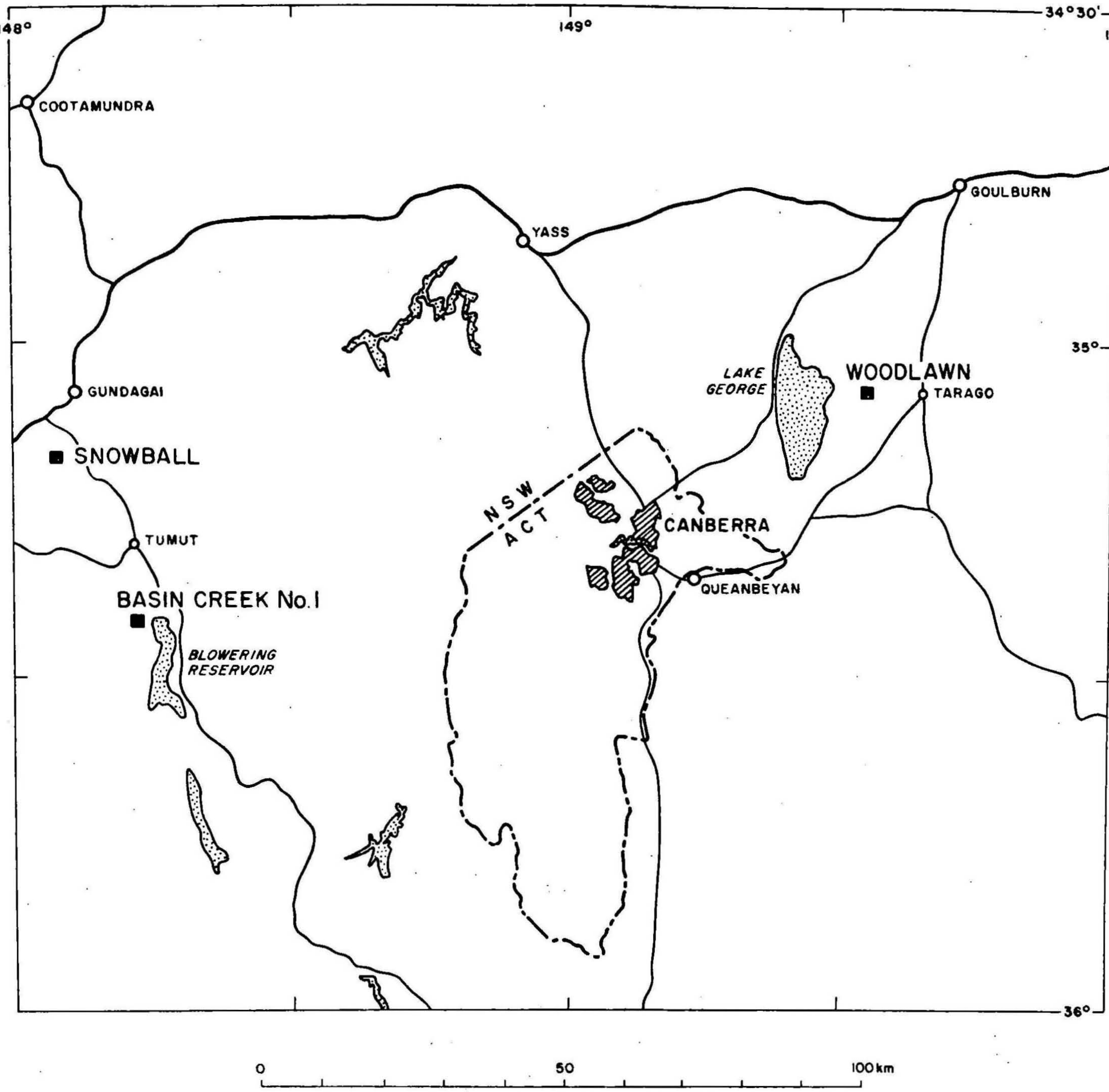
2. TEST SITES

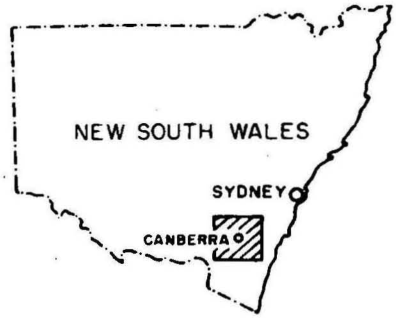
Woodlawn test site

The Woodlawn deposit is located some 75 km northeast of Canberra. The regional geological setting and mineralisation are described by Malone et al. (1975). Briefly the orebody is situated within steeply dipping Silurian-Ordovician acid volcanic rocks of the Lachlan Geosyncline. The deposit is an arcuate sulphide body striking approximately north, with a steep westerly dip. The unfolded strike length is estimated to be 400 m and its down-dip length is 300 m. Mineralisation is predominantly massive, with pyrite, sphalerite, galena and chalcopyrite in order of decreasing abundance.

The Woodlawn deposit was considered to be an ideal test site. The deposit represented a known EM target (Young, 1976) with excellent geological and geophysical control. Several remote and intersection holes were open and one drillhole was available in the near-miss category. The barren drillholes could be used to determine the normal field and magnitude of geologic noise. The near-miss and intersection holes could be used to estimate the search radius of the DHP-4 equipment and the response of the orebody.

Fig. 1





LOCALITY MAP

Basin Creek test site

The Basin Creek No. 1 prospect is located in the Snubba Range, south of Tumut. The host rocks are phyllites and intermediate metavolcanics of the Middle Silurian Blowering Beds. Drilling in 1972/73 revealed several lenses of both massive and disseminated mineralisation. Chalcopyrite is the most abundant sulphide and is associated with sphalerite, pyrite and galena. Previous geophysical investigation (Ogilvy, 1974) indicated that the massive sulphide lenses are small and only moderately conductive (0.02 - 1 S/m).

The Basin Creek prospect offered two drillholes intersecting ore-grade mineralisation and several drillholes in possible near-miss situations. Severe topographic variations in the area could be expected to introduce spurious distortions in the primary field. Despite these restrictions, it was considered important to assess the sensitivity of the DHP-4 to small targets of the Basin Creek type.

Snowball test site

The Snowball mineral lease is located some 10 km south of Gundagai. The prospect contains a disseminated sulphide body within vertically dipping Silurian metavolcanics. The mineralisation is predominantly chalcopyrite with minor pyrite and magnetite. Severe topographic variations were also encountered at the Snowball prospect and only one intersection hole was accessible for EM logging. No reliable geo-electric property measurements were available, but S-P and single-point resistance logs show distinct lows associated with the mineralised zone.

3. GEOPHYSICAL BACKGROUND

Principle of operation: The principle of operation of the DHP-4 equipment is based on the fact that if a conductor is subjected to an alternating primary electromagnetic field, eddy currents are induced in the conductor and produce a secondary electromagnetic field. The Scintrex DHP-4 equipment employs a large transmitting loop laid on the ground to establish the primary field and a down-hole receiving coil to detect the primary and secondary fields in the hole. The amplitude and phase of the magnetic field component co-axial with the drillhole are measured with respect to the amplitude and phase of the signal in a fixed reference coil at the drillhole collar. The presence of a conductor near the drillhole is indicated by anomalous phase readings and departures of the total field from the normal primary field. With the DHP-4 unit, measurements are made at a fixed frequency of 2000 Hz. A schematic representation of a drillhole EM survey using the DHP-4 equipment is shown in Figure 2.

Instrumentation: The DHP-4 equipment consists of three standard units. The transmitting unit comprises a 1 kW motor-generator, a current regulator, and a large single-turn insulated loop. The reference and down-hole coils are each constructed from 2000 turns of insulated copper wire wound on silicon-iron strips. The outside diameter of each coil is 19 mm (0.75") and permits access to all standard diamond-drillholes.

The measuring unit comprises a cable drum, 300 m of cable, and an amplifier unit with appropriate attenuation and phase-shifting networks. The signal from the receiving coil is compared with that in the reference coil to give relative signal strength in millivolts and phase difference in degrees.

Data presentation

Ideally a system of plotting which shows the departure of the total field from the normal primary field is required. Such a method would be similar to the "reduced ratio" representation used in Turam. However, an attempt to normalise the down-hole amplitude using the free-space approximation was in most cases unsuccessful, and discrepancies between the observed and calculated primary amplitudes were noted. The failure of the free-space approximation is attributed to scattering of the primary field in the earth.

Nevertheless, theoretical free-space calculations of the primary field do provide a means of differentiating between amplitude deviations caused by geometrical effects (e.g. drillhole deviations and field reversals) and deviations caused by subsurface zones of anomalous conductivity. Hence theoretical amplitude curves are presented with the field results to assist the interpretation of the data. In all cases, the axial component of the free-space primary field has been used to permit direct comparison with the observed amplitude data. The derivation of the formula used in calculating the free-space axial field due to a square current loop is based on the magnetic field formula for a finite line source of current.

The DHP-4 measures amplitude in millivolts, normalised with respect to the reference signal. The amplitude measurements have been expressed as a percentage of the appropriate free-space primary field strength at the top of the drillhole. Phase angle measurements are given in degrees.

Directional information

The response of a down-hole EM system to a conductor depends on the coupling between the conductor, receiver, and transmitter. With the DHP-4 system the coupling can easily be altered by changing the size and/or location of the transmitting loop. Directional information may be obtained by running surveys with the loops in each quadrant surrounding the drillhole. The quadrant in which the maximum response is recorded is an indication of the direction to the conductor.

Field reversals

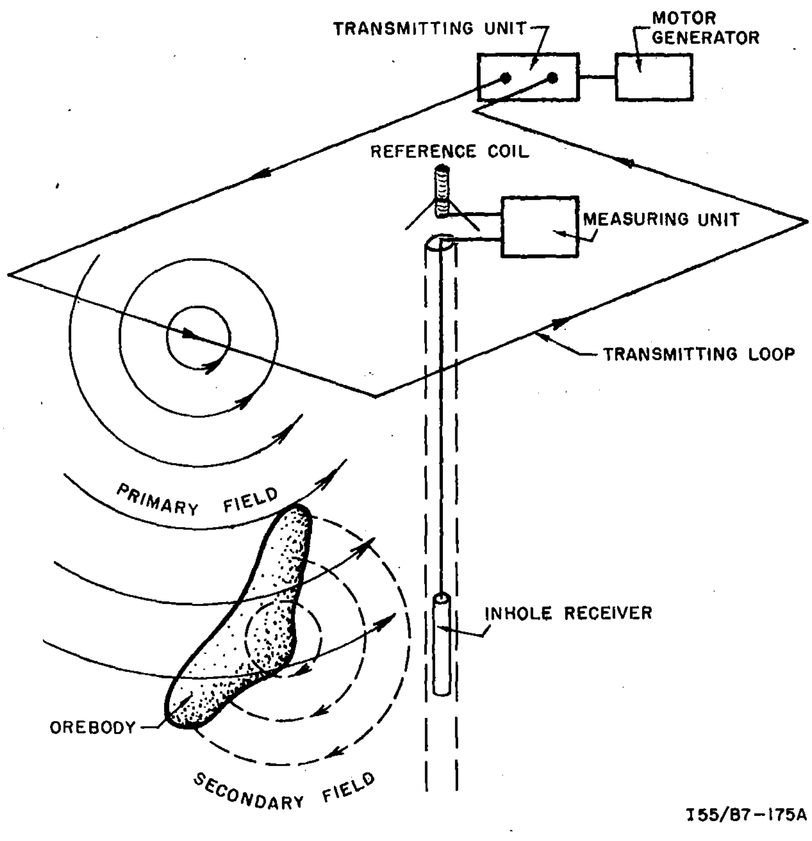
If a drillhole passes beneath the circumference of the surface transmitting loop the direction of the axial component of the primary field will undergo a 180^{o} phase change at some point, and the amplitude curve will pass through a minimum. In interpreting the results of DHP-4 surveys it is important to separate these geometric effects from anomalies caused by conductive bodies.

SURVEY DETAILS

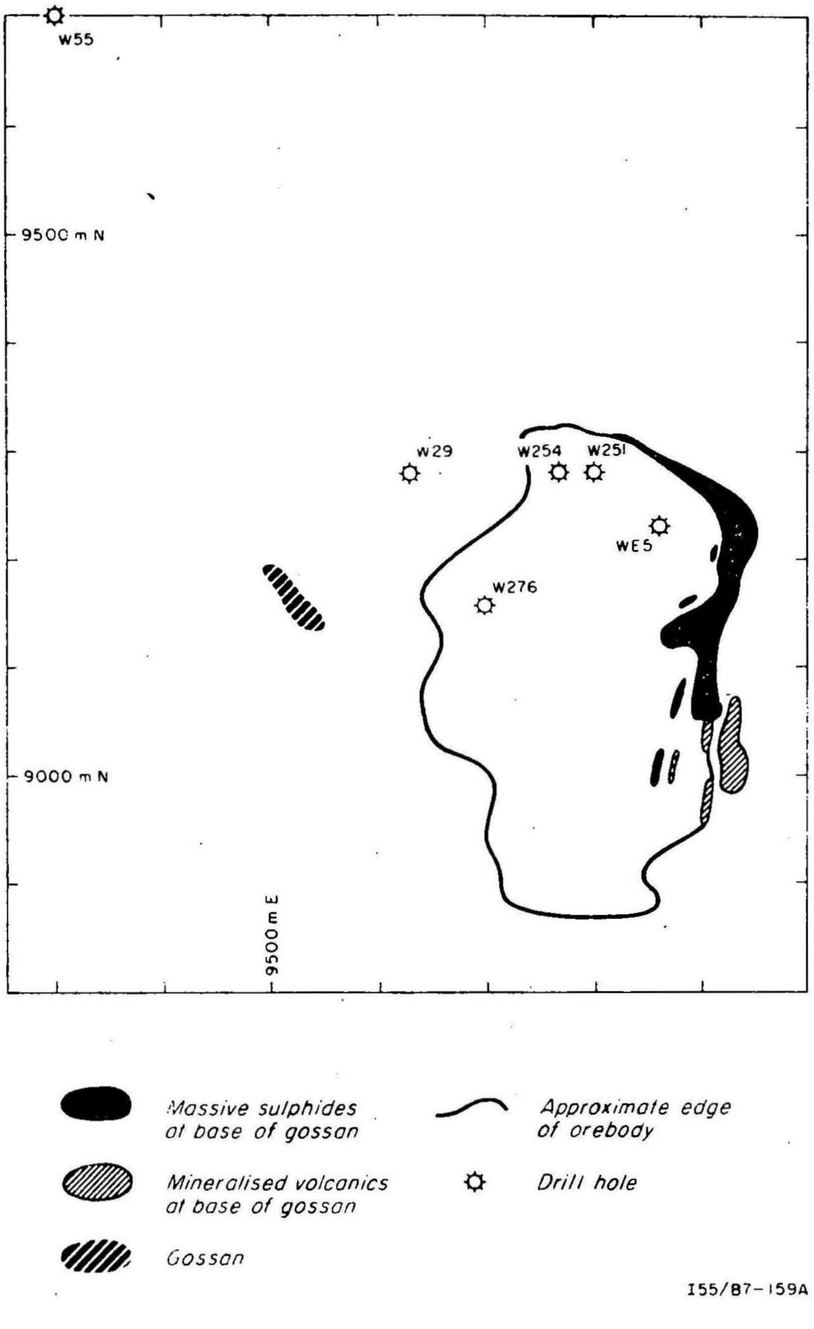
Details concerning the sizes, positions, and orientations of the loops are given in Table 1.

Transmitting loops were square and had side lengths of from 50 m to 400 m. Some holes were surveyed with loops of various sizes and in various positions in an attempt to increase the response of the orebody by changing the coupling characteristics of the survey.

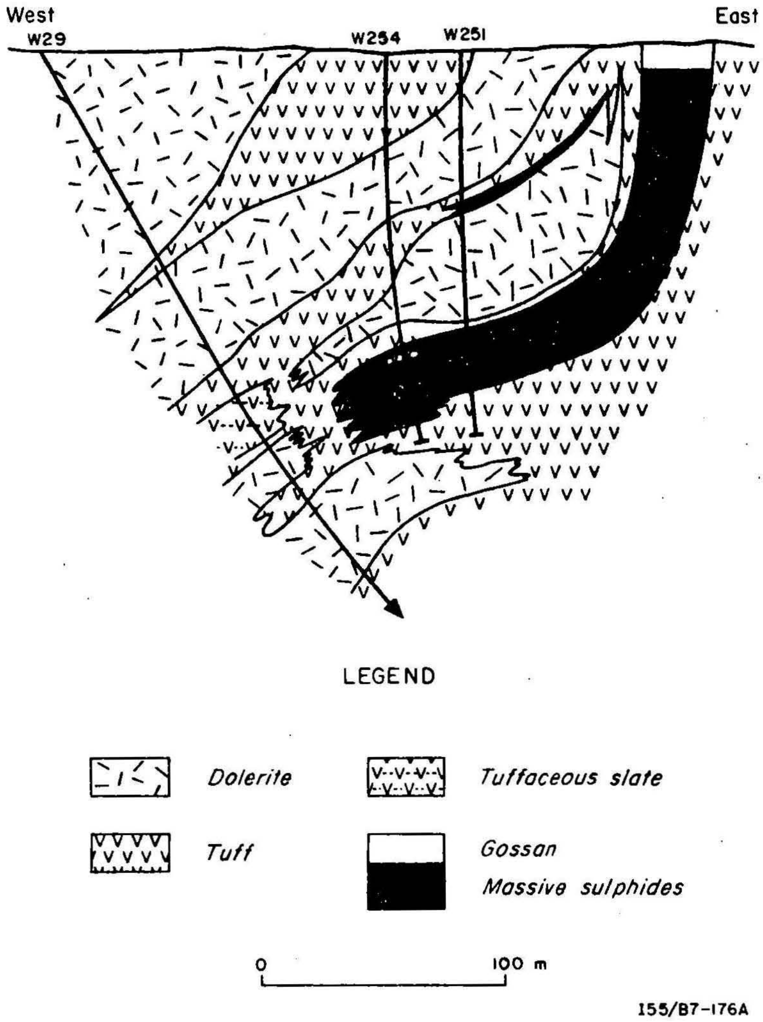
Fig. 2



SCHEMATIC REPRESENTATION OF A DHP-4 SURVEY



LOCATION OF DRILL HOLES - WOODLAWN



CROSS-SECTION TRAVERSE 9280N - WOODLAWN

4. WOODLAWN RESULTS

Six drillholes were surveyed with the DHP-4 equipment at Woodlawn. W55 was a barren hole remote from the orebody, W29 was a near-miss drillhole at the northern end of the orebody, and drillholes WE5, W251, W254, and W276 intersected the orebody. The location of the holes relative to the orebody is shown in Figure 3. DDH W29, DDH W254 and DDH W251 were drilled along traverse 9280N, and the location of these holes relative to the orebody is indicated in the cross-section shown in Figure 4.

Drillhole W55

W55 is a barren hole remote from the Woodlawn orebody and was surveyed with a 400 x 400 m loop centred on the hole collar. The results of the down-hole EM survey and the geological log of the hole are shown in Figure 5.

Down-hole resistivity logging of this hole (Young, 1976) showed that the dolerite and tuff have resistivities in the range 100-10 000 ohm-m. Both the amplitude and the phase curves are smooth and no anomalies are evident. The amplitude curve decreases monotonically down the hole and is similar to the calculated free-space amplitude curve. The phase curve shows a gradual increase with depth.

The smooth amplitude and phase curves indicate that the DHP-4 system is insensitive to variations in conductance associated with changes in lithology. However, as only the co-axial field component was measured, the lack of response to changes in lithology might in part be attributed to poor coupling between the loop, probe, and rocks. The gradual increase in phase with depth can be attributed to scattering of the primary field in a conductive earth.

Drillhole W29

W29 represented an ideal test hole in that it was relatively free of mineralisation and was thought to pass within 30 m of the orebody as shown in Figure 4. This hole was surveyed with a variety of loop sizes and loop locations as shown in Table 1.

TABLE 1 - SURVEY DETAILS

Test Site	Drillhole	Loop Size (metres)	Loop Centre	Orientation with magnetic north (degrees)
Woodlawn	W55	400	W55	0^{o}
	W29			
	Case 1	300	W29	"
	Case 2	400	420 m E of W29	"
	Case 3	200	W251	"
	WE5	200	WE5	"
	W251	200	W251	"
	W254	200	W251	"
	W276			
	Case 1	300	W276	"
	Case 2	100	W276	"
Basin Creek	DDH1	50	48 m SW of DDH1	25^{o}W
	DDH8			
	Case 1	50	60 m W of DDH8	10^{o}W
	Case 2	400	70 m SW of DDH8	25^{o}W
	DDH9	400	"	"
	DDH10	"	"	"
	DDH14	"	"	"
	DDH15	"	"	"
Snowball	DDH6			
	Case 1	100	DDH6	5^{o}E
	Case 2	100	100 m S of DDH6	0^{o}
	Case 3	360	DDH6	15^{o}E

Case 1: Figure 6 shows the EM results obtained with a 300 m x 300 m loop centred directly over the collar of W29. The observed amplitude curve correlates almost exactly with the theoretical amplitude curve, and no anomalous response is evident. The phase curve shows a gradual increase opposite the projected position of the orebody but the increase in phase is similar to that observed in W55, and is only marginally larger.

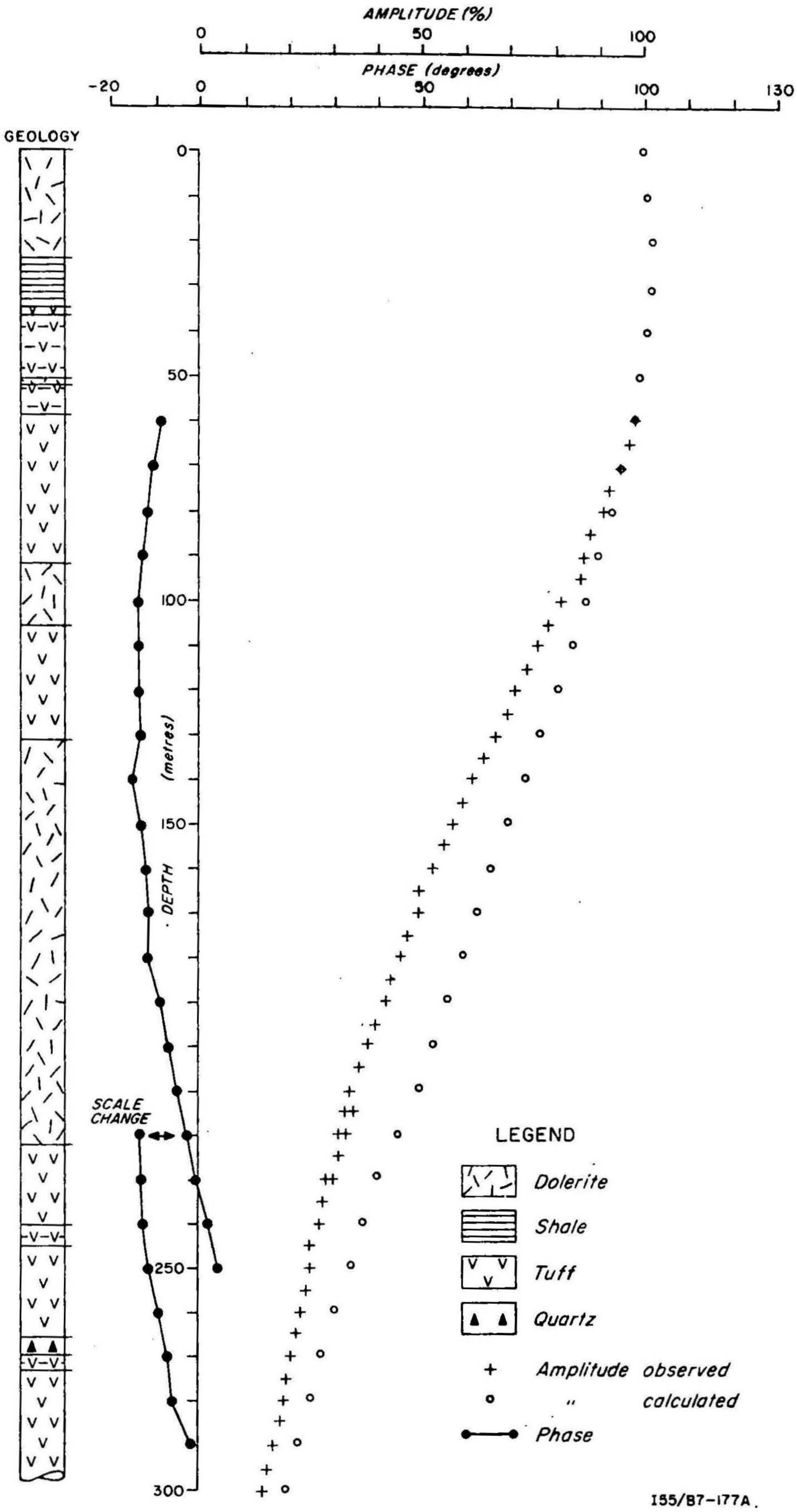
The poor response to the orebody in this case may be due to unfavourable EM coupling as indicated by the schematic representation of the primary and secondary field geometries shown in Figure 7. Note that as the primary field parallels the orebody, minimum induction occurs and a weak secondary field will result. Further, as both secondary and primary fields have strong flux linkages with the receiving coil, the relative strength of the orebody response is small.

Case 2: Figure 8 shows the EM results obtained with a 400 m x 400 m loop centred 420 m east of W29. This loop position was chosen because the primary field of a loop in this position would have greater flux linkage with the orebody.

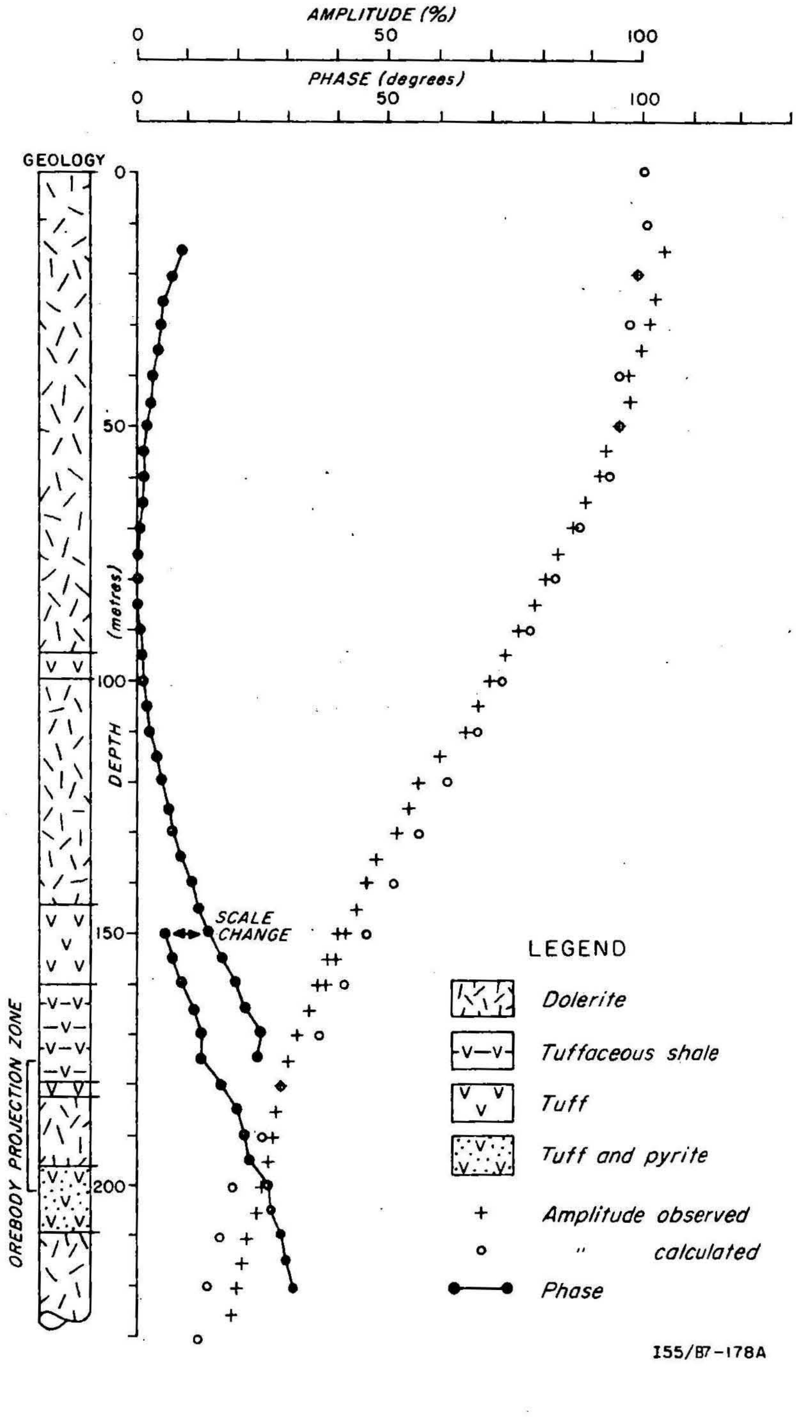
Although the observed and theoretical amplitude curves differ in magnitude, their basic shape is similar. In particular the small minimum observed in the amplitude curve at 160 m is not far removed from the minimum in the theoretical curve at a depth of 170 m. If the anomalous behaviour of the phase and amplitude curves at 160 m is attributed to a geometric effect then no anomalous EM responses were observed in this case.

Case 3: Figure 9 shows the results obtained in W29 with a 200 x 200 m loop centred on drillhole W251. A simplified view of the field geometries for this position as shown in Figure 10 suggests that optimum EM coupling would be obtained for the enhancement and detection of secondary magnetic fields. As the primary field is near vertical at the centre of the loop, maximum flux linkage with the orebody and minimum linkage with the coaxial receiving coil will occur. Also secondary fields generated in the orebody will have maximum flux linkage with the receiving coil.

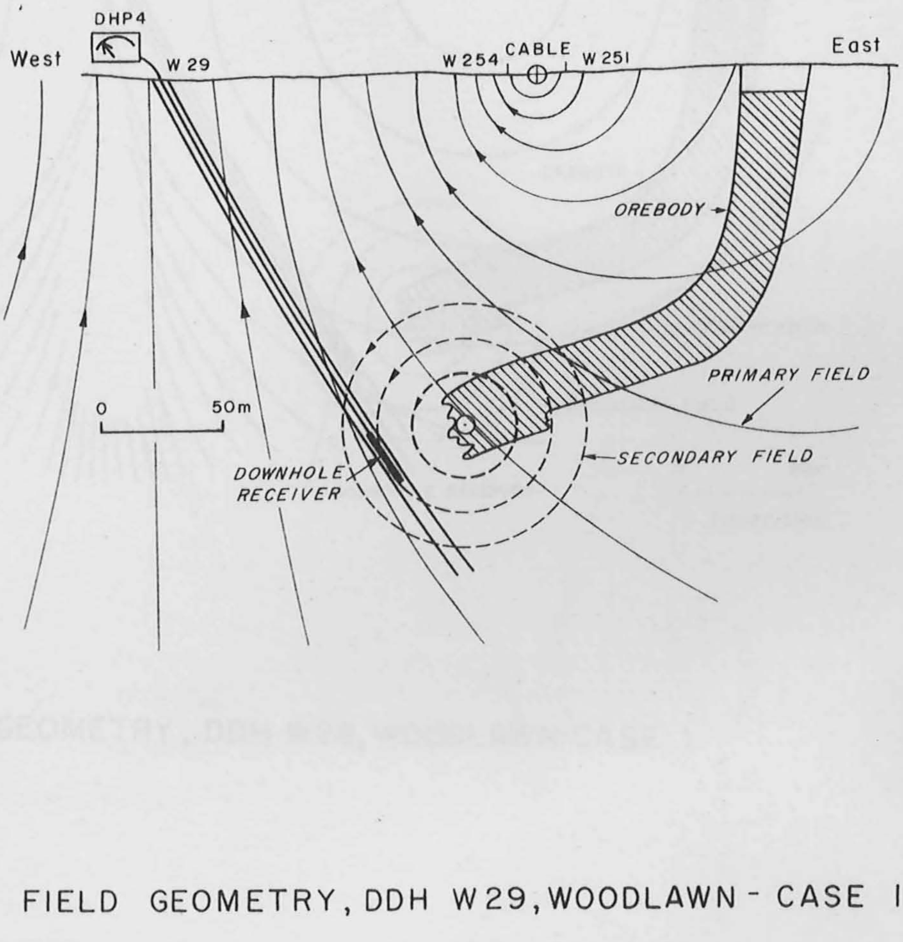
The theoretical amplitude curve shows an anticipated field reversal near 130 m down the hole but there is no corresponding reversal in the field data. This disparity may be attributed to distortions in the primary field caused by the orebody, or because the reversal is not discernible at such low field intensities.



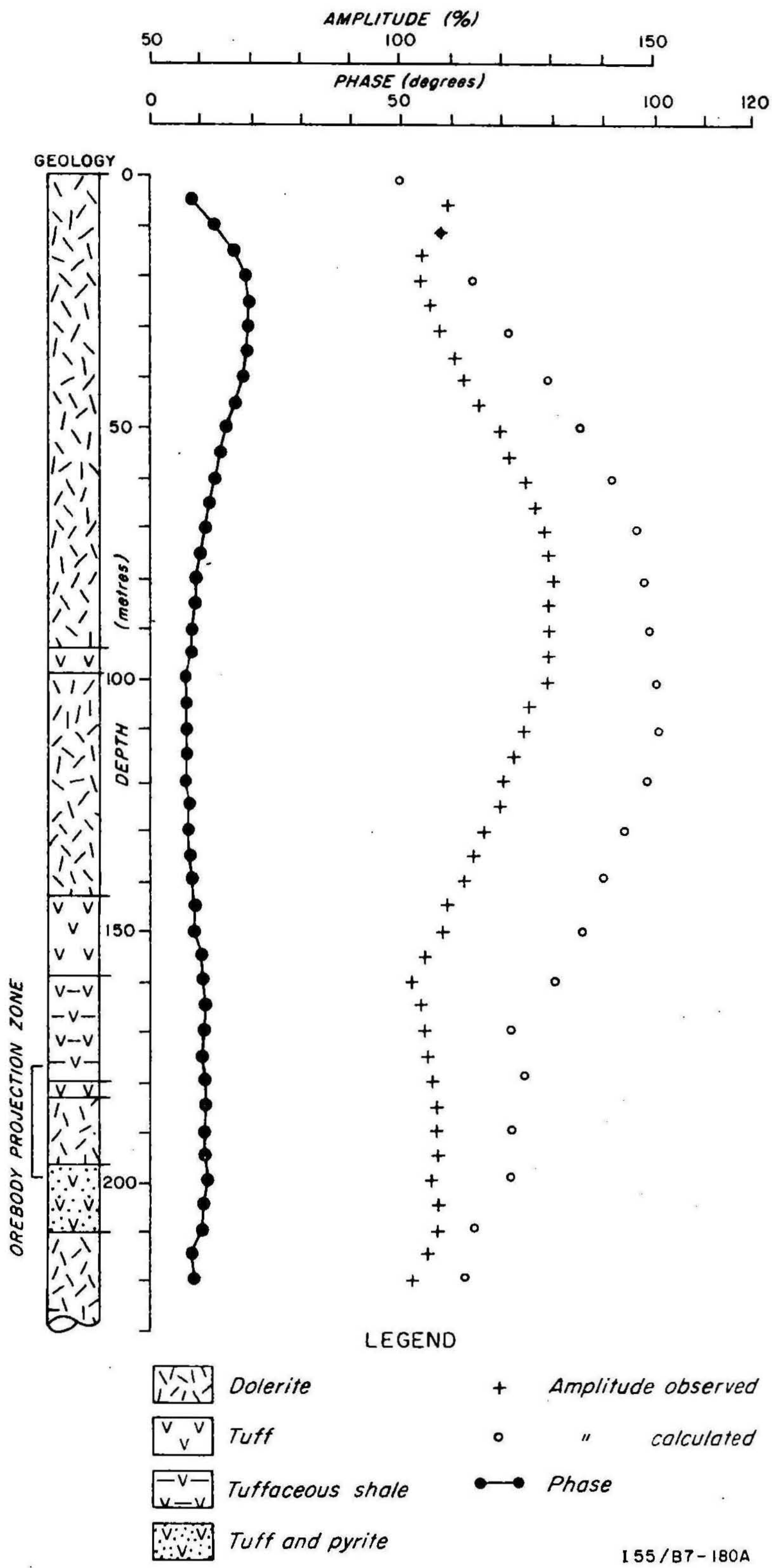
DDH W55, WOODLAWN



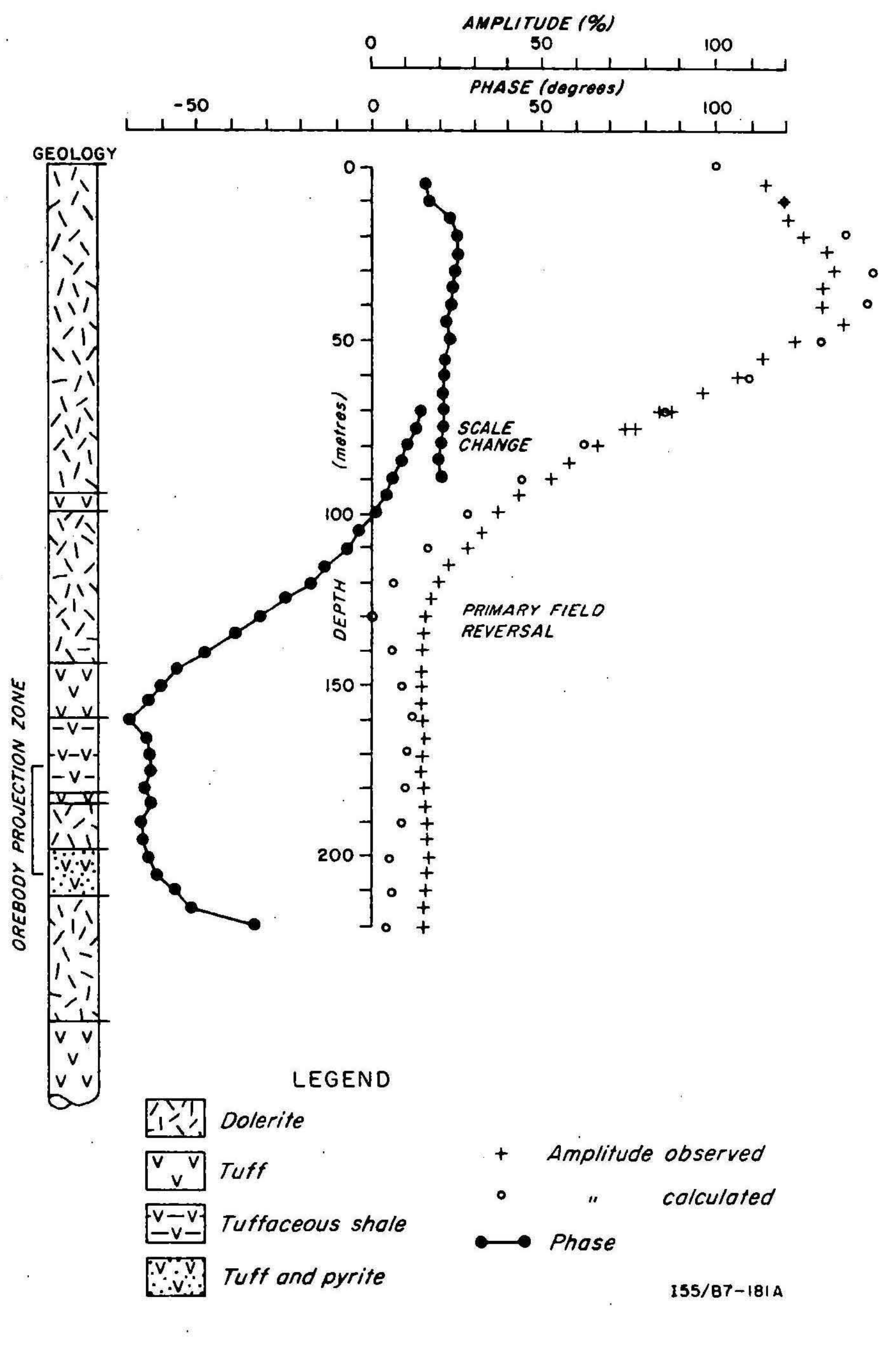
DDH W29, WOODLAWN - CASE 1



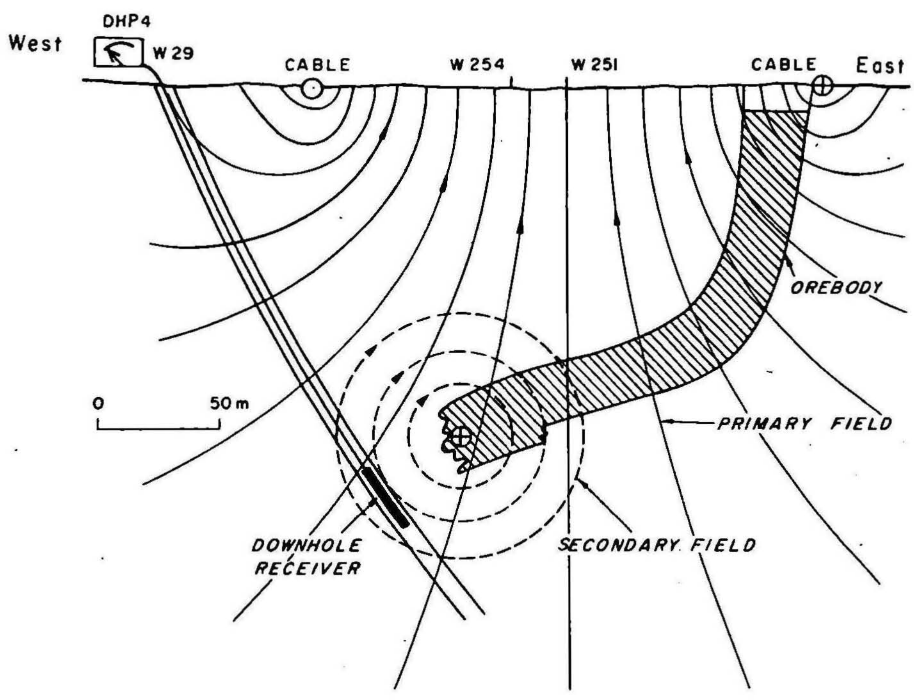
FIELD GEOMETRY, DDH W29, WOODLAWN - CASE I



DDH W29, WOODLAWN - CASE 2



DDH W29, WOODLAWN-CASE 3



FIELD GEOMETRY, DDH W29, WOODLAWN - CASE 3

A substantial negative phase anomaly was recorded opposite the orebody projection zone (drill depth 175-205 m) accompanied by what appears to be a negligible amplitude response. The anomalous response suggests a poor electrical conductor and most probably reflects the presence of nearby disseminated mineralisation rather than being a direct response to the massive ore intersected in drillhole W251.

Drillhole WE5

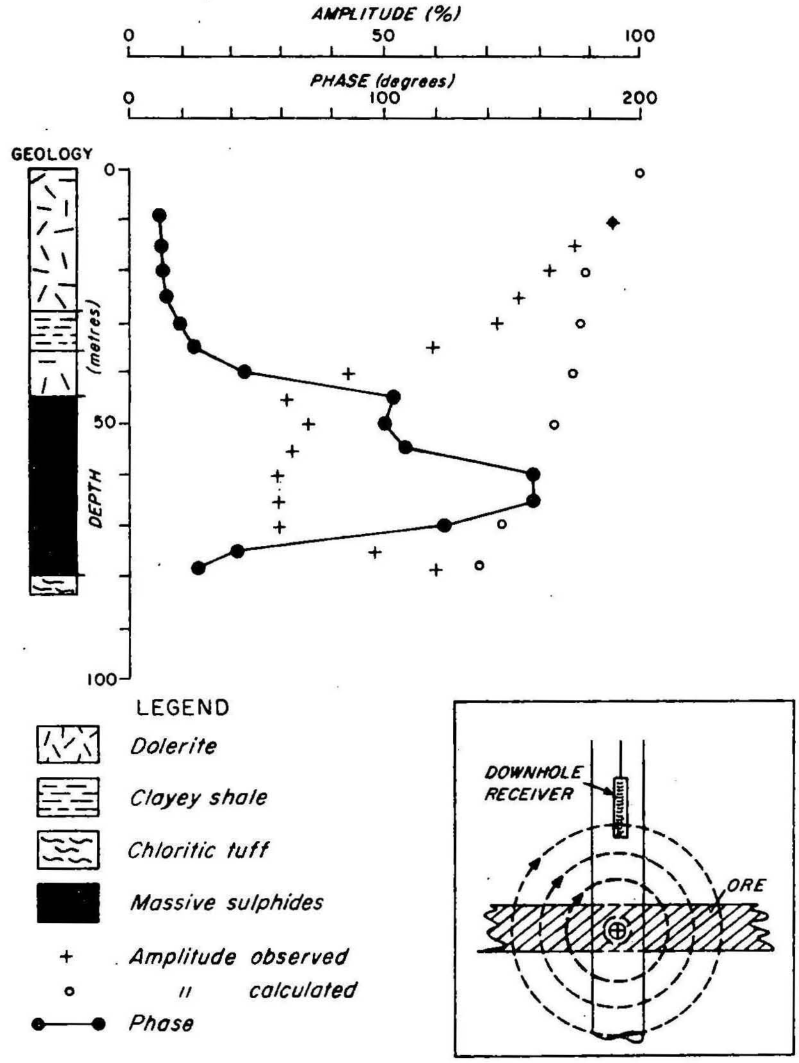
Figure 11 shows the EM response obtained with a 200 x 200 m loop centred on drillhole WE5.

This drillhole intersected massive sulphides between drill depths 47 and 80 m. On passing through the sulphides, a phase anomaly of greater than 155^{o} was recorded, together with a significant decrease in amplitude. The amplitude trough is attributed to attenuation of the primary field within the conductive sulphides. The response illustrates an inherent disadvantage of this method of down-hole measurement: with small loops, intersected ore zones may attenuate the primary field and effectively screen deeper conductors. Assuming an average ore conductivity of 10 S/m (Spies, 1977) the sulphides are some 9 skin depths thick. However, total shielding has not occurred due to the steeply dipping attitude of the conductor and the straddle position of the energising loop. The EM log does not penetrate far beyond the intersection zone, but a recovery of the field strength is evident after 75 m drill depth.

Anomalous amplitude and phase responses were recorded some 15-20 m before the intersection. However, it is necessary to note that when the drillhole intersects the orebody the co-axial search coil would invariably be minimum coupled with any secondary field generated by the conductor (see insert, Figure 11). The response is not therefore truly indicative of the DHP-4's optimum detection range.

Drillhole W251

Figure 12 shows the EM response obtained with a 200 x 200 m loop centred on drillhole W251.



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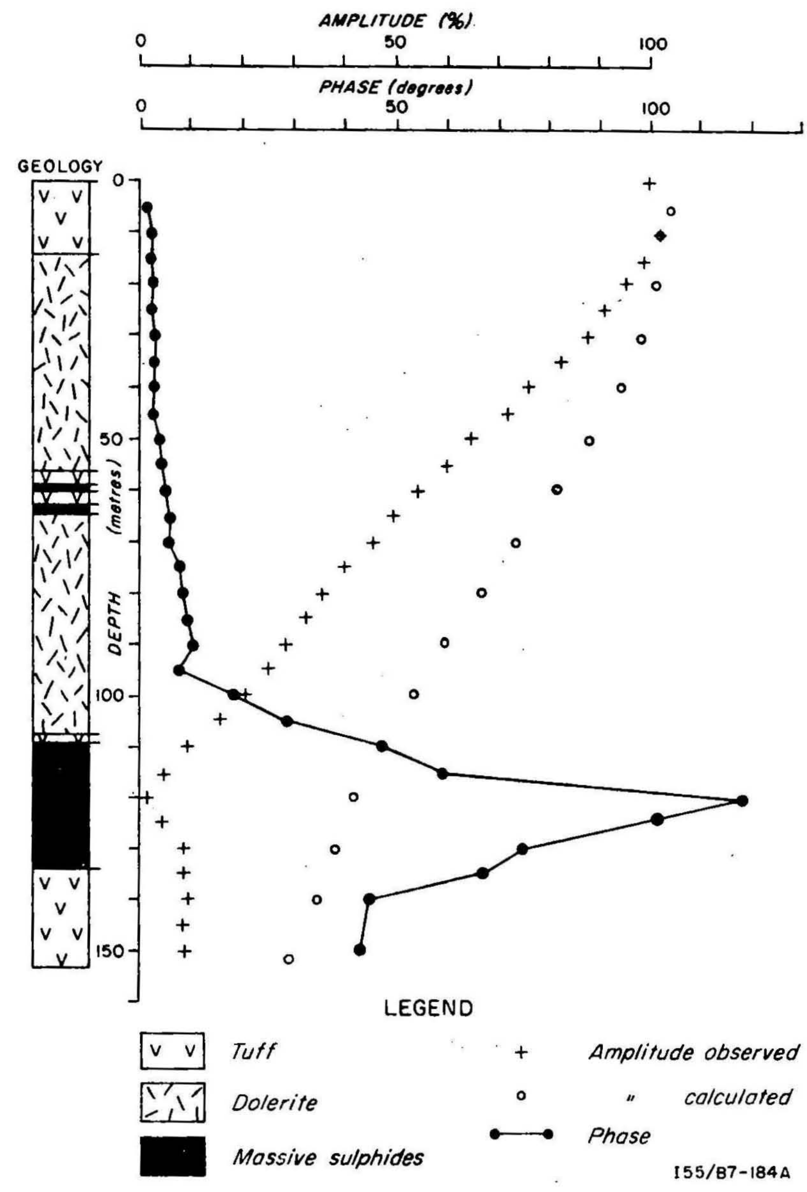
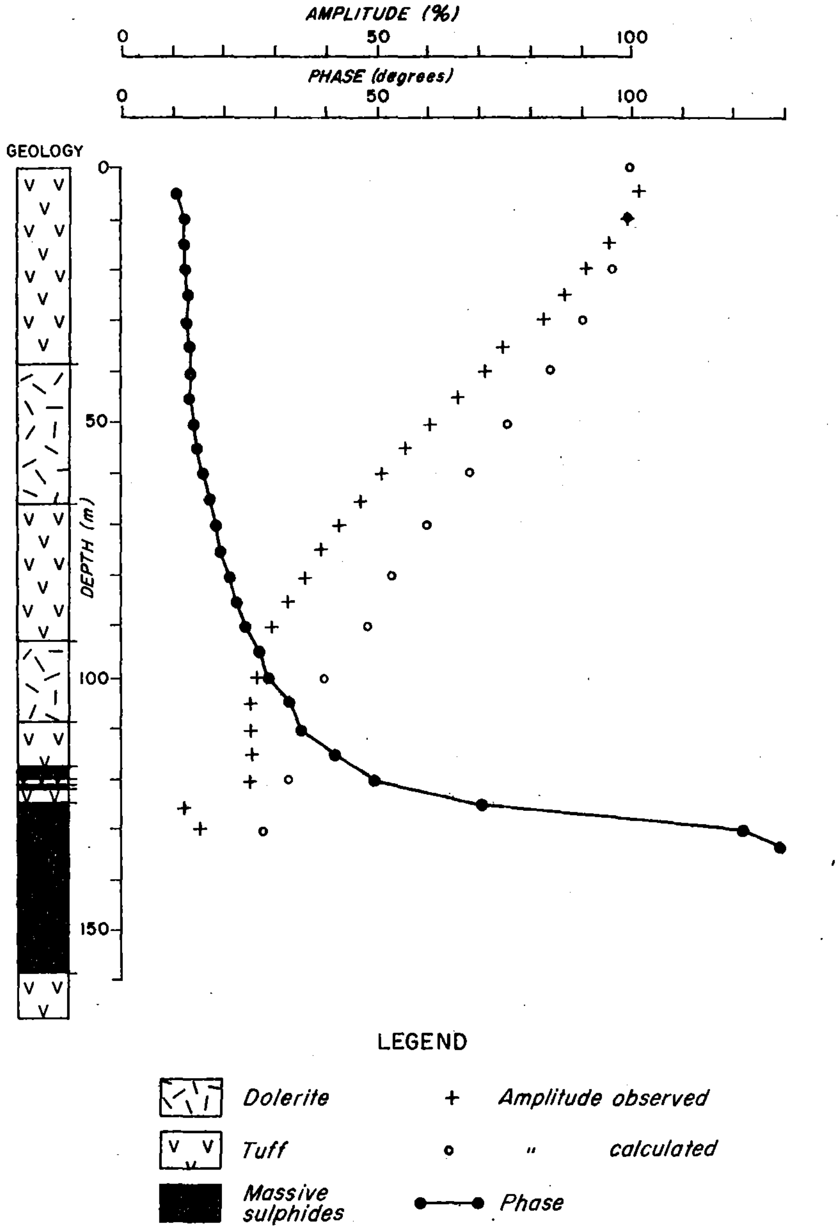
DDH WE5, WOODLAWN



DDH W251, WOODLAWN



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DDH W254, WOODLAWN

The drillhole intersected two minor shoots of massive sulphide at about 60 m, and the main ore zone between 112 and 135 m. The field curves show a typical amplitude trough in the major ore zone accompanied by a large phase anomaly of about 120^{o}. No EM response was obtained on passing through the minor ore shoots and no significant phase departure was observed until 10-15 m before the major ore intersection.

Drillhole W254

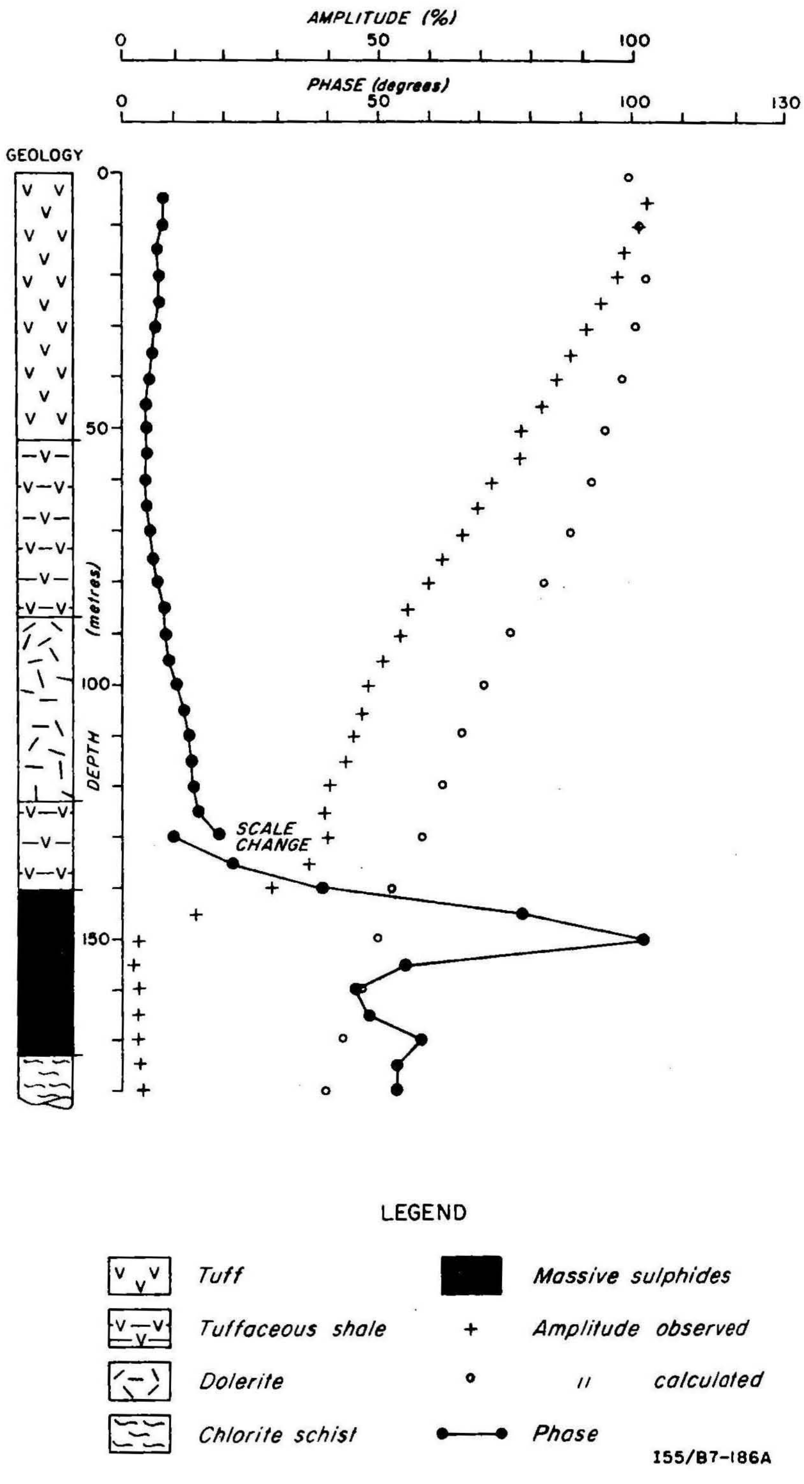
Figure 13 shows the EM response obtained in W254 with a 200 x 200 m loop centred on W251.

This drillhole intersected 30 m of massive sulphides between drill depths 107.5 and 151 m. The observed amplitude curve is similar to the theoretical curve except near the ore interface. As in other intersection cases, the phase angle measurements respond to the orebody but only some 15-20 m before the intersection.

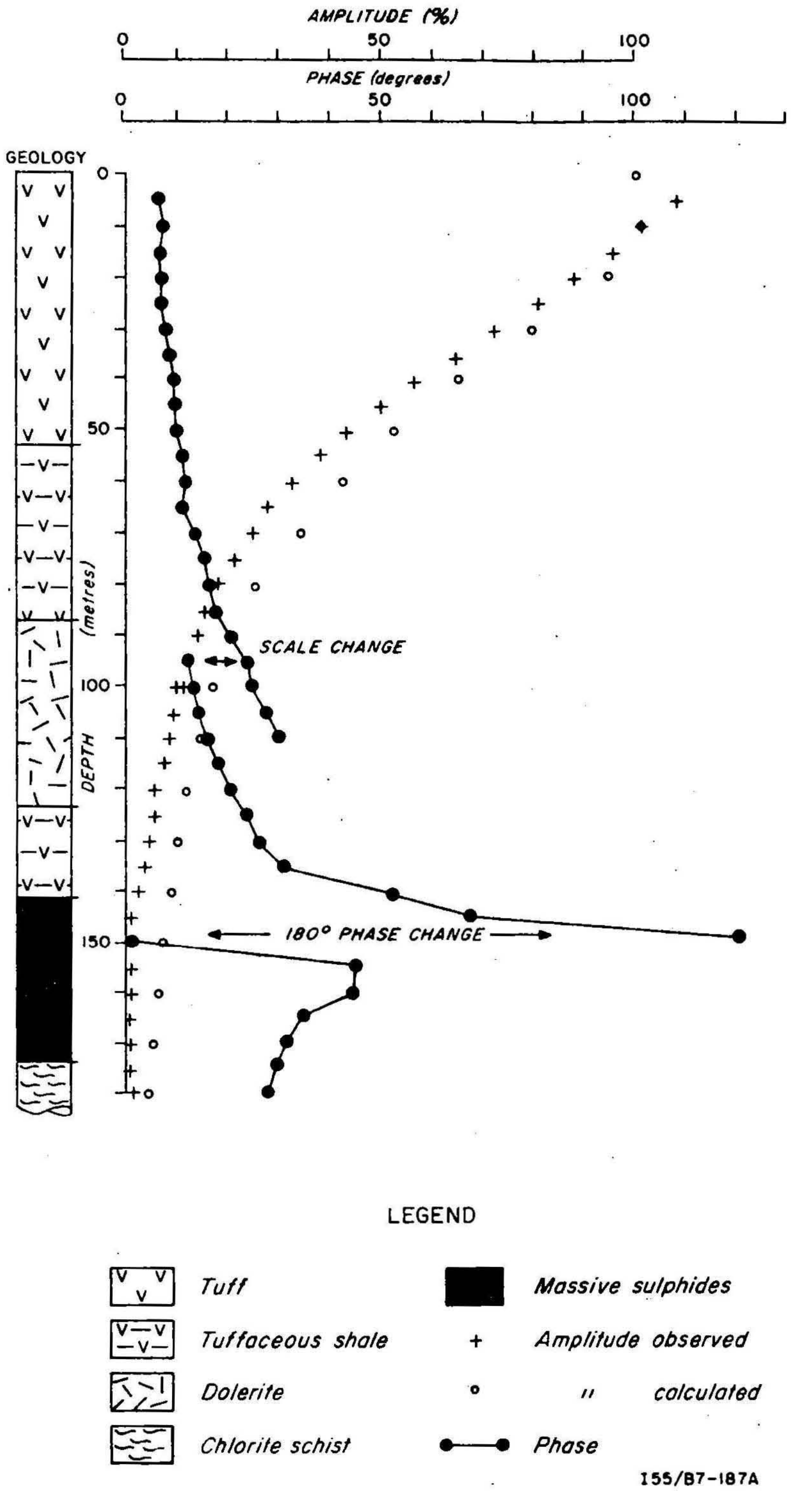
Drillhole W276

Case 1: Figure 14 shows the EM response obtained with a 300 m x 300 m loop centred on W276 which intersected the orebody between 140 and 170 m. The observed amplitude curve resembles the theoretical curve until the ore is intersected. Little or no anomalous EM response to the orebody was recorded before the intersection depth of 140 m. Within the ore zone, the EM response is characterised by a rapid decrease in amplitude and a large phase anomaly. Again assuming an average conductivity of 10 S/m, the ore intersection is some 9 skin depths thick. Unlike the intersection anomaly in hole WE5, there does not appear to be any recovery of the field strength below the ore zone, indicating that in this case total shielding has occurred.

Case 2: Figure 15 shows the EM response obtained with a 100 x 100 m loop centred on W276.

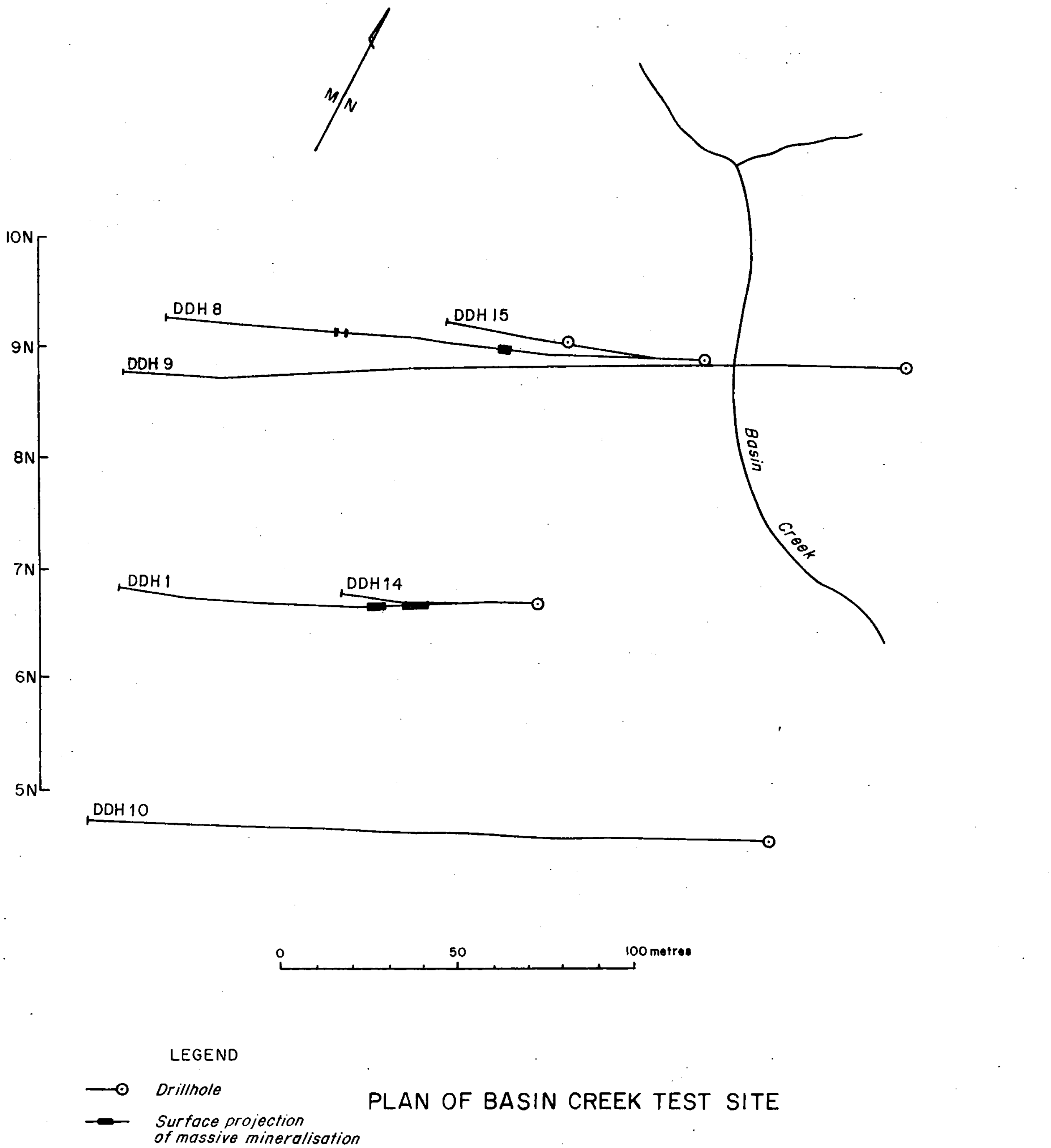


DDH W276, WOODLAWN-CASE 1



DDH W276, WOODLAWN-CASE 2

Fig. 16



PLAN OF BASIN CREEK TEST SITE

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The theoretical and observed amplitude curves show good correlation and, as expected, a more rapid attenuation than was observed with the 300 x 300 m loop. No anomalous amplitude response was recorded before the ore intersection at 140 m, although the phase curve shows a significant increase some 50 m before this depth.

A significant feature, not evident in the 300 x 300 m loop case, is the 180° phase reversal within the orebody at a drill depth of 150 m. According to the theoretical curve no geometrical reversal could be expected as the hole is approximately vertical. Hence, the reversal is attributed to scattering of the primary field in the conductor.

5. BASIN CREEK RESULTS

As indicated in Table 1 and Figure 16, six drillholes were logged at the Basin Creek No. 1 prospect. Two of the holes (DDH 1 and DDH 8) intersected small massive lenses of sulphides. DDH 9, 14, and 15 were drilled beneath the sulphide lenses but intersected only weak mineralisation and are therefore possible "near-miss" drillholes. DDH 10 was remote from the massive sulphide lenses but intersected weak mineralisation.

Theoretical amplitude curves are presented as a guide to interpretation but no correction has been made for the non-horizontal nature of the exciting loops. The rugged terrain restricts the amount of information that can be derived from a comparative study of the observed and theoretical amplitude curves.

Drillhole DDH 1

Figure 17 shows the EM response obtained in DDH 1 with a 50 x 50 m loop centred 48 m southwest of the drillhole collar. The loop was positioned directly over the ore grade mineralisation intersected in DDH 1 between drill depths 57.9 and 62.5 m.

A primary field reversal is evident in both the observed and theoretical curves, but no response attributable to the mineralisation was observed.

Drillhole DDH 8

Case 1: Figure 18 shows the EM response obtained in DDH 8 with a 50 x 50 m loop centred 60 m west of the drillhole. This drillhole intersected massive chalcopyrite mineralisation between drill depths 74.7 and 78.4 m.

Even though the inhole EM response is poorly defined owing to a field reversal, there does not appear to be any significant response to the mineralisation, either before or in the mineralised zone.

Case 2: Figure 19 shows the EM responses obtained in DDH 8 with a 400 x 400 m loop centred 70 m southwest of the drillhole collar. No anomalous response was recorded. The observed amplitude curve is similar to the free-space curve in the top part of the hole, and the phase measurements show no noticeable deviations. The difference between the observed and calculated amplitude below 80 m could be attributed to a deflection of the hole.

Drillhole DDH 9

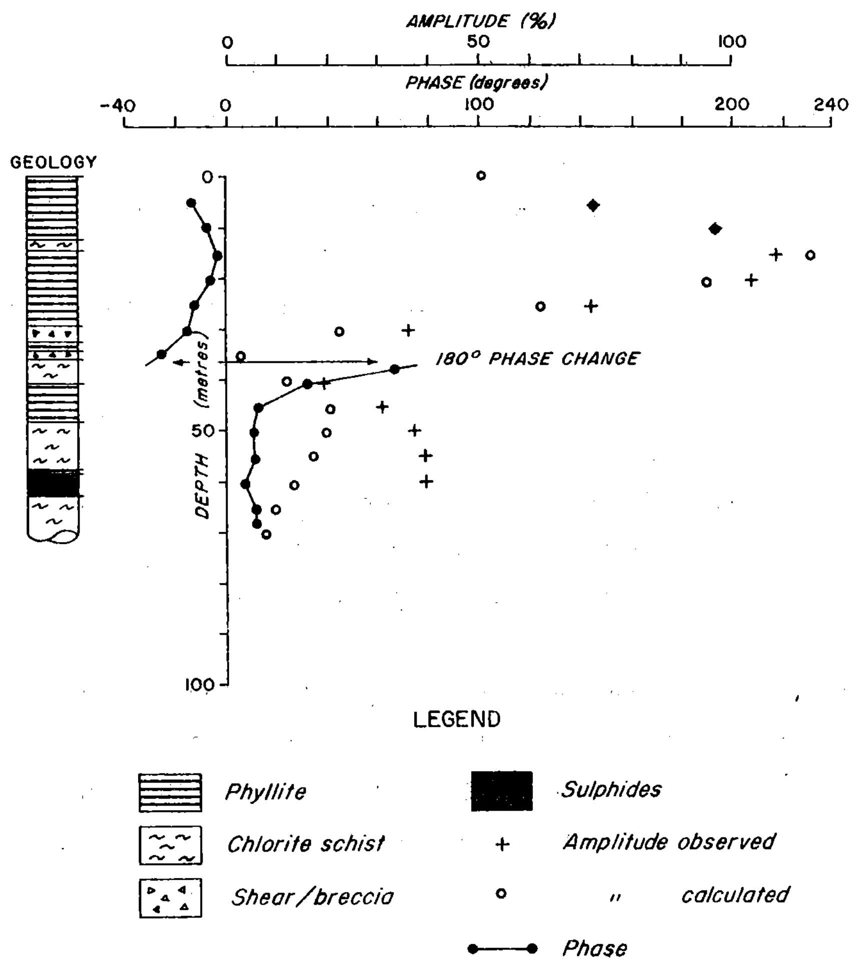
Figure 20 shows the EM responses obtained in DDH 9 with a 400 x 400 m loop centred 70 m southwest of DDH 8. DDH 9 intersected only minor mineralisation but was considered on the basis of geological and geophysical evidence to pass beneath a lens of massive sulphides.

No anomalous response was recorded in the amplitude curve which shows good agreement with the theoretical free-space curve. The phase curve shows a characteristic increase with depth but no anomalous response that can be attributed to a conductive sulphide body.

Drillholes DDH 10, 14, 15

Figures 21, 22, and 23 illustrate the results of EM logs made in drillholes DDH 10, 14, and 15 with a 400 m loop centred 70 m southwest of DDH 8. The amplitude and phase responses in all these holes are smooth and exhibit no features which would indicate the presence of a massive conductor. Correlation between the observed and calculated field amplitude is reasonably good.

PLATE 16



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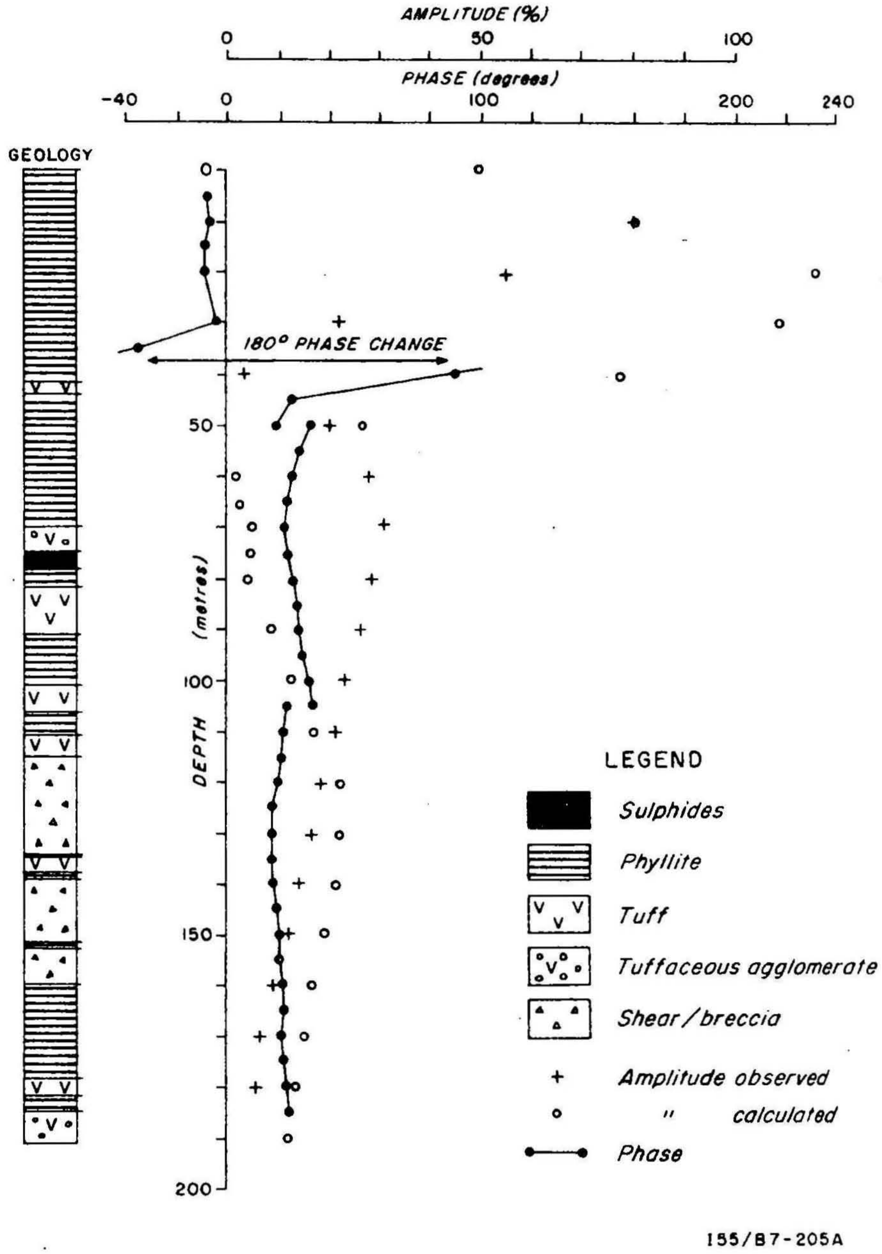
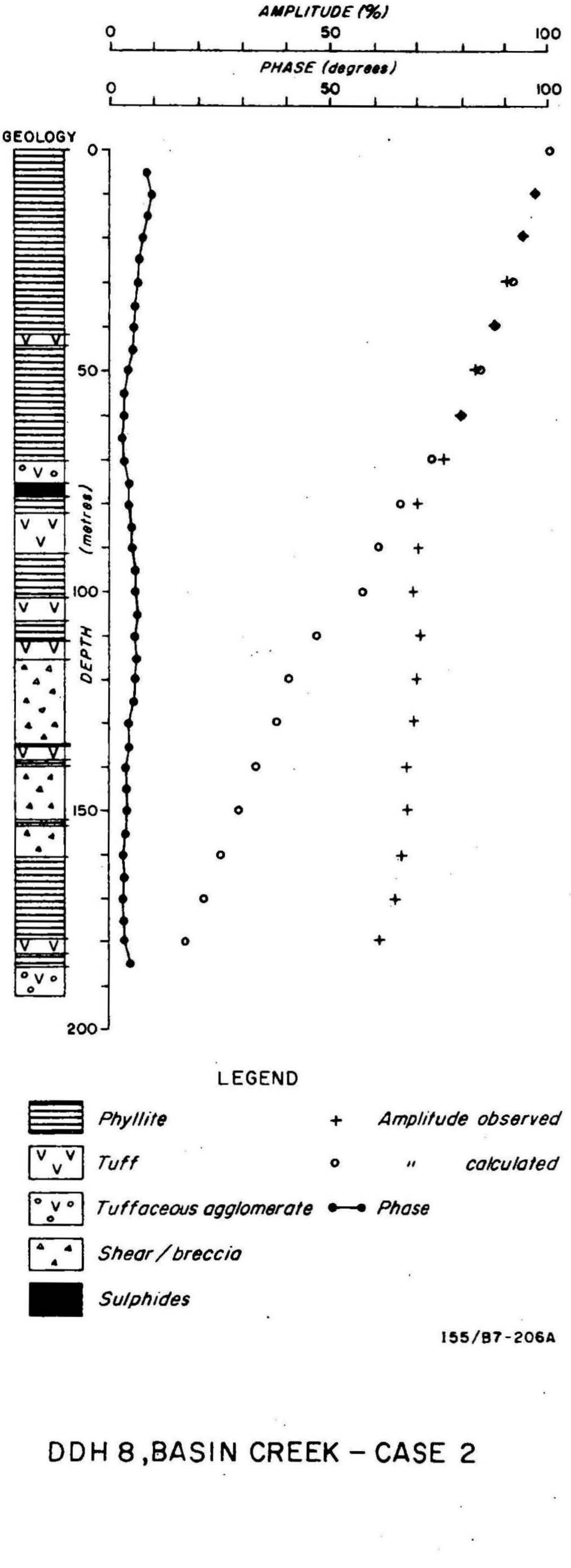
DDH1, BASIN CREEK

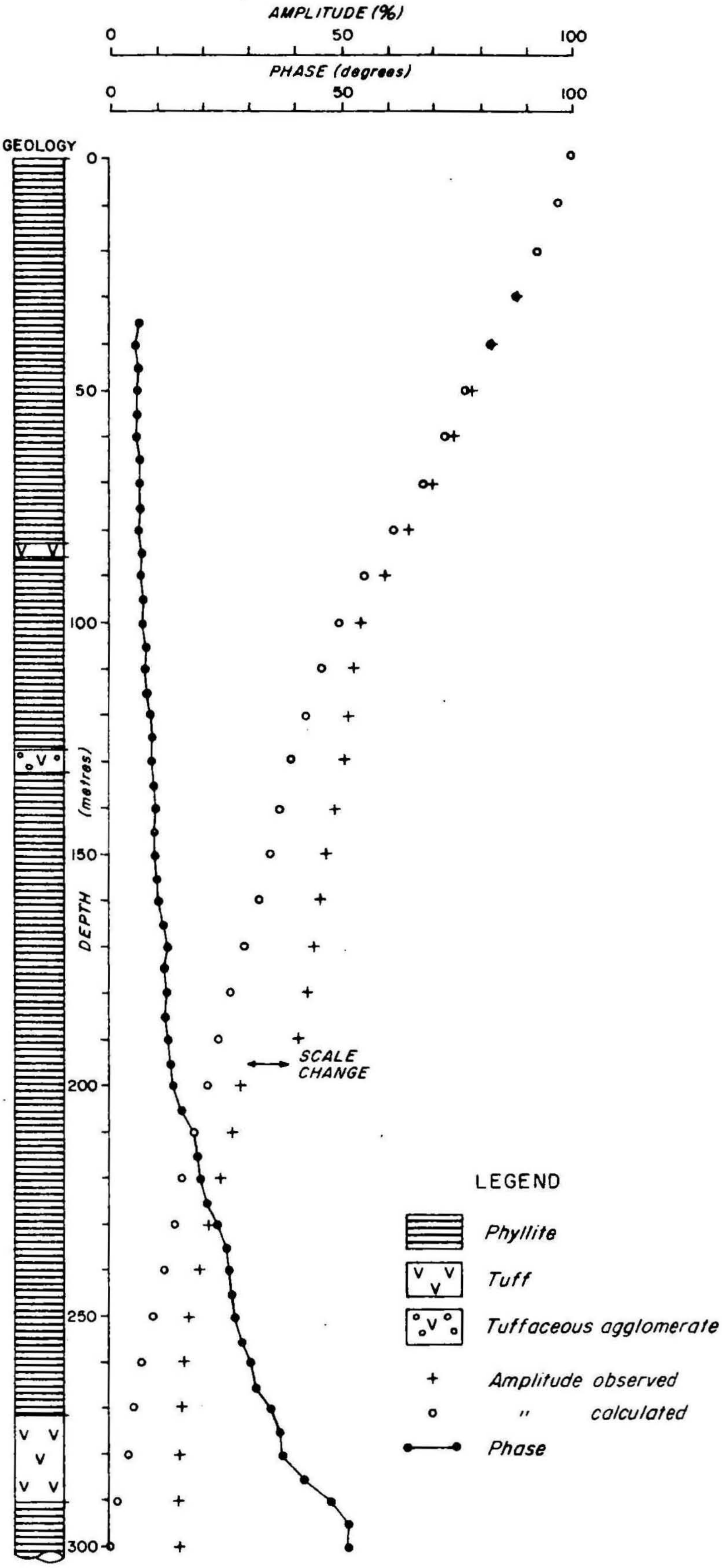
Fig. 18



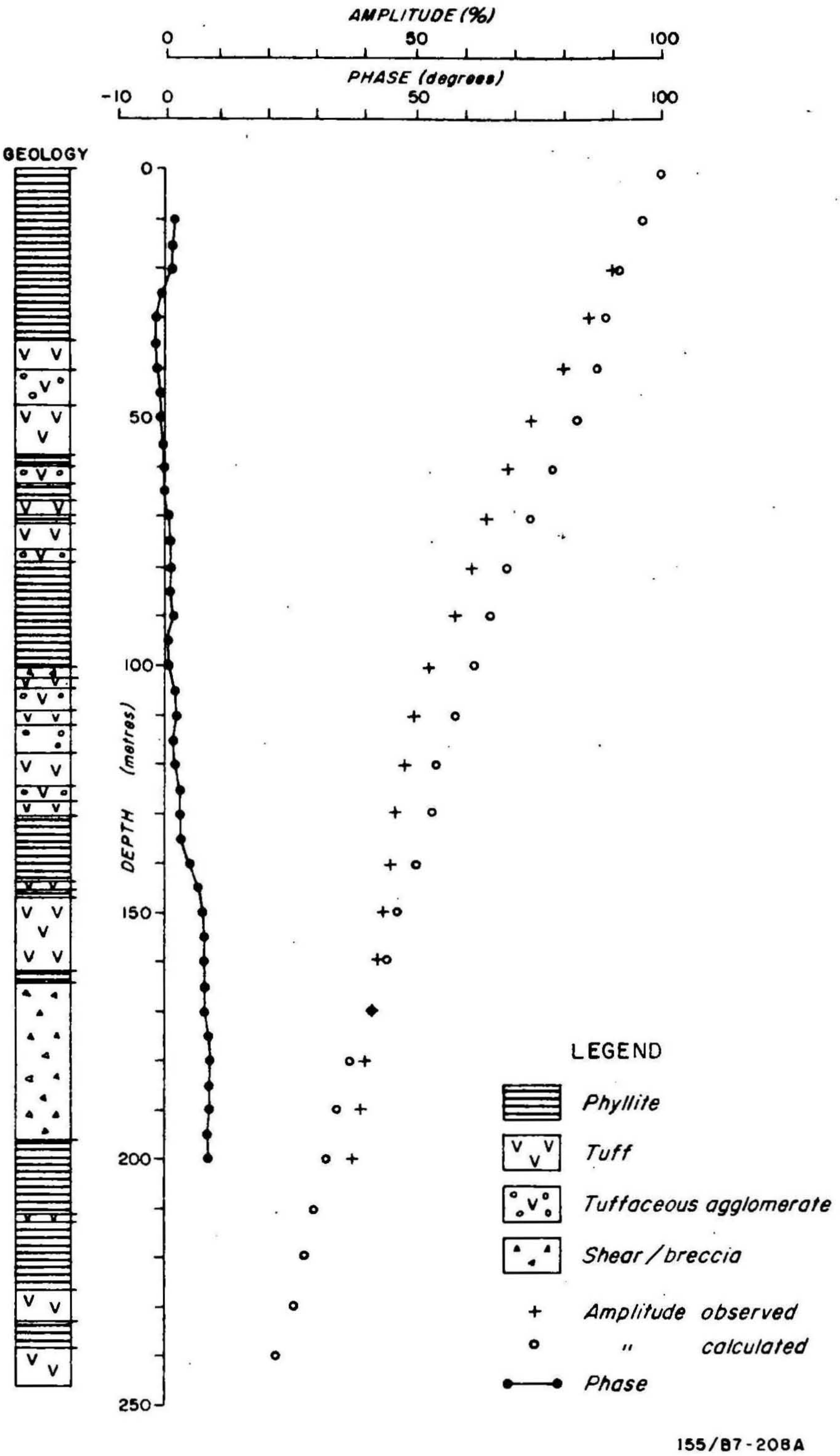
DDH 8, BASIN CREEK - CASE 1



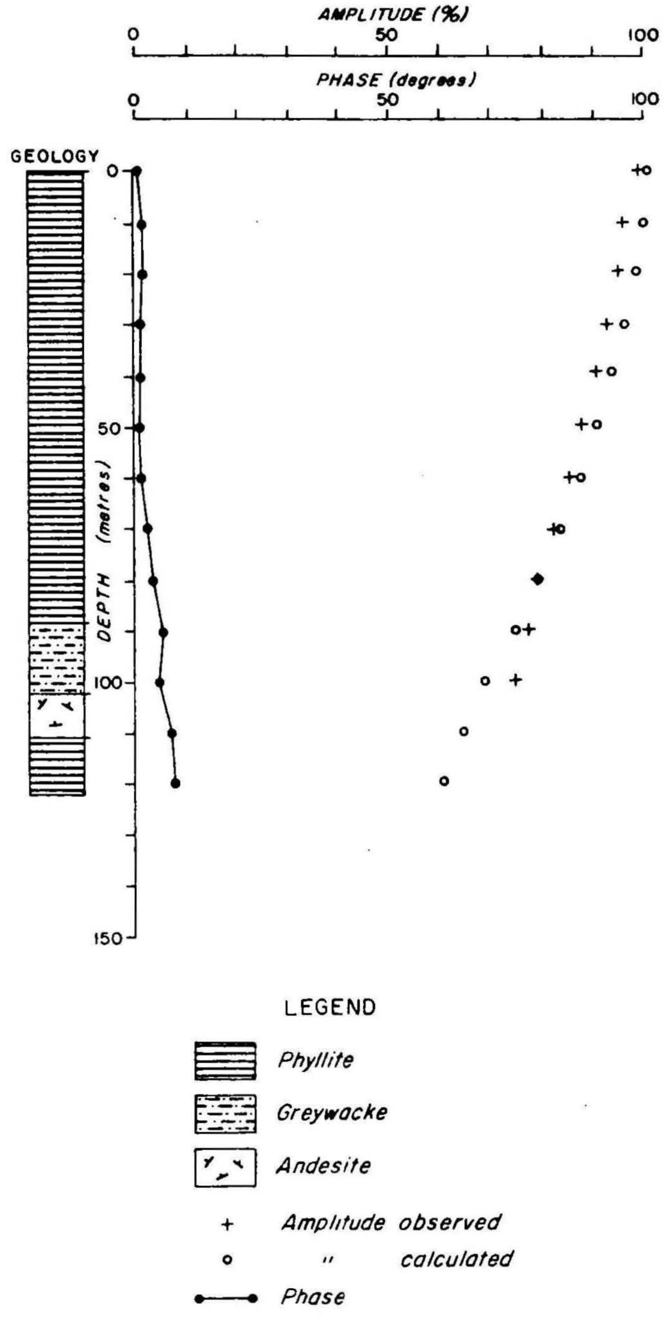
DDH 8, BASIN CREEK – CASE 2



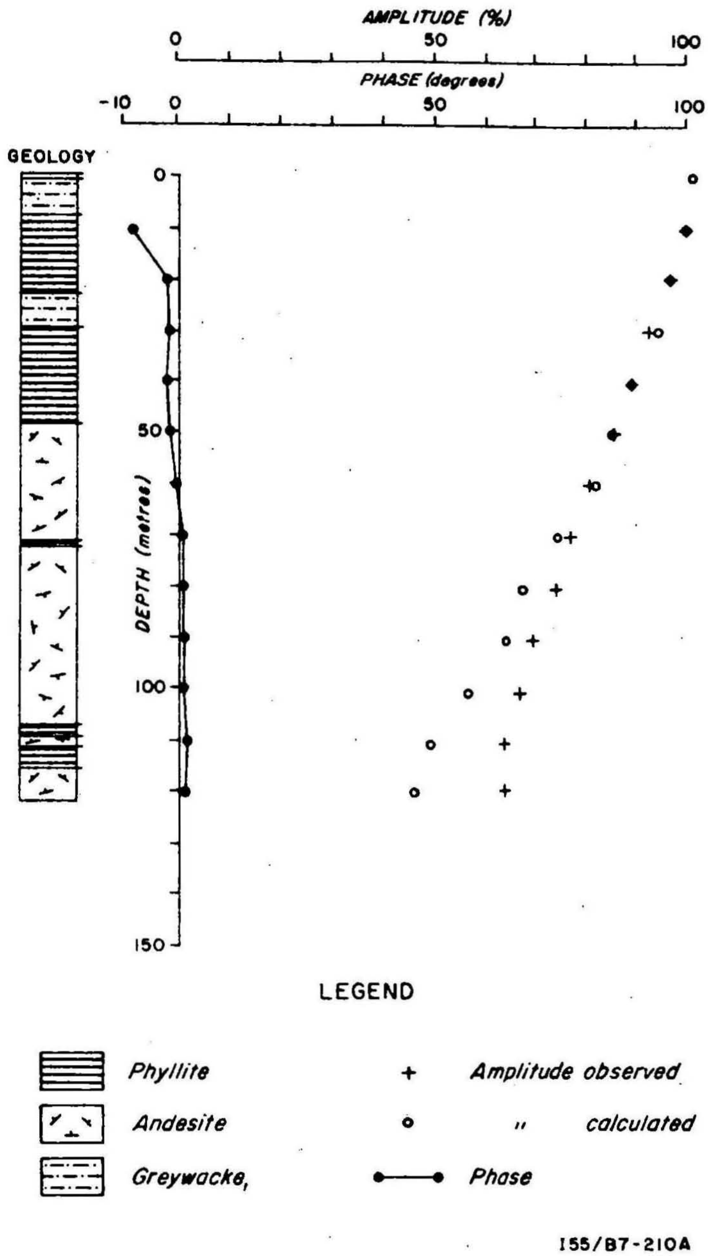
DDH 9, BASIN CREEK



DDH 10, BASIN CREEK



DDH 14, BASIN CREEK



DDH 15, BASIN CREEK

Discussion

It is evident that the DHP-4 system is an ineffective prospecting tool at Basin Creek. The lack of an intrinsic response to the massive sulphides in DDH 1 and DDH 8 illustrates the low sensitivity of the DHP-4 system to poor or small conductors.

6. SNOWBALL RESULTS

Only drillhole DDH 6, which intersected disseminated sulphides between 128 and 132.9 m, was available for logging. The hole was logged with several different loop configurations as indicated in Table 1. The relationship of DDH 6 to the zone of mineralisation is illustrated in Figure 24.

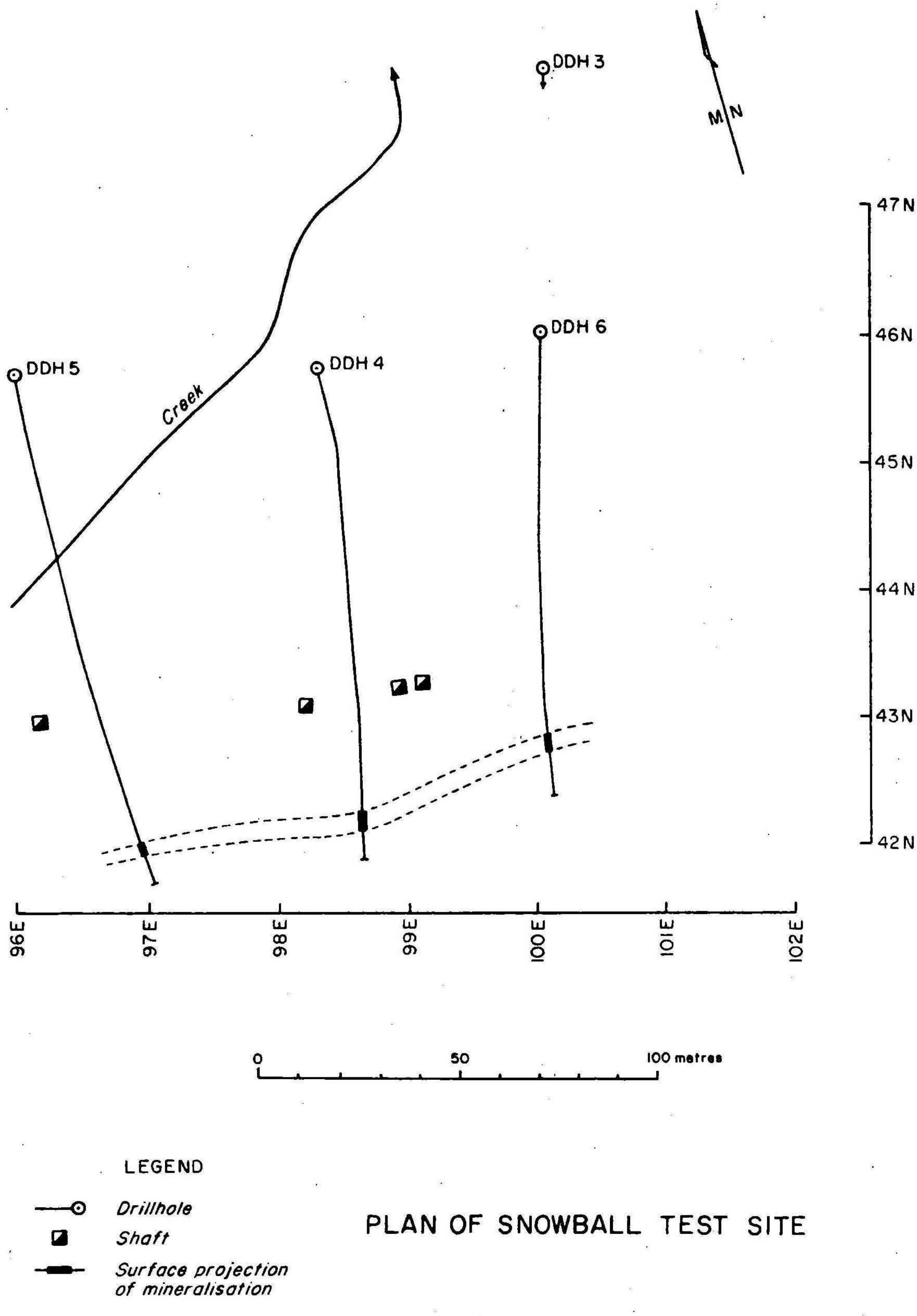
Drillhole DDH 6

Case 1: Figure 25 shows the results obtained with a 100 x 100 m loop centred on DDH 6. No anomalous response to the mineralisation was recorded. The observed amplitude curve is similar to the theoretical amplitude curve, and the phase curve shows a characteristic increase with depth, associated with normal propagation effects in a conductive earth.

Case 2: Figure 26 shows the results obtained with a 100 x 100 m loop centred 100 m south of DDH 6 and directly over the sulphide body.

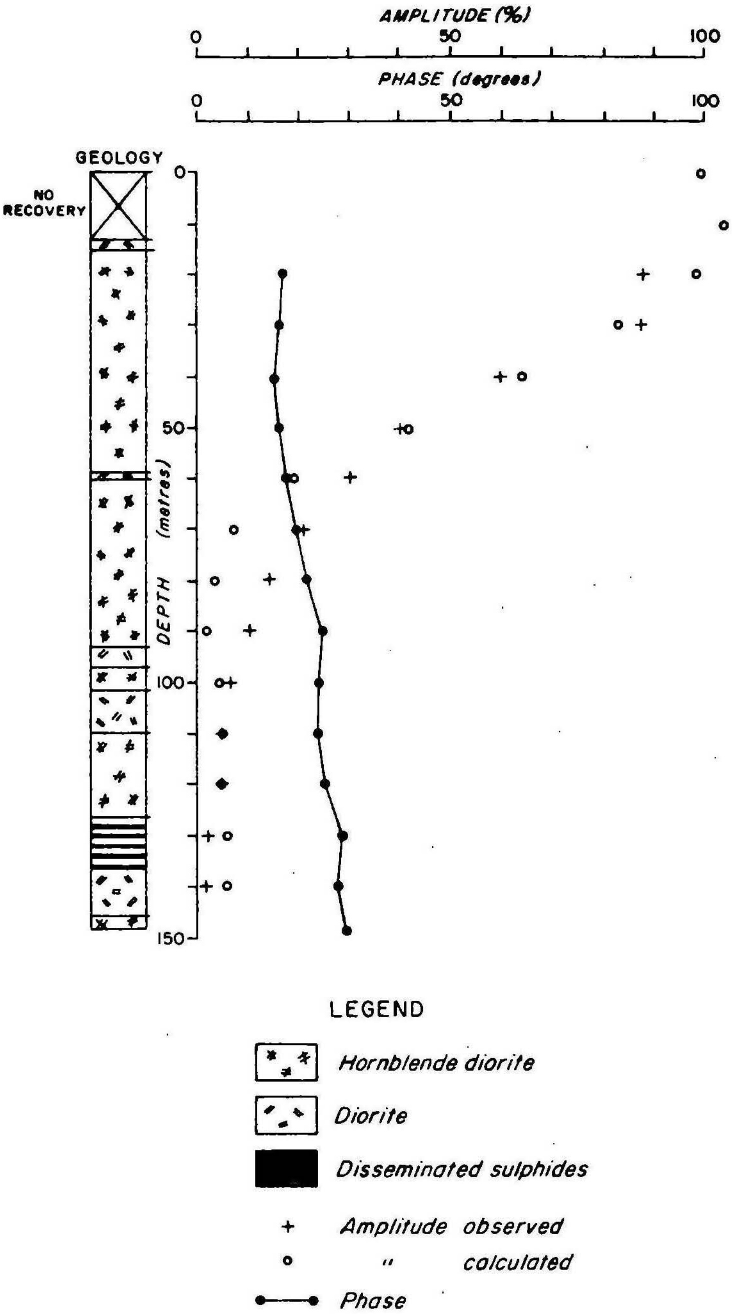
Despite the field reversal at 80 m, the primary field strength near the intersection zones was an order of magnitude higher than in the preceding case, being 35% of the surface value. A minor departure of the amplitude response from a smooth curve at 130 m might reflect the mineralised zone, but no corresponding phase response was recorded.

Case 3: Figure 27 shows the EM log obtained with a 360 x 360 m loop centred on DDH 6. With this loop configuration minor responses in both amplitude and phase were recorded in the intersection zone and might reflect a change in conductivity. No response to the mineralisation was recorded prior to the intersection.



PLAN OF SNOWBALL TEST SITE

155/B7-211A



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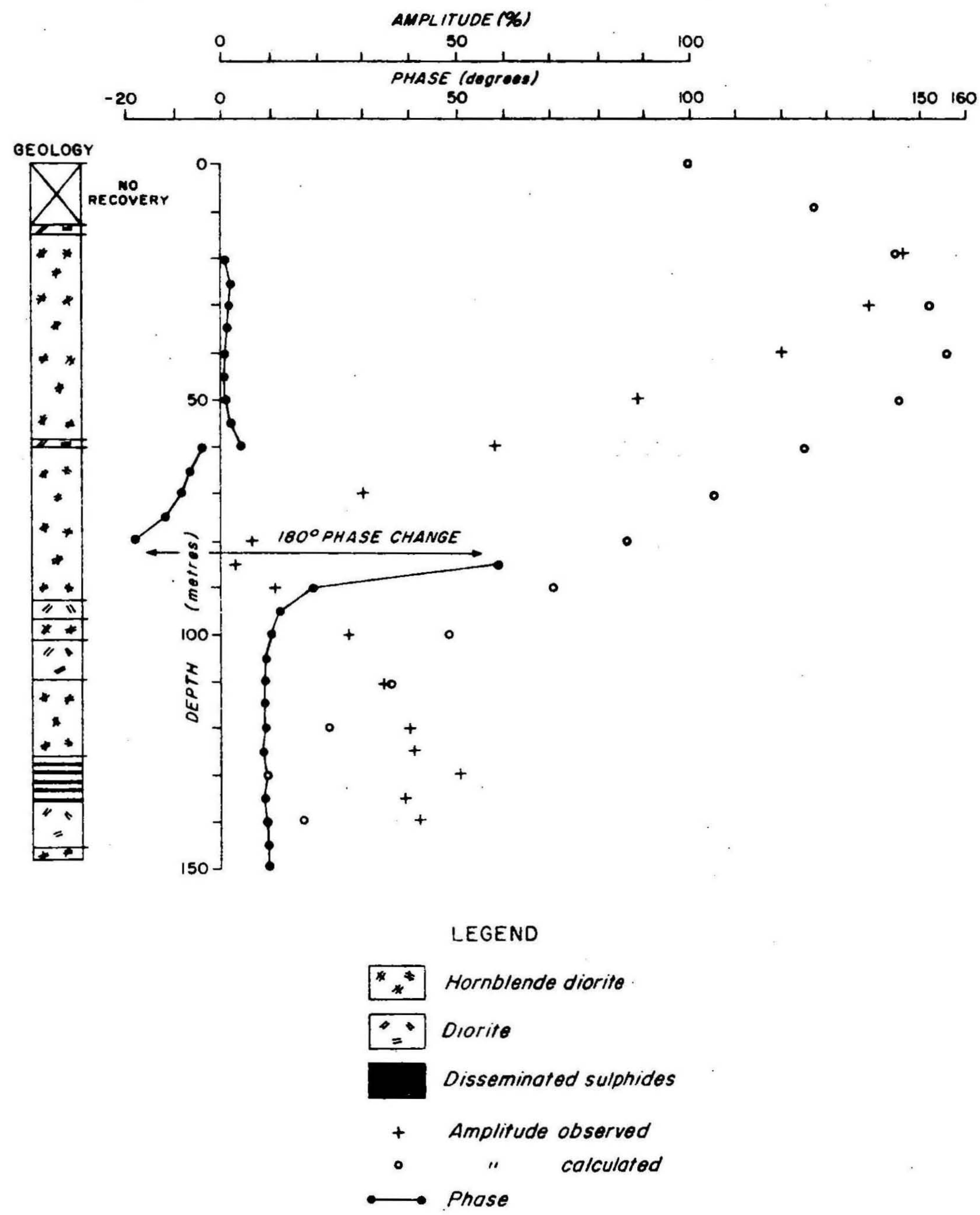
DDH 6, SNOWBALL-CASE 1



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DDH 6, SNOWBALL - CASE 2

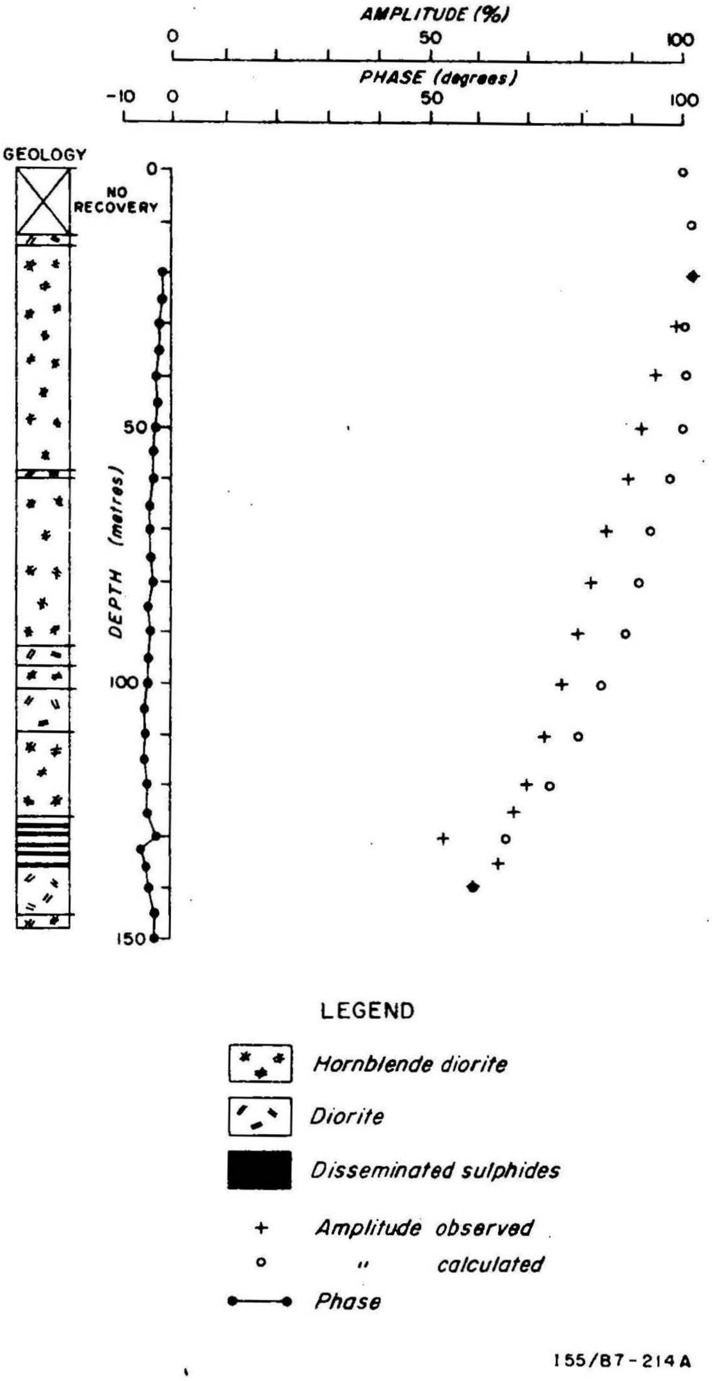
7. CONCLUSIONS

The field tests with the DHP-4 provide a guide to the effectiveness of fixed-source drillhole EM surveys, and to the response characteristics of massive sulphide deposits. The results confirm that the Woodlawn orebody is an excellent EM target, but show that the DHP-4 is not a very effective prospecting tool.

For optimum EM coupling, the maximum range of detectability at Woodlawn was shown to be roughly 30 m. However, in less favourable geometrical situations, as in intersection cases where the receiver-conductor coupling is minimal, and where there is minimal primary field linkage with the conductor, detectability could be only a few metres. No response to the Basin Creek and Snowball prospects was observed owing to the lack of suitable EM targets. However, the total absence of intrinsic response to massive chalcopyrite mineralisation at the Basin Creek prospect indicates the ability of the DHP-4 system to discriminate against small targets of this type.

The most serious weakness of the DHP-4 instrument would appear to be the geometrical restriction placed on detectability by measuring only a single component of the subsurface magnetic field. As the magnetic field to be observed is elliptically polarised (Grant & West, 1965), the co-axial magnetic component might be unaffected by the presence of an orebody. A significant improvement in overall detectability could be expected therefore by taking amplitude and phase measurements in three orthogonal directions. This possibility was recognised by Veksler & Plyusnin (1957) and confirmed by them in model and field studies.

Theoretical calculations established that some interpretational ambiguities may occur because of geometrical irregularities in the primary field. These difficulties may be aggravated by geometrical field reversals, which can occur when the drillhole extends beyond the transmitting loop circumference. Although unsuitable for normalisation purposes, the free-space approximation was found in most down-hole situations to be adequate for the identification of anomalous amplitude measurements. It was also shown that free-space considerations could assist survey design, particularly in avoiding reversals and in optimising coupling. Where possible the use of large loops is recommended. Large loops ensure a uniform primary field distribution in the area of interest, and an adequate signal-to-noise ratio at the required depth.



DDH 6, SNOWBALL – CASE 3

The nature of the tests precludes any determination of maximum usable operating depth. Reliable measurements were obtained in drillhole W55 at Woodlawn to a vertical depth of 290 m. Subject to ambient noise levels, ground conductivities, and transmitting power, there does not appear to be any reason why fixed-source systems should not be used in extremely deep drillholes. Another limitation of this type of down-hole EM method is the screening effect of intersected ore zones. This difficulty may be offset to some extent by using large transmitting loops.

In spite of the apparent ineffectiveness of the DHP-4 system, the method does warrant further development. The fixed-source systems have some intrinsic advantages over other down-hole systems. These advantages include the possibility of obtaining directional information by suitable arrangement of the surface transmitting loop, the insensitivity of the method to small targets, the possibility of using sophisticated instrumentation at the surface, and the smaller expense occasioned by any lost probes.

8. REFERENCES

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