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PRELIMINARY REPORT ON GEOPHYSICS GROUND FOLLOW-UP OF THE 1977 AIRBORNE SURVEY IN THE WADI BIDAH DISTRICT, KINGDOM OF SAUDI ARABIA

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ABSTRACT

Reconnaissance geologic and geochemical sampling was made during the 1978 field season at most of the 50 or so electromagnetic anomalies detected in the 1977 airborne electromagnetic (AEM) survey of the Wadi Bidah district. These Phase 1 studies also included reconnaissance geophysical traverses of nine of the AEM conductors. In addition the AEM anomalies were classified on the basis of this reconnaissance work into a list of priority targets for use in economic studies, and six AEM anomalies were selected for further studies.

During Phase 2 conducted in the 1979 field season, ground geophysical work consisting of electromagnetic (EM), self-potential (SP), and selected magnetic surveys were carried out in the six targets selected in the Phase 1 studies. These target areas in aggregate cover about 30 km^2, and are approximately half of the Wadi Bidah Class 1 and Class 2 priority targets found during the 1977 airborne electromagnetic (AEM) survey of parts of the Arabian Shield.

The results indicate possible extension of known reserves at the Rabathan area (AEM anomaly B-29), with possible potential for mineralization in the area extending 15-20 km north (anomaly B-13), where the geologic and geophysical environment is similar.

An important observation is that mineralization in the B-29 (Rabathan) zone is coincident with narrow SP anomalies superimposed on the larger, broader, and more formational-type SP anomalies encountered in both areas B-29 and B-13.

AEM anomaly B-25-26 area has geophysical characteristics that show in the groundwork and that make it an attractive drill target. EM and SP anomalies are associated, in part, with magnetic anomalies and with exposures of significant limonitic gossan.

Wadi al Khadra prospect, not included in the 1977 AEM survey, and the AEM anomaly B-25-26 area were also high-mineralization-potential products of the Phase 2 studies. Target area B-35 remains an unknown quantity, and AEM anomaly B-24 is almost certainly due to a carbonaceous schist.

Geochemical results, along with detailed geologic mapping and the geophysical data, indicate several potential mineralized targets. Further detailed geophysics (EM and SP) will assist in understanding the geophysical data thus far collected.

Further ground follow-up studies are recommended.

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INTRODUCTION

This report presents the preliminary results of the 1978-1979 ground geophysics follow-up of the 1977 airborne electromagnetic (AEM) survey in the Wadi Bidah district. The description and initial assessment of the 1977 AEM survey in the Kingdom were presented by Wynn and Blank (1979).

The Wadi Bidah district is located about 350 km by road southeast of Jiddah (fig. 1) and covers a north-trending belt of Precambrian metavolcanic and metasedimentary rocks approximately 15 km wide and 80 km long. The district defined in this report covers a somewhat larger area than that suggested by Earhart (1970), who indicated an area 15 x 45 km. The present investigation includes the area suggested by Earhart plus an additional area extending 35 km to the south.

The Wadi Bidah district has been of interest to explorationists for millenia as evidenced by numerous ancient mine sites and prospects. In recent times, exploration activity in the district has included geologic, geochemical, and geophysical surveys, along with diamond core drilling. Regional geologic mapping of the Wadi Bidah district is included in the 1:500,000-scale map of the Southern Hijaz quadrangle (Brown and others, 1962). In 1963 C. W. Smith, then with the Directorate General of Mineral Resources (DGMR), visited many of the ancient mine sites in the district in a reconnaissance geologic and geochemical mapping program (Smith, 1963). Earhart and Mawad (1970) studied the district and presented their findings and recommendations. During the period 1967-1971 the USGS Saudi Mission mapped the district at a scale of 1:50,000 and investigated many of the ancient mine sites by diamond core drilling (Earhart and Mawad, 1970; Alcott, 1969).

A second phase of diamond core drilling of some of the same ancient mine sites was undertaken by the USGS Mission between the years 1972 - 76 (Kiilsgaard and others, 1978). Riofinex geologists conducting a mineral assessment of the district in 1978 concentrated their efforts in the northern half of the district (Rionfinex, 1979).

Several investigators have studied the origin of the Wadi Bidah sulfide deposits. Earhart and Mawad (1970) suggested that the mineral deposits are volcanic strata-bound deposits emplaced at or about the same time as the host rocks. They further suggested that subsequent regional metamorphism and tectonic movement sheared, folded and remobilized the deposits into lenticular bodies of short strike length and shallow depth. Jackaman (1972) generally concurred with Earhart and Mawad's suggestion of the strata-bound nature of the deposits, as did Kiilsgaard and others (1978). The nature of the "graphitic" materials associated with the largest known sulfide deposit located at Rabathan was studied by Kiilsgaard and others. They indicated, as did Jackaman (1972), that the "graphitic material" was carbonaceous material that had originated from algae laid down as mats in a shallow sea; graphite was not detected. Subsequent metamorphisim carbonized most of the organic remains but was not of a grade high enough to convert the carbonaceous material to graphite. Consulted geophysicists concluded that the degree of metamorphism has little effect in changing the degree of conductivity of this carbonized organic material, but this conclusion should be supported by further laboratory measurements (Frischknecht, oral commun.)

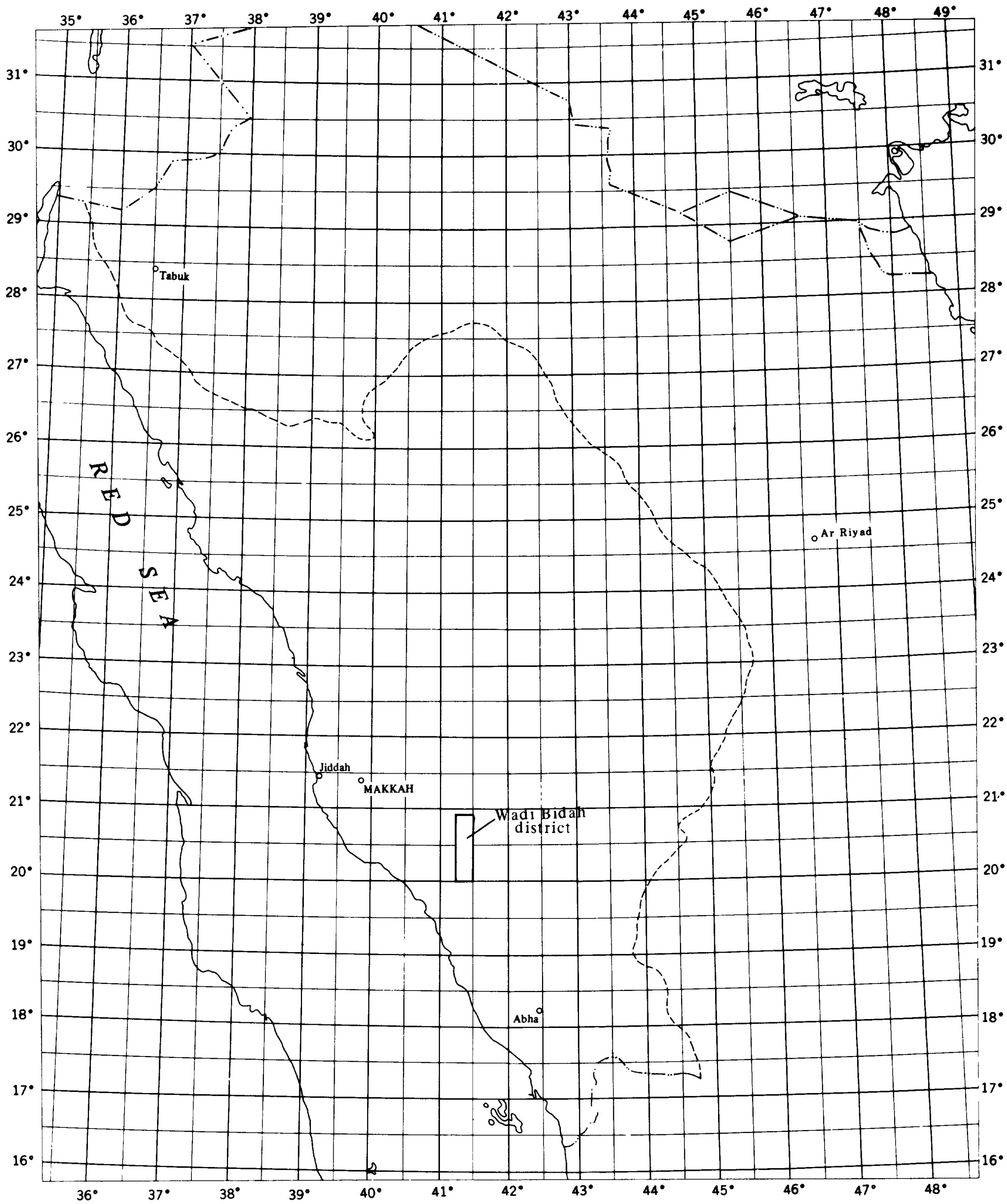

Figure 1.--Index map of western Saudi Arabia showing location of the Wadi Bidah district.

Previous geophysical investigations were confined to support of geologic investigations at ancient mines, mainly in the northern part of the district. Davis and Allen (1970) conducted an EM survey at the Mulhal and Mulgatha ancient mine sites. Kazzaz (1969) conducted a detailed EM survey of the Sha'ab al Tare ancient mine site. Flanigan and Kazzaz (Kiilsgaard and others, 1978) later conducted an SP survey at Sha'ab al Tare and EM work at the Gehab prospect. In the southern part of the district EM and SP surveys were made in the Mahawiyah area (Flanigan, 1970), and at the Jabal Murayyi (Worl and Flanigan, 1978) and Umm al Khabath prospects (Flanigan and Merghelani in Worl, 1978).

The district was covered by the 1966-67 airborne aeromagnetics survey of the Precambrian shield (Millon, 1969). A helicopter-borne electromagnetic and magnetic survey was conducted over selected targets in the northern half of the district (D. T. Sanders, unpublished report, 1968).

Current investigations (geological, geochemical, and geophysical) are an effort by the USGS Mission to assess the district, in a systematic manner, for its mineral potential. The southern half of the district was mapped geologically by Greenwood (1975), and the northern part by Green and Gonzales (1979). In 1977 an airborne, low-level, electromagnetic (AEM), and magnetic survey was flown over the district. A preliminary assessment of this survey is included in Wynn and Blank (1979). The present report will give a preliminary evaluation of the geologic and geophysical data from ground follow-up of some of the approximately 50 electromagnetic anomalies detected during the course of the AEM survey. Geochemical data currently being processed will be used to evaluate the geophysical data in an effort to define further the anomalous areas as potential drill targets for sulfide-mineralized rock.

Rock samples were collected at anomaly B-29 and at most of the other targets in Wadi Bidah for laboratory conductivity and magnetic susceptibility measurements.

The work on which this report is based was performed in accordance with a cooperative agreement between the U.S. Geological Survey and the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia.

PHASE 1 FIELD INVESTIGATIONS

Anomaly classification

Assessment of the AEM anomalies in the 1978 field season included brief helicopter reconnaissance of some of the anomalous areas by Wynn and Blank (1979). Further helicopter reconnaissance work was carried out by Worl and Flanigan, along with preliminary field and priority classification, some geochemical sampling, and selected reconnaissance ground geophysical EM traverses. The AEM anomalies (pl. 1) visited in this initial field reconnaissance were tentatively divided into the following four classes:

Class 1: AEM anomalies that are directly related to, or are on strike with, known mineralization and(or) ancient mines. Included in this group are isolated anomalies that, on the basis of preliminary geologic examination, appeared to have economic potential, that is, well-developed gossans, with or without visible mineralization, in a favorable sequence of rocks having favorable strike length (> 300 m)

Class 2: AEM anomalies for which, on the basis of geologic examination, the source of the anomaly seems to be apparent. There may be alteration or apparent formational sources such as carbonaceous schist. Gossans, if present, are either small in areal extent and strike length or the anomalous areas are inaccessible by ground transportation and thus are somewhat less desirable as exploration targets.

Class 3: AEM anomalies for which there is no apparent evidence for the source conductor and which will require ground geophysics to pinpoint the conductor, followed by geologic examination and geochemical sampling to assess the economic potential.

Class 4: AEM anomalies not visited or that are apparently associated with wadis. This group requires more photo and geologic control to locate so that a preliminary visit can be made, or, in the case of the wadi-type anomalies, a special geological and geochemical study to assess their value as potential exploration targets. Included also are AEM anomalies associated with known mineralization, such as Sha'ab al Tare; because much is already known about these anomalies from previous work, they were not visited in the reconnaissance survey.

The preliminary classification of the AEM anomalies (fig. 2) from the Phase 1 geologic reconnaissance is shown in table 1 below.

Table 1.-- Preliminary classification of airborne electromagnetic (AEM) anomalies in the Wadi Bidah district

Class 1	Class 2	Class 3		Class 4	
B-13	B-6	B-7	B-40	B-1	B-28
B-24	B-15	B-8	B-44A	B-2	B-34
B-25	B-21	B-11		B-3	B-36
B-26	B-39	B-14		B-4	B-37
B-29		B-16		B-5	B-38
		B-18		B-9	B-41
		B-22		B-10	B-42
		B-23		B-12	B-43
		B-30		B-17	B-44
		B-31		B-19	B-45
		B-32		B-20	B-46
		B-33		B-24A	B-47
		B-34		B-24B	B-51
		B-35		B-27	

Geophysical reconnaissance traverses

Reconnaissance geophysical traverses were made across nine areas of anomalous electrical conductivity as indicated by the AEM survey. These areas were selected to give a range of results across anomalies classified 1 to 4. The reconnaissance geophysical traverses consisting of EM and SP were conducted by Arabian Geophysical and Surveying Company Ltd. (ARGAS) under contract to the DGMR to locate accurately on the ground the anomalous zones detected by the AEM survey (ARGAS, 1978).

The nine areas selected for reconnaissance geophysical traverses included AEM anomalies: B-1, B-2, B-7, B-8, B-11 and 18, B-13, B-24, B25 and 26, and B29 and are shown on figure 2. Of the above nine areas, B-13, B-24, B-25 and 26, and B-29 along with B-25 were selected for further study during the 1979 field season and will be discussed in more detail later.

Anomaly B-1 is located on the west side of Wadi Bidah and is in a series of metavolcanic rocks, mainly quartz sericite schist. Brown limonitic silicic rocks form resistant ridges within and adjacent to the anomalous zone. The EM data (ARGAS, 1978) show a complex anomaly consisting of at least two or more zones of conductive rocks in an area estimated to be 150 -200 m wide. No definite SP anomaly is associated with the EM conductor. The conductive zone is thought to reflect the contrast in conductivity between highly sheared rocks of a major north-trending fault zone and the surrounding country rocks.

Anomaly B-2 is a north-trending anomaly containing the ancient mine site of Mulgatha. The EM data show two distinct anomalies probably related to faulting. The two zones are about 20 m and 100 m wide. The narrowest zone is associated with a low amplitude (40-50 mv) SP anomaly. This area was not visited in the 1979 field season, but the anomalous zones should be sampled for geochemical evaluation.

Anomalies B-7 and B-8 are isolated (one-line AEM anomalies) on strike with each other, about 1 km apart, and on strike with anomaly B-1. Both anomalies are in a series of metavolcanic rocks. The anomalous zone at anomaly B-7 is covered by alluvial outwash from metavolcanic rocks to the west. Towards the north of anomaly B-7, along strike, is extensively altered and sheared quartz-sericite schist. This zone of quartz-sericite schist probably passes through the anomalous area. The EM data show a single weak conductor approximately 25 m wide. A low-amplitude SP anomaly (-40 mv) is associated with the EM conductor. The anomalous zone is most likely to be associated with a local increase in conductivity in a fault zone, and possibly includes weak sulfides.

To the north, anomaly B-8 is in a geological environment similar to that of B-7. The EM conductor is slightly more complex. The anomaly is approximately 100 m wide and conductance is low, less than 2 mhos. No clear SP anomaly is associated with the conductive zone. Anomaly B-8 is most likely caused by the same structural zone as B-7. Anomalies B-1, B-7, and B-8 probably do not have very high potentials for economic minerals. They do, however, show that the fault zones in the Wadi Bidah area can be expected to be somewhat more conductive than the surrounding rocks. The SP anomaly in B-7 might be caused by weak or disseminated sulfide mineralization.

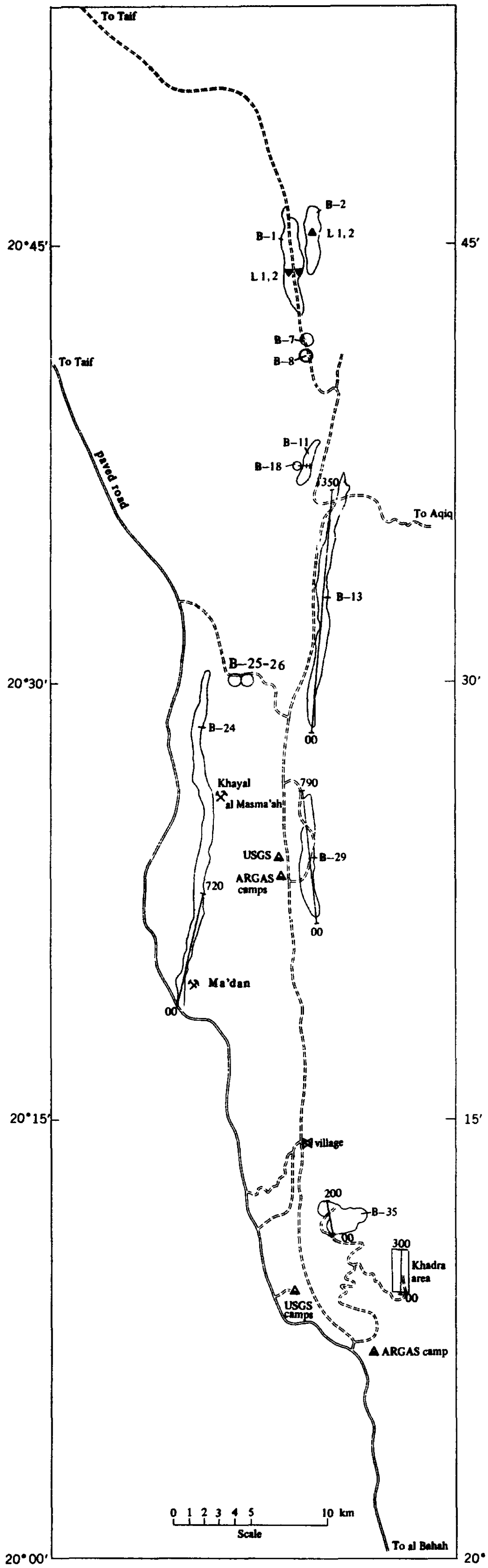

Figure 2.--The locations of airborne electromagnetic (AEM) anomalies being studied in the Wadi Bidah district. Also shown are locations of base lines for Phase 2 reconnaissance geophysical surveys.

AEM anomalies B-11 and B-18 are located directly north of the intersection of the Wadi Bidah and Aqiq roads. Anomaly B-18 lies along a zone (100 m wide) of highly altered, light-tan to brown, quartz-sericite schist. The zone is similar in nature to the probable fault zone described for anomalies B-1, B-7, and 8. The EM data show a rather weak electromagnetic conductor over this zone, and no strong SP response associated with it. Farther to the west, at the site of anomaly B-11, the EM conductor is stronger and has an apparent conductance of 3-4 mhos. An interesting SP anomaly (-140 mv) is associated with the EM conductor. The rocks in this area are intermixed metavolcanic and metasedimentary rocks altered to chlorite and sericite schist. A prominent (1 - 2 m wide) outcrop of tan to buff limestone or dolomite extends through the area. This area was not mapped in detail; geochemical samples, however, were taken along the geophysical traverses to ascertain the mineral potential in outcrop of the area. Results of the geochemical analyses are not yet available; should the results prove encouraging, the area should be looked at in more detail.

Geophysical reconnaissance traverses, geologic examination, and spot geochemical sampling were made at anomalies B-25 and 26, B-13, and B-29 during Phase 1 (1978) of the ground follow-up work and were selected for further work during the Phase 2 study conducted in the 1978-79 field season.

PHASE 2 (1979) FIELD INVESTIGATIONS

Six areas were selected for more detailed study in the 1979 field season on the basis of Phase 1 results. The areas selected either showed anomalous copper or gold values or the geophysical and(or) geological environments were such as to warrant a closer examination. An interdisciplinary team approach was used so far as was practical during the execution of the Phase 2 field investigations. The geologist-geochemist-geophysicist team approach proved extremely useful during the progression of field work. The exact location of the anomalous geophysical areas were pinpointed on the ground for careful examination by geologic mapping and geochemical sampling. A valuable interchange of ideas permitted the possible nature of the geophysical anomalies and their causative sources to be discussed and examined at the outcrop.

The six areas selected for investigation during Phase 2 cover approximately 30 km^2. While all of the results of the geophysical, geochemical, and geological mapping have not been completely integrated at this time, some preliminary observations can be stated and used for guidelines for further work in the Wadi Bidah district.

Geophysical surveys

The six areas investigated during 1979 are AEM anomalies B-25 and 26, B-29, B-13, B-24, B35, and an ancient mine site at Wadi al Khadra. The Wadi al Khadra area was not covered in the 1977 AEM survey; it was later selected for investigation because of its geologic environment relative to other targets and because of the presence of extensive ancient workings. The locations of the six areas are shown on figure 2 along with base lines, which generally indicate the center of the investigated areas.

The field survey was conducted by ARGAS under contract to the DGMR and supervised by USGS geophysicists.

The geophysical methods used on the Phase 2 geophysical surveys were slingram electromagnetic (EM) and self potential (SP). In addition, magnetic profiles were made over selected areas or parts of areas by USGS personnel.

The slingram method is a moving source-receiver electromagnetic technique, where electromagnetic energy is transmitted into the earth by a transmitting coil. Two components (real or in-phase and imaginary or out-of-phase) of the primary and secondary electromagnetic fields are measured by a receiving coil at some fixed distance from the transmitting coil. A reference cable linking the two units permits the measurement of phase, and allows the measurements to be expressed in terms of percent of the primary field. Traverse lines were surveyed prior to the geophysical measurements being taken so that constant horizontal distances might be maintained in the rather rough topography and also to provide accurate slope tilts so that the coils might be maintained in a constant coplanar configuration. The slingram unit used in this survey was capable of making measurements at five frequencies (222, 444, 888, 1777, and 3555 Hz) and at coil separations of as much as 250 m. Measurements were taken at 50 m intervals along traverse lines spaced 200 or 400 m apart. The measurements were made using horizontal coplanar coil configuration at a coil separation of 200 m. This spacing permitted effective depth penetration of as much as 100 m in some cases.

Discussion of preliminary results

B-29 area

Area B-29 is located on the east side of Wadi Bidah and covers the Rabathan area, the prospect considered to have with the highest mineral potential (Earhart and Mawad, 1970; Kiilsgaard and others, 1978). Rabathan as described by Earhart and Mawad included the southern part of AEM anomaly B-13 and the northern half of B-29. In this discussion we will restrict the Rabathan area to include only AEM anomaly B-29. Rabathan (B-29) is about 1 km wide and 8 km long covering the north-trending belt of rocks that hosts the Rabathan ore body described in some detail by Kiilsgaard and others (1978).

The Rabathan zone consists of highly sheared greenstones of the Baish group. (Kiilsgaard and others, 1978). Calcareous quartz-sericite schist and chlorite schist are the main rock types. Carbonaceous material in bands of variable thickness is plentiful, being interbedded with and having undergone the same shearing and contortion as the schists. Resistant ridges in some places contain a high percentage of silicic-calcareous-carbonaceous rocks within the more abundant calcareous quartz schists; locally thin stringers of dolomitic, buff-colored rocks are also abundant. In other areas the dolomitic buff rocks described by Kiilsgaard and others (1978) as calc-silicate rocks form the principle rock in the lens-shaped ridges that are aligned north-south.

Geophysical measurements were made in the Rabathan area along east-west traverses spaced 200 m apart. The station interval was 50 m, and geochemical sampling was carried out at 25 m intervals along the geophysial traverses. However, because the analyses of the geochemical sampling are not yet available, the discussion to follow will be confined to the geophysical results and geologic observations.

The results of the electromagnetic survey survey at Rabathan are presented on a contour map (pl. 1) of the real and imaginary components of the measured secondary electromagnetic field at 888 Hz. On the imaginary component map, the conductive zones are indicated by the highest negative values.

The EM data shown on plate 1 indicates nearly continuous zones of rocks of high conductivity aligned north-south through the area. In the southern part of the area near line 50N and station 10E the most conductive rocks lie in a zone estimated to be 50 m wide and extending to the north for the entire length of the surveyed area. The EM data show that the rocks in the continuous zone differ in conductivity as evidenced by the narrow elongated anomalies within the conductive zone. In the central part of the mapped area at line 370N the north-trending anomaly splits and the eastern zone traces out the drilled ore body. A second conductive zone lies to the west of the main EM anomaly and is most clearly seen on the imaginary component map. The secondary EM conductor nearly continuous over the mapped area north of line 370N and is nearly parallel to the main EM anomaly. The western conductor is not as wide nor is it as conductive as the eastern conductor. In parts of the area, especially in the north half, three conductors can be traced from the EM data.

The SP data have been contoured (pl. 1) to show lines of equipotential in millivolts (mv) referenced to one base electrode. Results of previous core drilling have been illustrated in the geophysical map by showing the drill hole location and the horizontal projection of the hole in approximate azimuth.

The SP data show that in the Rabathan zone a broad SP anomaly about 600-800 m wide extends northward across the entire mapped area. Riding upon this broad SP low are spikes of 100 to 200 mv amplitude that trace out lens-like zones of SP response. These lenticular anomalies range in dimensions from 50 to 100 m wide and from 200 to 600 m long. One of these anomalies along line 370N is coincident with the ore body at diamond drill hole 4 (DH-R4).

In order to attempt to understand the relationship between the geophysical anomalies and the geology, profiles showing the EM and SP anomalies together with the geology were constructed and are shown in figures 3 through 9.

The relationship of the geophysical data to the ore body at DH-R4 and geology is shown on figure 3. Here, the real component EM data show that the the principle EM conductor lies west of the mineralized zone, centering at about station 5 west. At station 20E there is a small response that may be associated with the mineralized zone. A second EM conductor, not completely traced out, is seen at about station 40W. This conductor is west of the zone of interest and is near the western edge of Wadi Bidah.

The SP data shown on figure 3 illustrates the broad SP low extending across the area. Two narrow SP anomalies are seen forming the rather complex

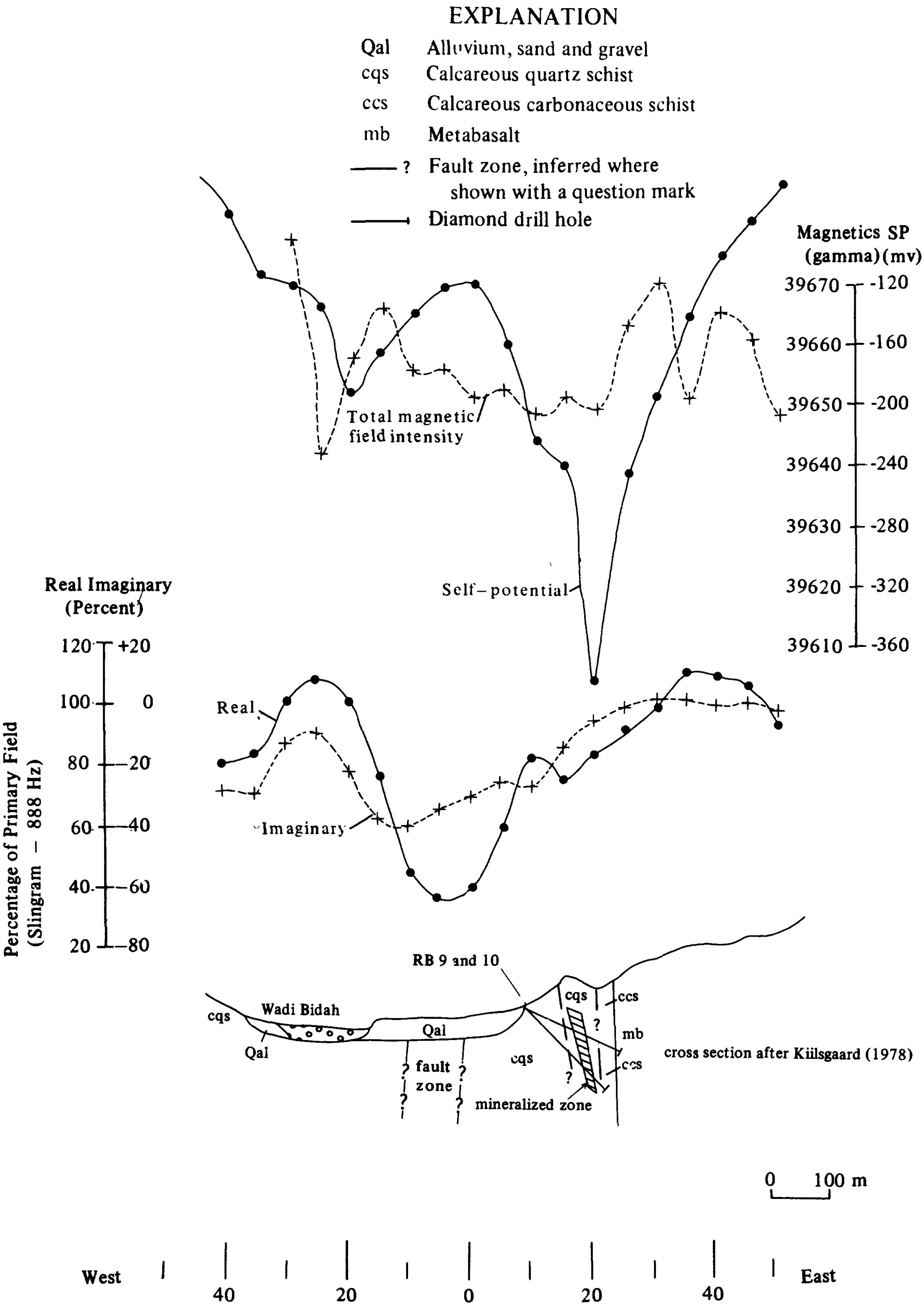

Figure 3.--Self-potential and electromagnetic profiles along line 370N in the Rabathan area showing the relationship of geophysical data to geology.

SP response. The eastern-most of these narrow SP anomalies lies over the mineralized zone. There is no certain way to ascertain the exact cause of the SP anomaly here; it may be in part due to the electro-chemical cell composed of the mineralized zone combined with ionic conduction in a concentration of carbonaceous material in the schistose country rocks. The cause of the large EM anomaly located at station 5 west is not readily apparent from the surface. It forms a topographic low here and in most other places and is mostly covered with alluvial materials. This anomaly has no SP response associated with it and is probably the electromagnetic expression of a zone of concentrated shearing and faulting.

The relationship of the geophysical data and the geology at line 130N is shown in figure 4. Here the EM data are complex and sugget multiple conductors. The imaginary component data clearly suggests three narrow zones of conductive rocks in the area from station 25W to 20E. The complex SP response mirrors the EM data along this line. The broad SP response extends from about station 30W to 30E, and three negative SP peaks are superimposed on the broad anomaly. The eastern-most of these SP peaks lies in the zone of interest east of Wadi Bidah. From station 0 to the east, rocks are calcareous quartz schist locally metamorphosed to greenstone and chlorite schist. At station 100E the schists are seritized, folded, and faulted in a narrow (10 m wide) fault zone. The resistant ridge at station 20E contains abundant silicic carbonaceous rocks in thin stringers up to 2 m thick in massive dike-like outcrops. Hematitic, calcareous, tan to buff stringers of rocks are abundant in the zone. This zone is fairly typical of the anomalous SP zones in the Rabathan area. Results of geochemical sampling indicate anomalous copper values, reaching a high of 350 ppm in a small gossan outcrop.

The geophysical data on line 230N (fig. 5) is similar to that seen across the mineralized zone along profile 370N. The main EM conductor lies to the west of a smaller secondary conductor; the largest of the SP anomalies is associated with this secondary EM conductor. There is little outcrop along the western half of the profile, although calcareous quartz schists crop out at about station 10 E. At station 10E there is also some evidence of ancient prospecting in the form of dump material; no mineralization, however, could be seen in the dump materials or adjacent to the now-filled prospect pits. This area might well have been an ancient quarry site, since it is close to ancient home sites. However, at station 15E to 20E, in the area of the largest SP anomaly and secondary EM conductor, a small silicic hematitic gossan about 1 - 2 m wide and 8 - 10 m long is exposed. The SP anomaly is more than 200 m long. This length is highly intriguing, and geochemical sampling and geologic mapping will bear heavily in assessing this area as a potential mineral target. From the geophysical point of view, although this zone is marginal in strike length, it is one of the most interesting in the Rabathan area. Should the analysis of geochemical samples prove encouraging, the area should be mapped in detail and outlined by additional detailed geophysical work to select an optimum drill site.

Two SP anomalies are associated with the broad EM anomaly on line 330 N (fig. 6). There is little or no outcrop along the line from station 10 west through Wadi Bidah. Calcareous quartz schist is the main rock type, cropping out from station 10W to the eastern end of the profile. Some elongated zones (0.5 m wide) of buff to brown, dolomitic, siliceous rock are aligned along the schistosity of the country rock. No apparent reason for the

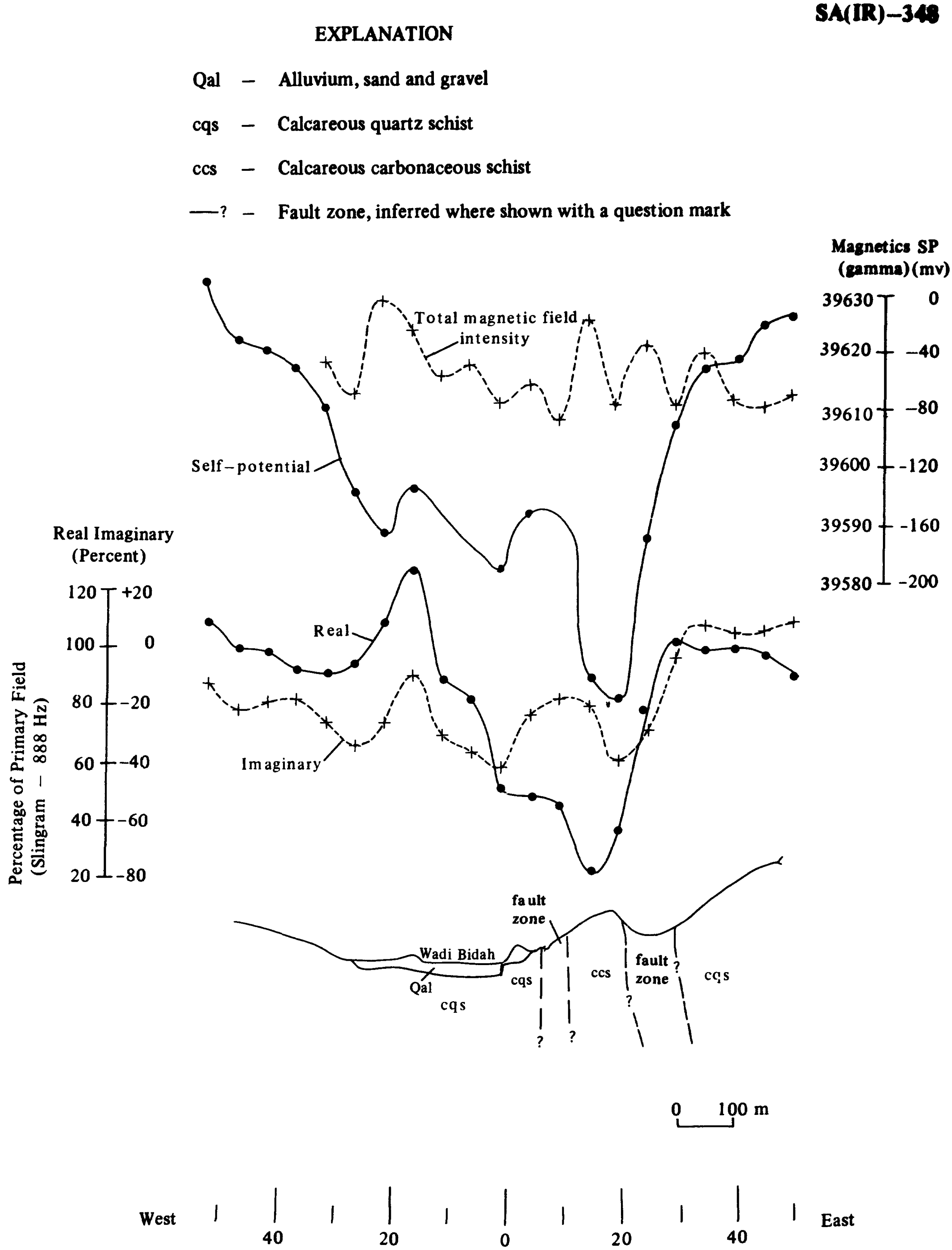

Figure 4.--Self-potential and electromagnetic profiles along line 130N in the Rabathan area showing relationship of geophysical data to geology.

EXPLANATION

Qal – Alluvium, sand and gravel

cqs – Calcareous quartz schist

ccs – Calcareous carbonaceous schist

mb – Metabasalt

—? – Fault zone, inferred where shown with a question mark

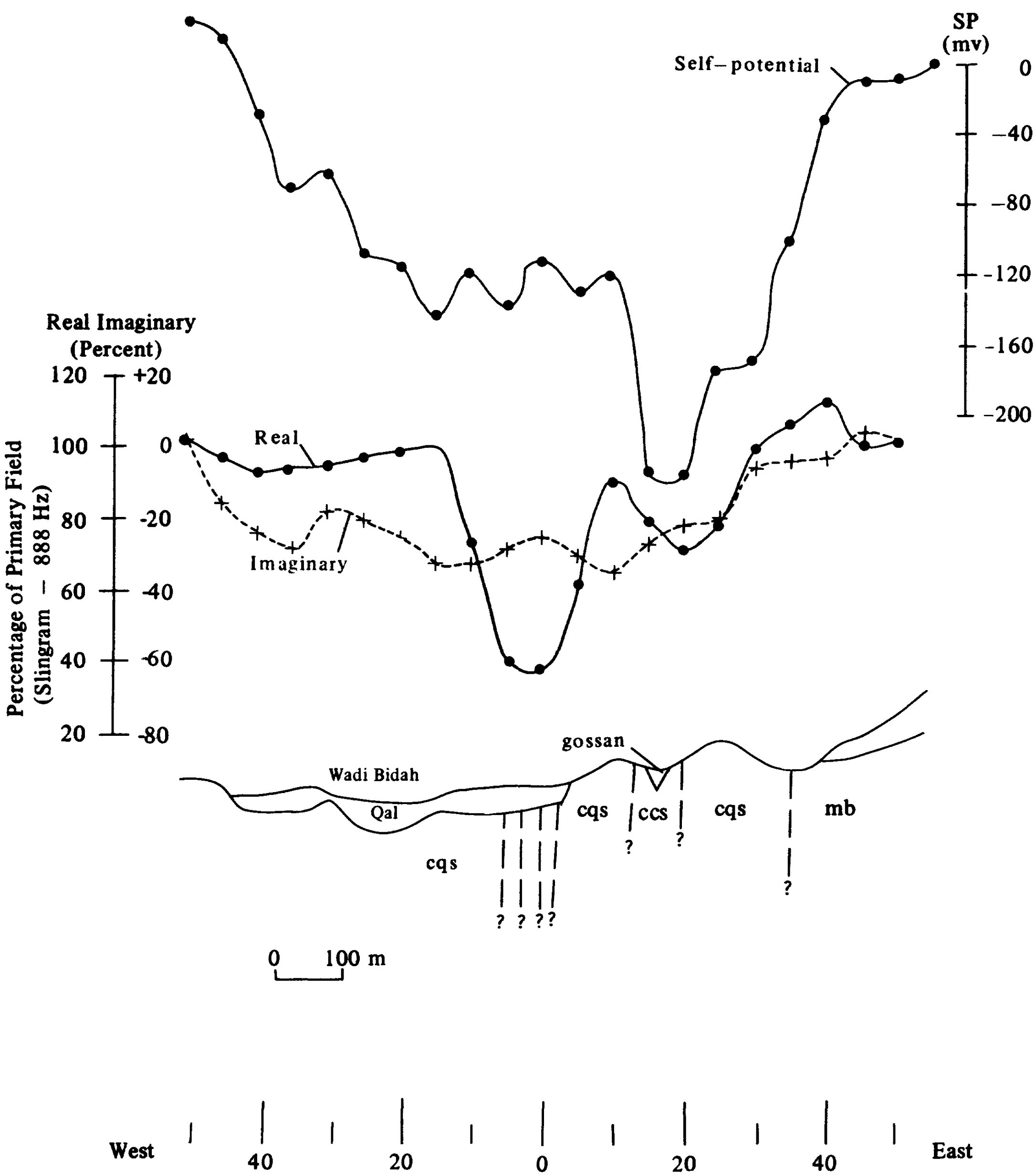

Figure 5.--Self-potential and electromagnetic profiles along line 230N in the Rabathan area showing the relationship of geophysical data to geology.

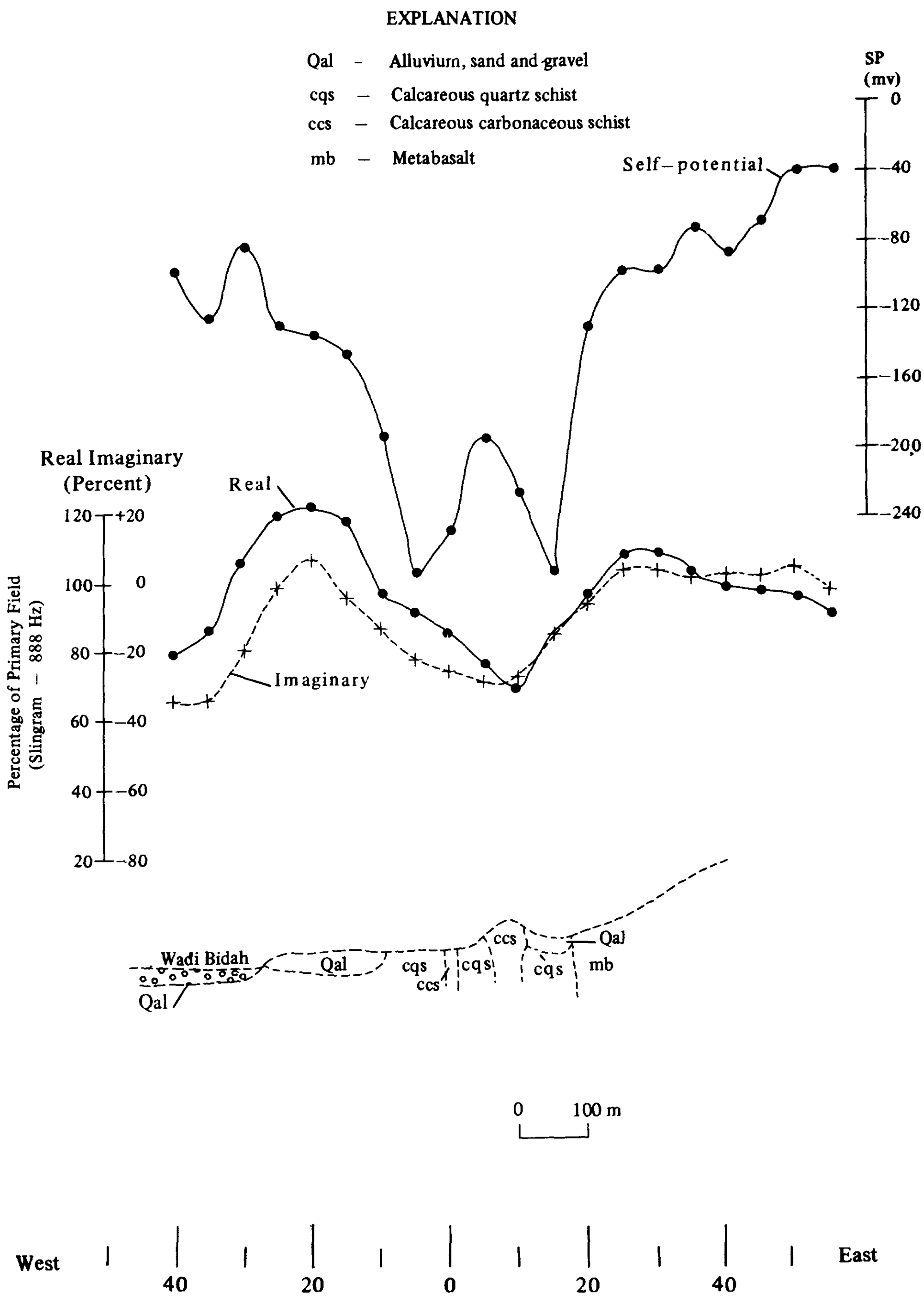

Figure 6.--Self-potential and electromagnetic profiles along line 330N in the Rabathan area showing the relationship of geophysical data to geology.

anomalous geophysical expression can be seen in the area. Here again geochemical results will be necessary to evaluate further this zone.

Three distinct EM conductors are outlined along profile 450N in the Rabathan area (fig. 7). The zones are rather narrow, probably less than 10 m wide. The SP data are clearly associated with the central EM conductor. Calcareous quartz schist is the main country rock in the area east of Wadi Bidah. Some evidence of shearing of the center EM conductor in the area is implied by the local seritization and increased schistosity in the rocks. Thin veins of calc-carbonaceous silicic rock are aligned with the schistosity. The percentage of the carbonaceous rock visible at the surface, however is low, also, the surface carbonaceous rock is non-conductive (table 2). It is difficult to attribute the geophysical anomaly to concentrations of this carbonaceous material in the country rock based on surface rock conductivity studies. There is, however, no way of knowing the effect of the carbonaceous material at depth where weathering and leaching have had less effect on the conductive nature of the carbonaceous material.

To the north at profile 530N (fig. 8) the EM data show three conductive zones, probably the continuation of the structure observed along profile 450N (fig. 7). The two eastern-most EM responses, at 200 m coil separation, produce a broad complex anomaly. Narrow, multiple conductors, such as apparently exist at this profile, might be better resolved with the slingram method and coil separation of 100 m or less. However, the depth of exploration would be lessened accordingly. The principle SP anomaly is associated with the central EM anomaly. Calcareous quartz schist is the main country rock along profile 530N, to the east of Wadi Bidah. In the area of the central EM-SP anomaly significant amounts of silicic carbonaceous rocks contain abundant oxides of iron. The silicic rocks form a resistant ridge about 100 m wide in its widest place and 600 m long. The silicic carbonaceous rocks are abundant, but probably form a small percentage of the total rock volume, along the entire length of the ridge. Dolomitized limonitic brown rocks form thin veins and stringers along the resistant ridge. Some silicic gossan veins are in evidence, particularly in the southern part of the zone. Diamond drill hole R-3 tested the southern extention of the gossanized zone and intersected mineralized rock (2.2 percent copper across 4.3 m (Earhart and Mawad, 1970). The SP data (pl. 1) show that this zone of rocks continues on a northerly strike and delineates another zone 200-300 m long, between profiles 610N and 630N. It is interesting to note that drill hole R-1 penetrated massive sulfides at shallow depth. Drill hole R-1 is on strike to the north of the anomalous SP zones discussed above. The geochemical data and geologic mapping will assist further evaluation of these zones.

The profile along line 670N (fig. 9) crosses a small, well-developed silicic gossan about 425 m east of the base line. Drill hole R-2 confirmed the presence of massive sulfides associated with the small gossan. The EM data along this profile (fig. 9) show two distinct EM conductors and an additional weak conductor over the gossan and mineralized zone. The smaller of the two EM conductors is near a small wadi draining water from the west, and the area is largely covered by alluvium. The largest of the EM conductors lying at station 70 east is covered by alluvial fan debris from the hills to the east. A small SP response (20-30 mv) is associated with this zone. It seems most likely that the EM response is due primarily to a conductive fault

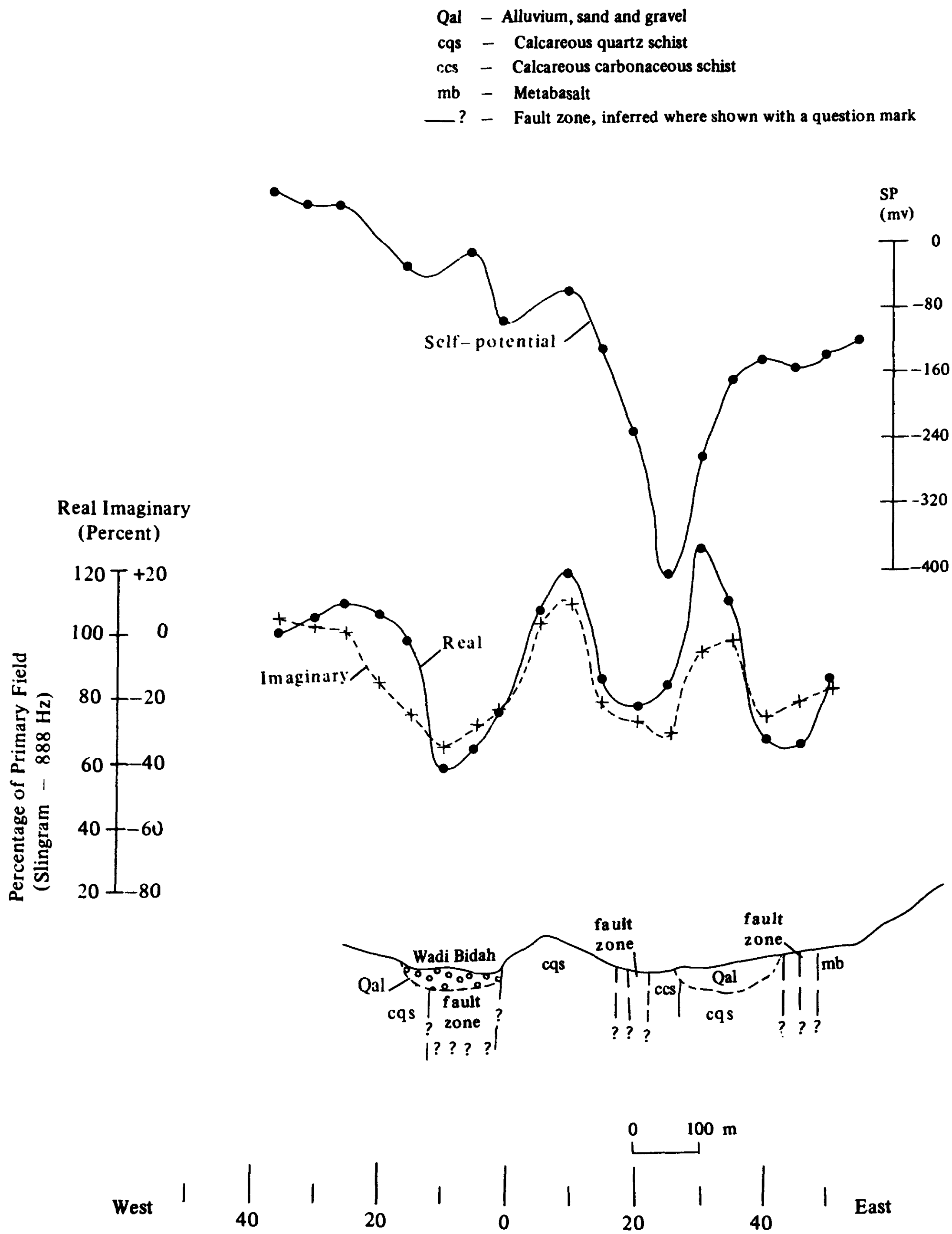

Figure 7.--Self-potential and electromagnetic profiles along line 450N in the Rabathan area showing relationship of geophysical data to geology.

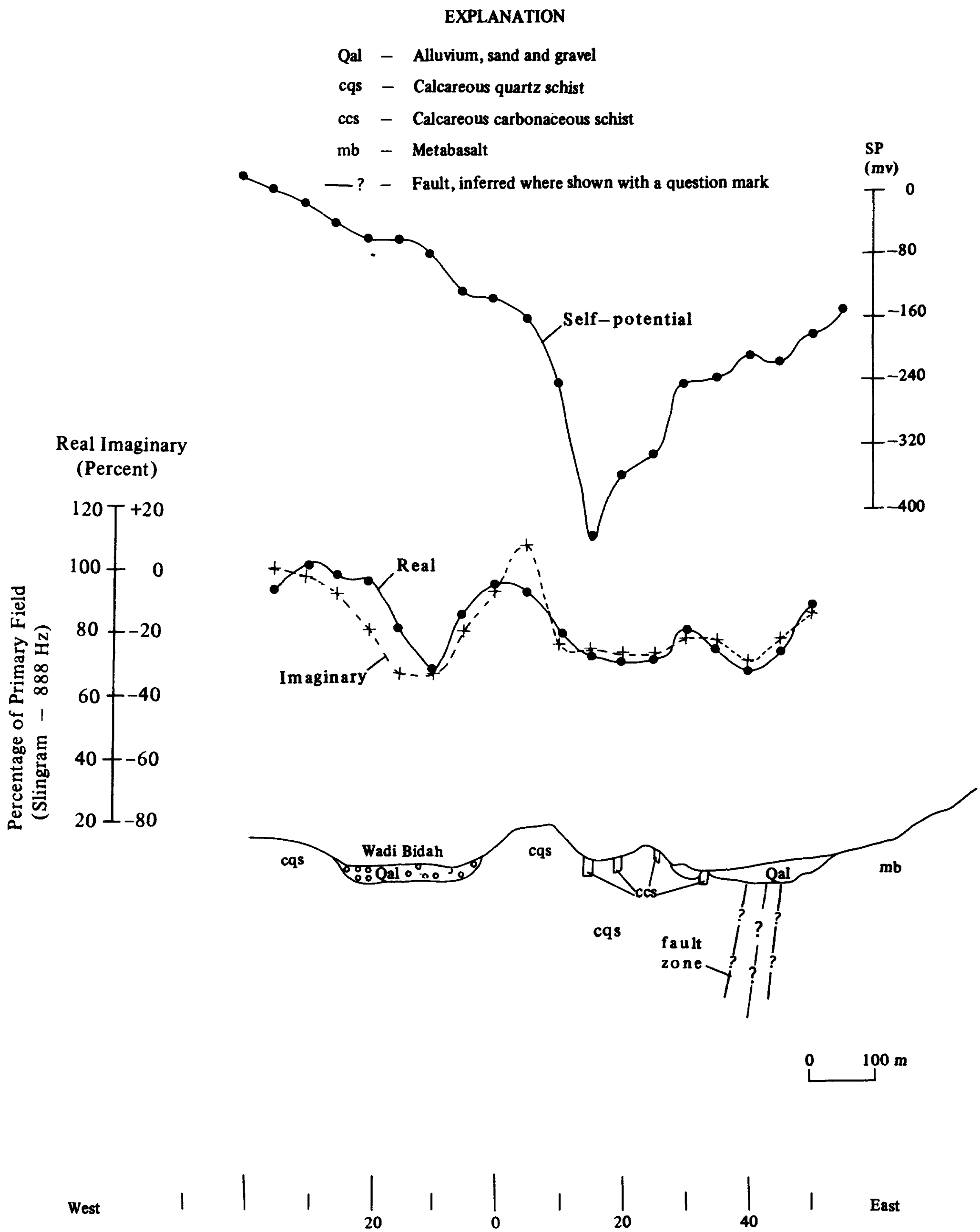

Figure 8.--Self-potential and electromagnetic profiles along line 530N in the Rabathan area showing relationship of geophysical data to geology.

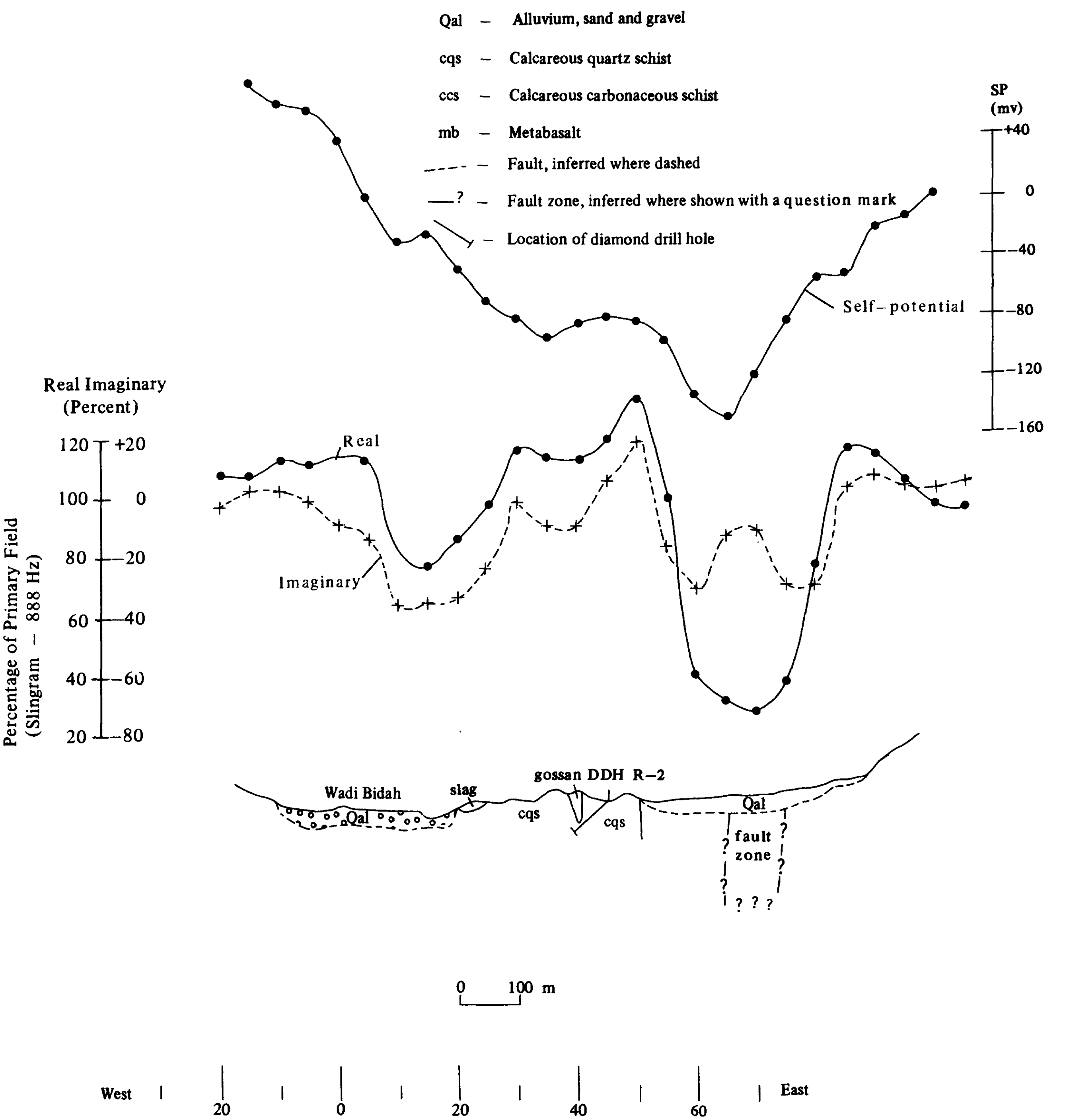

Figure 9.--Self-potential and electromagnetic profiles along line 670N in the Rabathan area showing the relationship of geophysical data to geology.

zone. To the north at profile lines 730N and 750N (pl. 2) this fault zone (?) also is associated with a strong SP anomaly. Rocks in this area are largely covered by alluvial fan materials so that exposures are few; however, in those areas that can be seen, schists are highly altered, and hematitic-stained mylonitized quartz is abundant. Some veins of hematitic, silicic gossan are aligned along the schistosity of the rocks. Geochemical sampling may be of little use because of the pervasive cover in this area. The zone should be detailed by means of induced polarization (IP) lines to delineate further its two-dimensional structure. Drilling and trenching accompanied by geochemical sampling may be worthwhile to evaluate its economic potential.

In an effort to understand the conductive nature of the "graphitic schist" described by Earhart and Mawad (1970) a preliminary study was made of rocks containing the carbonaceous material that Kiilsgaard and other indicate is not graphite (Kiilsgaard and others, 1978). Samples were collected and EM conductivity and magnetic susceptibility measurements were made. All of these samples were chosen because of an apparent association with an EM-SP anomaly and the appearance, at least, of being graphitic. All samples were nonconductive within the range of the testing apparatus (Scintrex CTU-2 using coil #3, the most sensitive, at 100 Mhz. Table 2 summarizes the results of these measurements, and shows that not one sample of carbonaceous rock collected at the surface in Wadi Bidah is conductive. Conductive values range from 1.89×10^{-4} to 8.5×10^{-3} mohs/m. Massive sulfide samples taken from cores from the Rabathan ore-body, however, showed conductivities of >3000 mohs/m. Nevertheless USGS Electromagnetic Branch explorationists caution against placing too much emphasis on properties inferred from surface rock measurements, inasmuch as the effect of unweathered carbonaceous material at depth is not known (Moss and Frischknecht, oral communication).

B-13 area

Area B-13 is nearly 15 km in length (fig. 2) and is a northern extension of the zone discussed previously under anomaly B-29. Its area is nearly double that of B-29. The cause of the interruption of the AEM anomaly is not clearly understood but may be the higher terrain clearance of the survey aircraft required by the rugged topography. A map of aircraft terrain clearance is being compiled to check this supposition. B-13 does not appear to be directly related to the trend that includes targets B-1, B-7, B-8, and B-11 described previously, because its northern tip is displaced nearly 3 km east of the southern edge of B-11, in the vicinity of the Al Aqiq road intersection.

Because of the large extent of anomaly B-13, the ground geophysical traverses were spaced 400 m apart for a distance of about 12 km, with lines averaging 1 km in total traverse. The traverse spacing of 400 m is useful for reconnaissance purposes only, and does not permit the compilation of a map as was done for anomaly B-29. Certain generalizations, however, can be made, and several profiles will be examined in detail.

In the southern part of B-13, the anomaly appears to be caused by a single conductor. In the central and northern parts of the target area, this apparently single conductor diverges to as many as five discrete EM-SP anomalies. It is most probable that, even in the south, the apparent single conductor is made up of several thin conductors that cannot be resolved using

Table 2.--*Physical properties of rock samples from Wadi Bidah*

Sample	Susceptibility (10^{-6}cgs)	Length (centimeters)	Conductivity (mhos/meter)	Description	Location of Sample
78 Bi-1	19	3.0	<0.5	quartz porphyry	Anomaly B-5
78 Bi-3	48	3.8	<0.5	gossanized, felsitic, flow-banded	B-25, 26
78 Bi-4	1396	2.9	1.4	-do-	B-25, 26
78 Bi-5	45	3.9	<0.5	-do-	B-25, 26
78 Bi-7	64	3.5	<0.5	weakly foliated greenstone	B-35A
78 Bi-8	25	2.5	<0.5	gossan-schist	B-35A
78 Bi-9	30	2.0	<0.5	felsic-silicic drill core	Rabathan, L-159, B-29(?)
78 Bi-10	28	3.9	<0.5	same, with chlorite	Rabathan, L-159, B-29(?)
WB-1	20	2.2	<0.5	carbonaceous schist	B-24, Line 250, Sta 15W
WB-2 a	16	2.6	<0.5 (1.89×10^{-4})	carbonaceous schist	B-24, Line 310, Sta 15W
WB-2 b	16	2.6	<0.5 (3.2×10^{-4})	-do-	-do-
WB-3 a	13	2.7	<0.5	carbonaceous	B-35, Line 70N, Sta 80E
WB-3 b	16	2.6	<0.5 (9.3×10^{-4})	-do-	-do-
WB-4	18	2.6	<0.5 (1.2×10^{-3})	carbonaceous schist	B-35, Line 100E, Sta 30N
WB-5	18	2.6	<0.5 (2.6×10^{-3})	carbonaceous schist	B-35, Line 110N, Sta 25E
WB-6	15	2.6	<0.5 (1.6×10^{-3})	"felsite" schist	B-35, Line 160N, Sta 25W
FB-1	26	2.3	<0.5 (3.0×10^{-3})	carbonaceous hematite	
FB-2	30	2.4	<0.5 (8.5×10^{-3})	carbonaceous	B-13, Line 480N, Sta 40E
FB-3	42	2.3	<0.5 (1.7×10^{-3})	similar	
FB-4 a	59	2.6	<0.5 (4.1×10^{-3})	marl	B-29, Line 10N, Sta 45W
FB-4 b	59	2.6	<0.5	marl	-do-
FB-5 a	44	2.6	<0.5 (4.8×10^{-3})	flow-textured gossanized felsite	B-29, Line 460N, Sta 15E
FB-5 b	47	2.7	<0.5 (5.7×10^{-3})	-do-	-do-
FB-6 a	23	2.6	<0.5 (3.7×10^{-3})	"magnetite"/hematite?	B-29, Line 390N, Sta 15W
FB-6 b	57	2.5	<0.5 (7.8×10^{-3})	breccia	-do-

Table 2.--*Physical properties of rock samples from Wadi Bidah* [continued]

Sample	Susceptibility (10^{-6}cgs)	Length (centimeters)	Conductivity (mhos/meter)[1]	Description	Location of Sample
FB-7	18	2.6	<0.5 (1.2×10^{-3})	mafic, homog rock	B-24, Line 1, Sta 30W, Khayal al Masna'ah
FB-8 a	28	2.7	<0.5	marl	Bir:8 km south of W. Bidah field camp
FB-8 b	29	2.7	<0.5 (1.20×10^{-3})	marl	-do-
FB-9 a	24	2.6	<0.5 (5.6×10^{-3})	felsitic marl	-do-
FB-9 b	25	2.6	<0.5 (6.8×10^{-3})	-do-	-do-
FB-10	42	2.6	<0.5 (2.6×10^{-3})	mag/hematite marl	B-29, Line 530N, Sta 30E
FB-11	41	2.6	<0.5	mafic homog rock	B-29, Line 140N, Sta 17.5E
78 MA-2	2662	6.5	720	carbonaceous rock with flour pyrite	Masane Anomaly #14 for comparison
MADEN-1			2.2	schistose, mostly carbonaceous	B-24, Line 150N, west of Maden mine
RAB-1			<0.5	carbonaceous schist	B-29, DDH RB-4 at Rabathan
RAB-2			1200	massive sulfide	-do-
RAB-3			> 3000	massive sulfide	-do-

[1]Values of conductivity shown in parenthesis were determined in laboratory measurements at Denver, Colo.

a 200-m coil spacing on the EM system. It is probably incorrect to suggest continuous conductive zones along the entire length of the anomaly. More likely, the conductive zones are discontinuous, lens-like, tabular features produced by metamorphism and folding of the original rocks, much like the anomalies seen in B-29 where the line spacing was 200 m. For this reason no attempt was made to correlate conductors between lines on a map using 400 m spacing.

SP anomalies tend to be broad over the length of B-13, but have pronounced principle peaks in the northern and southern parts. In the central part of B-13, the SP anomaly is broad, has a low amplitude (-100 to -150 mv), and most clearly is composed of multiple (at least five) sources spaced over a traverse distance as much as 600-700 m. So many SP anomalies are along so many profiles that it becomes difficult to apply the "small-spike-on-broad-SP-anomaly" test (derived from area B-29) to AEM target B-13. Extensive geochemical sampling is being carried out, however, using the ground EM-SP profiles to guide roughly the sampling. If results are encouraging, an exploratory drilling program should be guided by the geochemistry for general location, and interpreted results from the EM for specific drill-orientation. A sufficient number of fill-in lines of SP and EM should be made to permit compilation of one or more local maps to define the three-dimensional character of the conductors anticipatory of the drilling. The SP data, incidentally, cannot be quantitatively analyzed, but may be used to help eliminate unmineralized conductors from the rest.

In light of the non-conductive nature of the "graphitic" (called carbonaceous henceforth) samples collected, the potential is substantially increased for each EM conductor that has an associated SP anomaly to be caused by a sulfide deposit. Detailed EM-SP measurement may show relationships that will delineate the sources of the large number of EM-SP anomalies. The possibility remains that extensive sulfides, perhaps thin bodies each, are buried throughout target areas B-13 and B-29.

The following discussion analyzes three representative profiles from area B-13, chosen from among the best conductors encountered in the survey. No geology is available on these profiles and the geochemical results are as yet unavailable. As a result, no specific economic assessment of the anomalies will be made at this time.

Figure 10 shows a profile along line 280 N, in the southern part of the AEM anomaly B-13. The EM conductor appears to be a single symmetrical (vertically-dipping) feature nearly 140 m wide extending from station 28E to station 42E. Quantitative analysis gives this conductor a conductance of about 25 mhos (moderate to good), and its top is at or near the surface (less than 10 m depth). This conductance value may be deceptive because it probably results from a dilution of several good yet narrow conductors by 150 m of barren country rock or alternately it may be the response of a broad shallow conductor. The SP anomaly is substantial (nearly -250 mv) but is still within the range that could be caused by sulfides. Several peaks on it are possibly indicative of multiple sources of variations in resistivity along paths of SP current flow, or of other possible causes (such as rock-geometry effects, rock-porosity variations, and so forth).

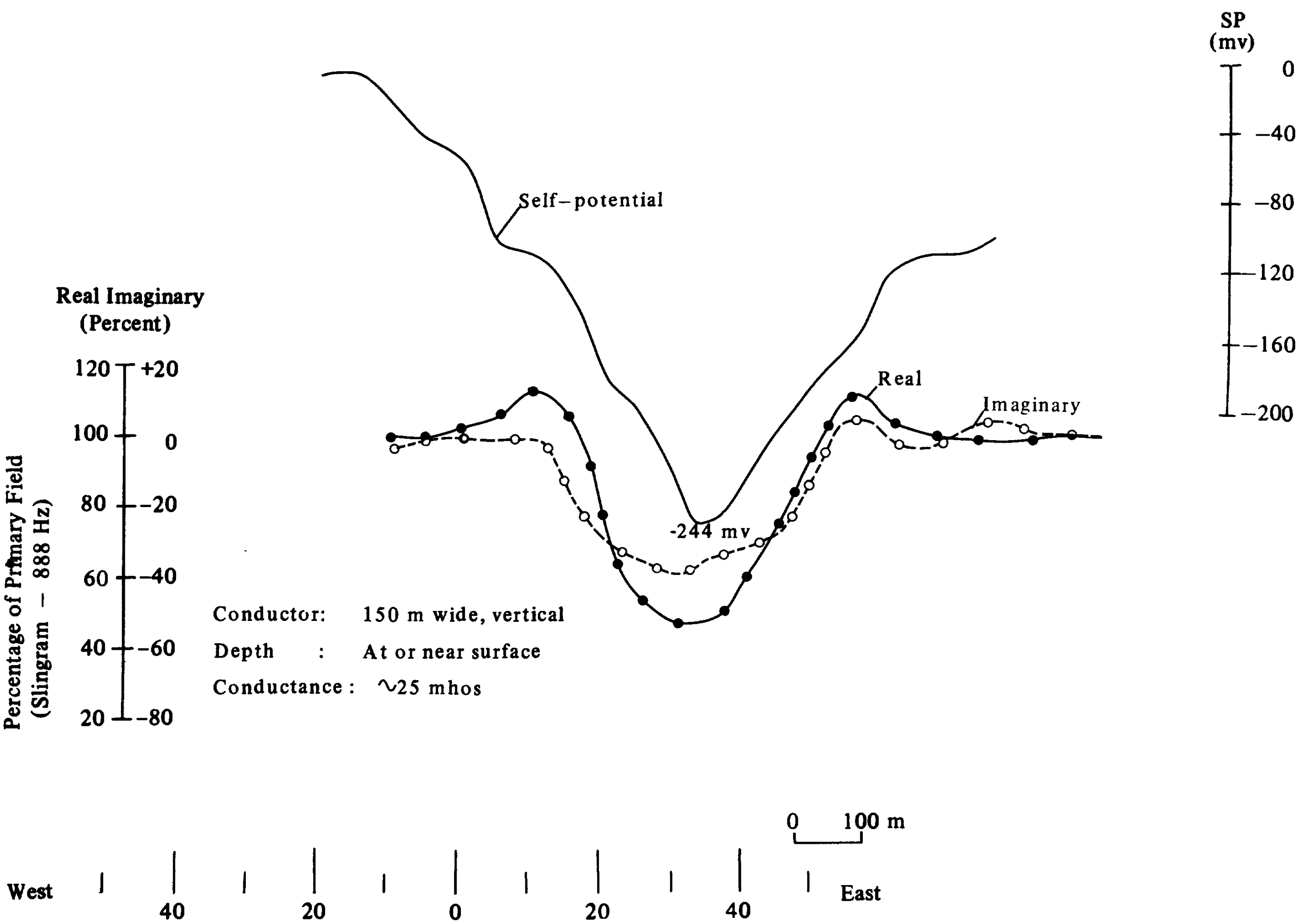

Figure 10.--Self-potential and electromagnetic profiles along line 280N in the area B-13.

Figure 11 shows a profile along line 640N, in the central part of the B-13 target area. This profile is typical of the results from this central zone and in this case shows at least five discrete SP-EM anomalies, all of which are not exactly coincidental. Because of the mutual interference of these anomalies, a quantitative estimate of conductor parameters is not possible. The five conductors range over nearly the entire length of the profile, from station 5W to station 70E, a traverse distance of 750 m.

Figure 12 shows a profile along line 1000 N, an example of the good conductor character in the northern part of anomaly B-13. The real component data show an apparent single conductor, but the imaginary component data show it to be composed of at least two conductors spaced along at least 200 m. The SP anomaly appears to be a single discrete peak centered in the middle of the 200 m-wide conductive zone. A faint shoulder on the east side at about station 20E might imply another weaker sulfide or graphite lens there. The SP amplitudes (-250 mv maximum) are encouraging, and do not exclude sulfides.

In summary, AEM target area B-13 contains a large number of conductive bodies that are possibly nongraphitic, but nevertheless give good SP results. A fuller analysis of the economic potential of this very large area awaits the geochemical results, however. In light of the laboratory conductivity tests, the economic potential of this area could be substantial. If geochemical results are not encouraging, then limited drilling might be required to assess the cause of the EM-SP conductors (if not caused by sulfides), and laboratory petrophysical and petrographic work should be included. If a systematic geochemical sampling program shows encouraging results, then fill-in geophysical work will be required to delineate the structure of the conductors prior to drilling.

B-25-26 area

This AEM anomaly consists of two moderate-sized targets approximately 2 km east of the northern tip of anomaly B-24, and therefore near the extreme western edge of the Wadi Bidah target area (fig. 2). The initial airborne reconnaissance by Wynn and Blank (1979) reported gossans at each of the target areas and nearby road access. The high priority of the targets caused by their limited lengths and slow AEM decay ratios further justified their inclusion in the Phase 2 exploration program.

Figure 13 shows the self-potential map of the B-25, 26 target area. The two SP anomalies, designated here the east anomaly and the west anomaly, are parallel, trend roughly N.30°E., have distinct northern and southern lobes. They appear to be tied together at their southern lobes, and each has its maximum amplitude (-300 mv and -250 mv going west to east) in the northern lobes; amplitudes are high but are consistent with sulfide sources.

The real component (in phase) EM map of the B-25-26 area (fig. 14) shows the strongest EM response over the northwest lobe shows the strongest EM response over the northwest lobe of the SP anomaly (fig. 13), being more exactly coincident with most of the latter. The real component anomaly is roughly L-shaped; however, a small lobe reaches eastward towards the northeastern SP anomaly, where there is a poorly-defined but substantial real component anomaly in its own right. Over the northwestern SP anomaly, the real component EM amplitude decreases to 40 percent, a very substantial

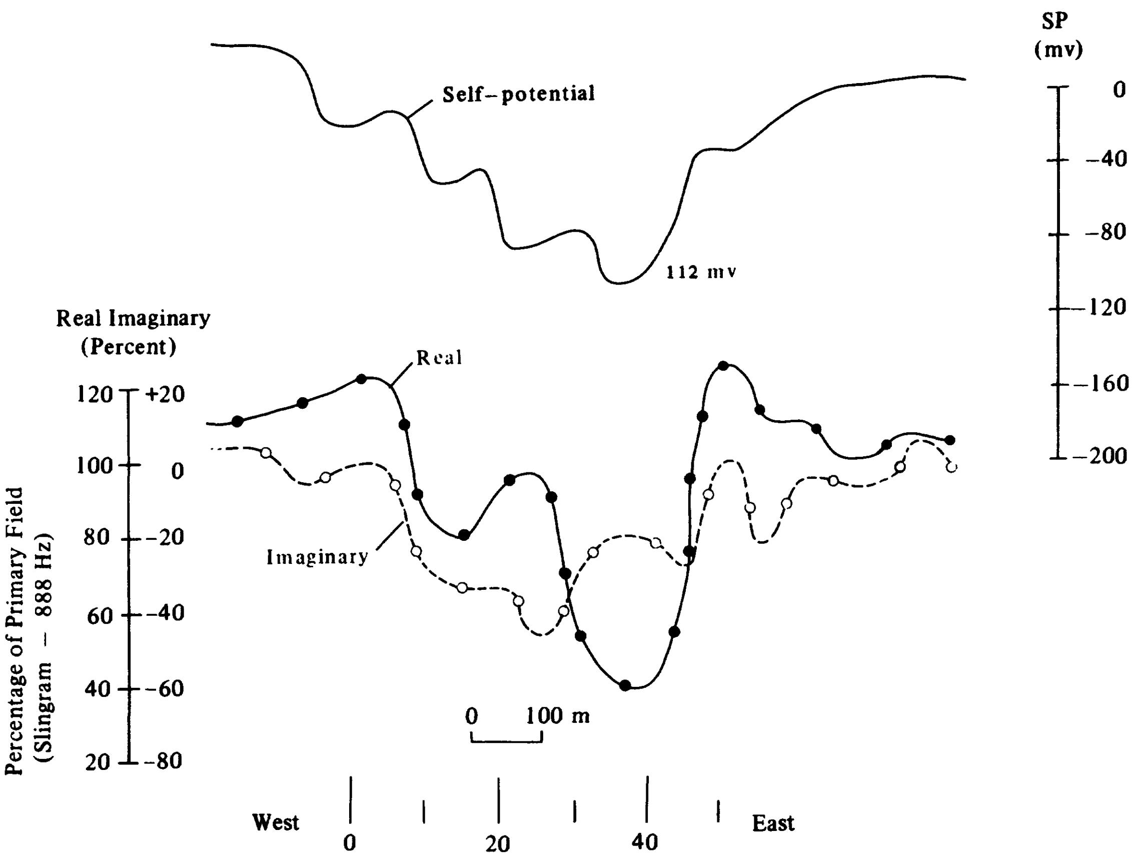

Figure 11.--Self-potential and electromagnetic profiles along line 640N in the area B-13.

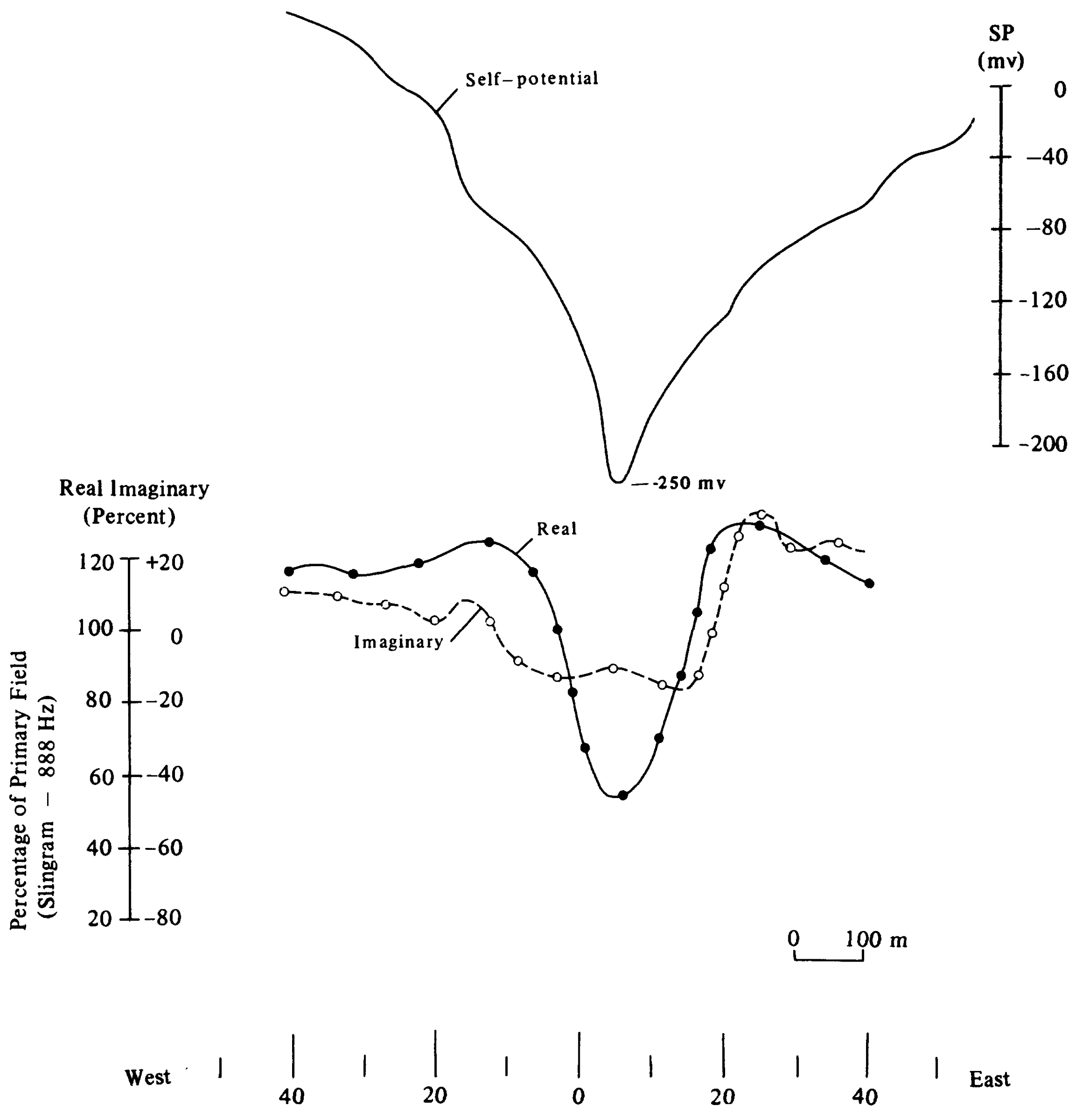

Figure 12.--Self-potential and electromagnetic profiles along line 1000N in the area B-13.

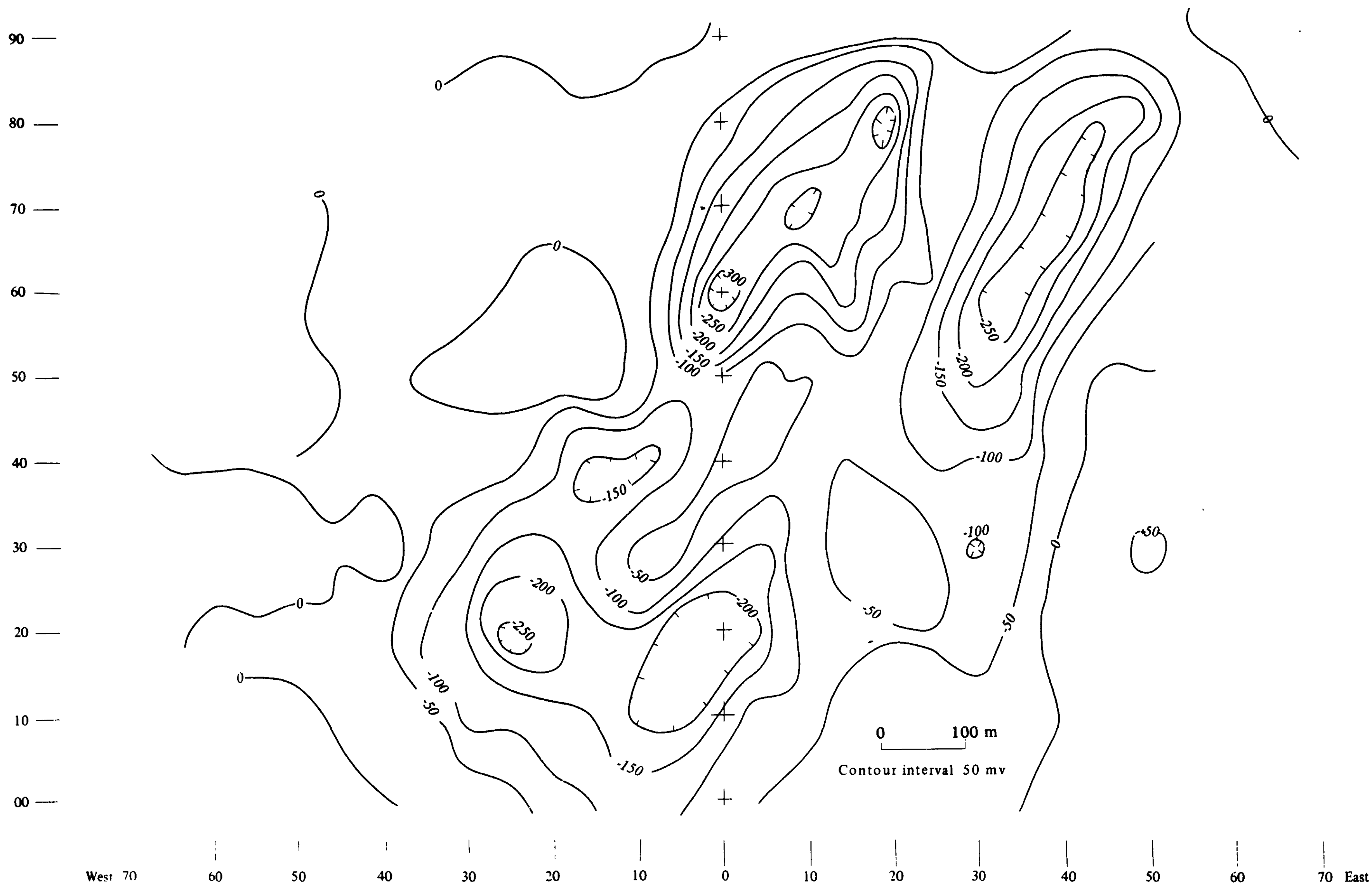

Figure 13.--Self-potential map of the B-25-26 target areas.

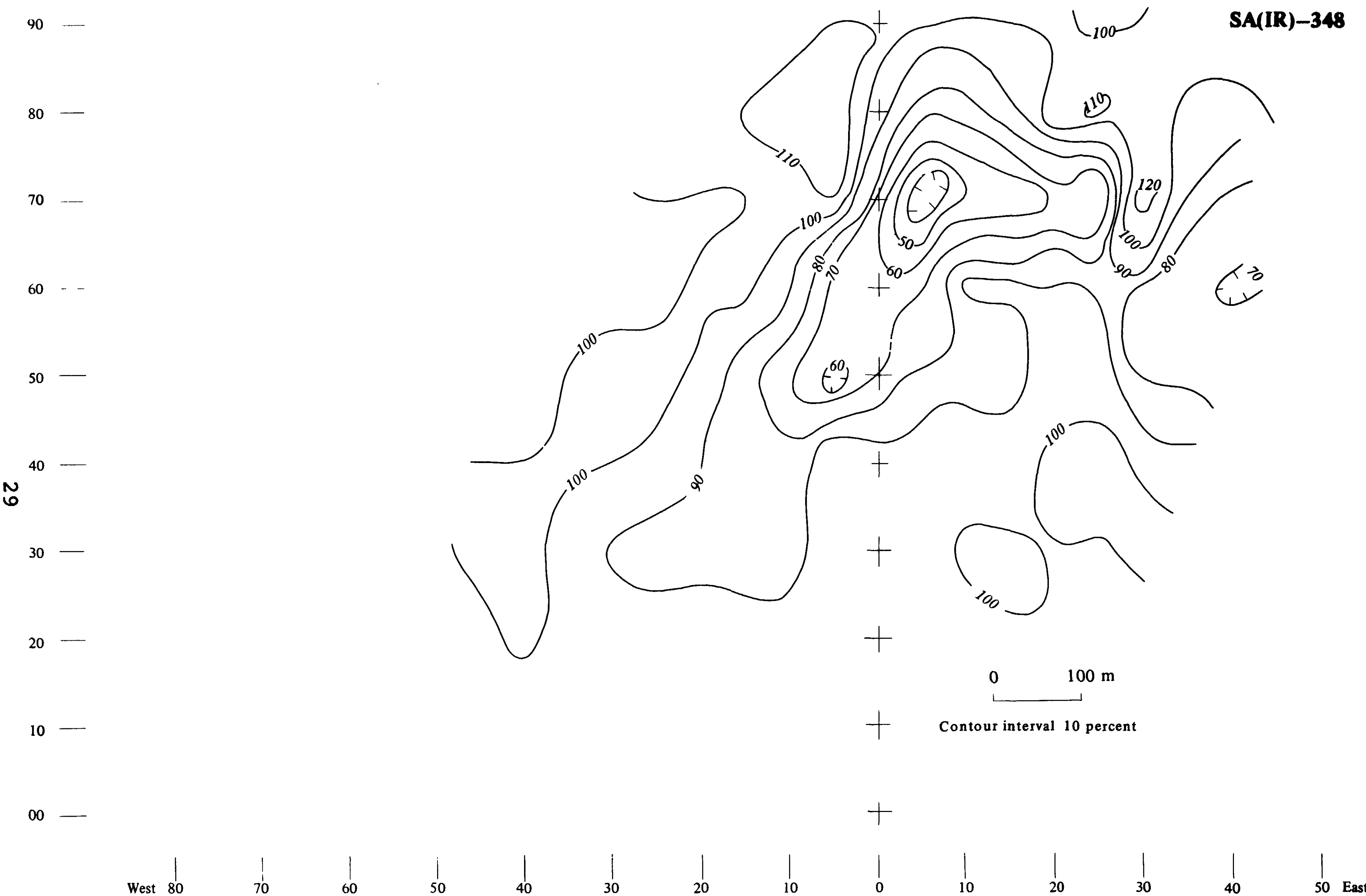

Figure 14.--Real component (in-phase, 880 Hz) electromagnetic map of the B-25-26 target areas.

conductor. Over the northeastern SP anomaly, the real component EM amplitude dips below 70 percent, still a significant response.

Figure 15 shows the imaginary component results in area B-25-26. The imaginary component anomaly is broader and more diffuse than the real component real component anomaly, the two most substantial anomalies being located over the western conductor. A small offset between real and imaginary component data suggests that the imaginary component extends into the southeastern lobe of the SP anomaly.

Figure 16 displays the ground magnetic data for the B-25-26 area. The most striking feature is the magnetic high exactly coincident over the northwestern SP-EM anomaly. A strong dipolar feature lies over the north tip of the southwestern SP-EM anomaly, and there is virtually no expression over the entire eastern SP-EM anomaly. This magnetic anomaly may be associated with magnetite or possibly pyrrhotite in a sulfide zone.

An examination of the previously run lines (ARGAS, 1978) from Phase 1 allowed an analysis of one of the best EM-SP anomalies. This anomaly is located at station 400W of line L-3 of that survey (marked 1 on figure 14), and has a coincident SP anomaly of -280 mv. The conductor dips to the east at some angle shallower than 60°, has a width of less than 10 m, and has a depth of burial of probably 10 to 20 m to top. Its conductance is about 30 mhos.

Figure 17 summarizes the relationships discussed in area B-25-26. Geologic mapping and geochemical sampling are still incomplete, but it is interesting to note that the geophysical anomalies have a strike length of nearly a kilometer, along which the rocks are overlain by limonitic and hematitic gossan. The different geophysical character of the two main anomalies trending N. 30°E. suggest a massive sulfide body beneath the western anomaly, and a poorer or more disseminated sulfide deposit beneath the eastern anomaly. This conclusion may be opposite to that based on geologic examination because the western anomaly zone indicates iron-oxides and the eastern anomaly sulfides. Depending on the results of the geochemistry, as few as one and as many as four drilling targets might be outlined. The northwestern anomaly, and probably the southwestern anomaly, should be explored by drill in any case.

B-24 area

The B-24 target area lies in the center of the western edge of the Wadi Bidah AEM survey. Its southern tip is approximately coincident with the village of Mahawiyah on the Taif-Abha highway. Two ancient mines are on the extreme eastern edge of the anomaly, the Ma'dan mine near Mahawiyah and the Khayal al Masna'ah mine about 13 km north of Mahawiyah (see fig. 2). The anomaly is about 22 km long.

The Ma'dan mine has been described by Abu-Rashid (1971) and Alcott (1969). Three diamond drill holes at the main workings were described by Alcott (1970). The mines and the AEM target area are in a belt of schistose rocks, mostly chloritic, derived from mafic volcanic rocks. Minor quartz-sericite schists in the zone were probably derived from felsic volcanic rocks. Zones of limonitic schist are common, but it was not clear to Alcott

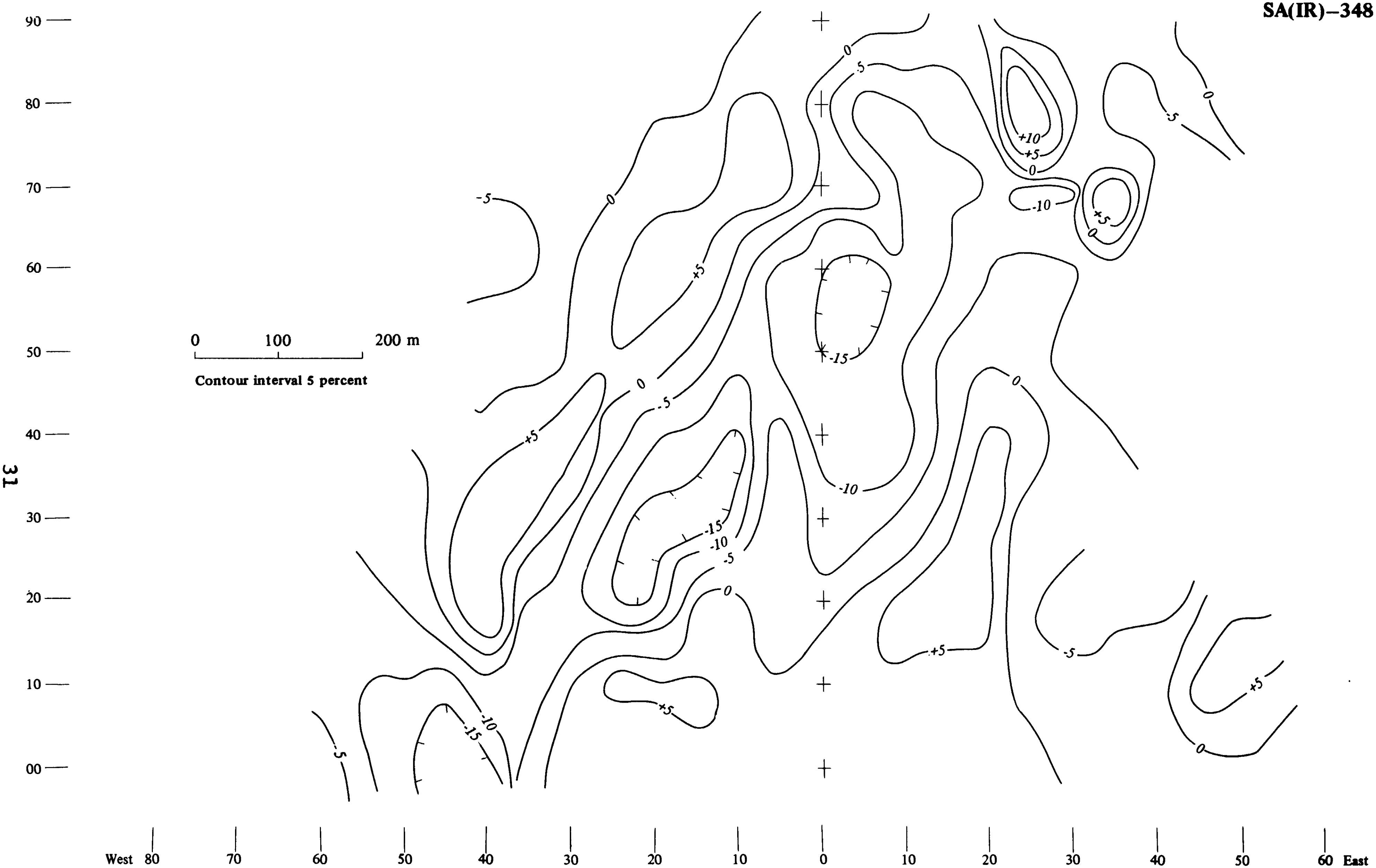

Figure 15.--Imaginary component (out-of-phase, 888 Hz) electromagnetic map of the B-25-26 target areas.

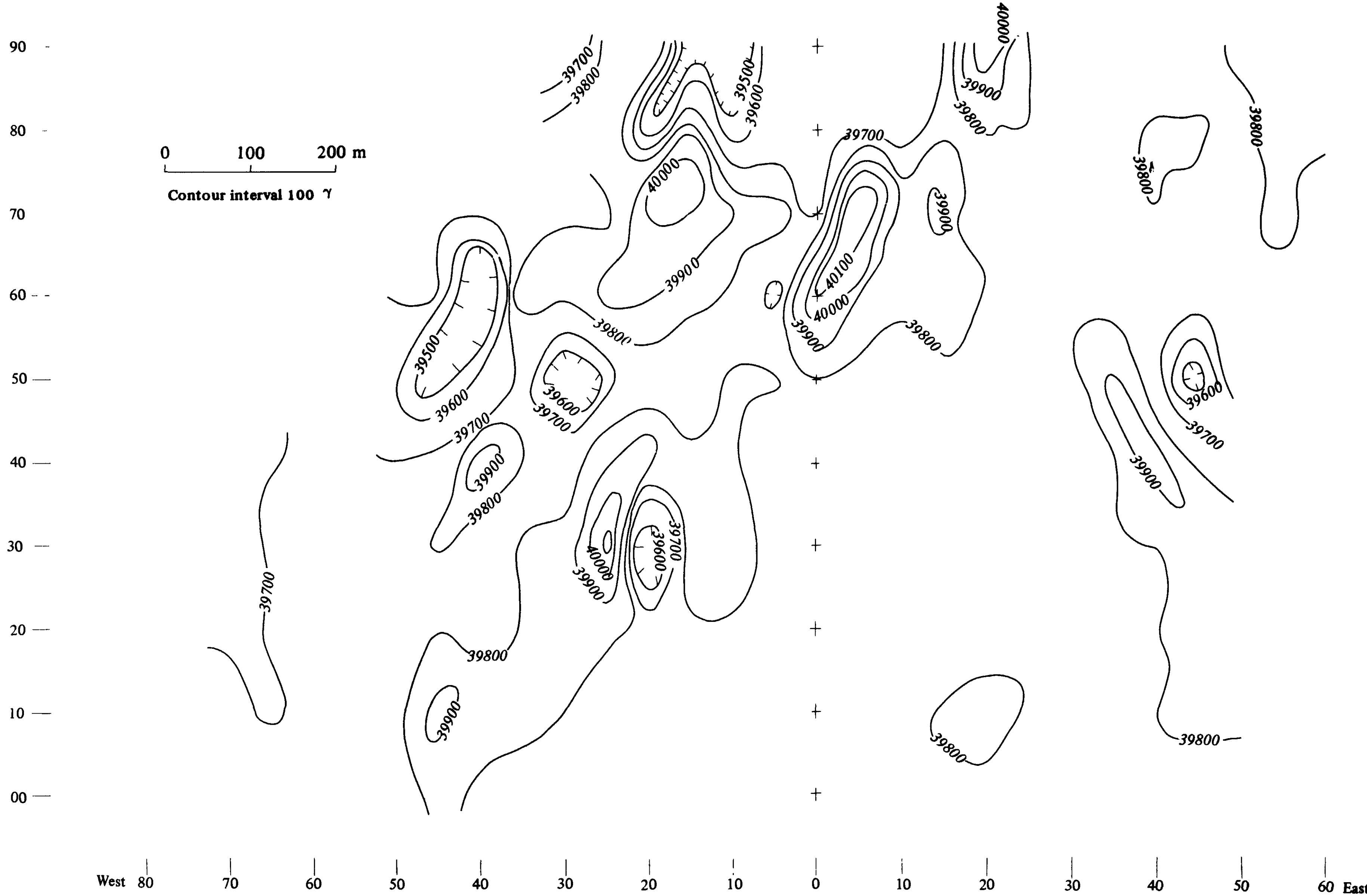

Figure 16.--Magnetic intensity map from ground measurements in the B-25-26 target areas.

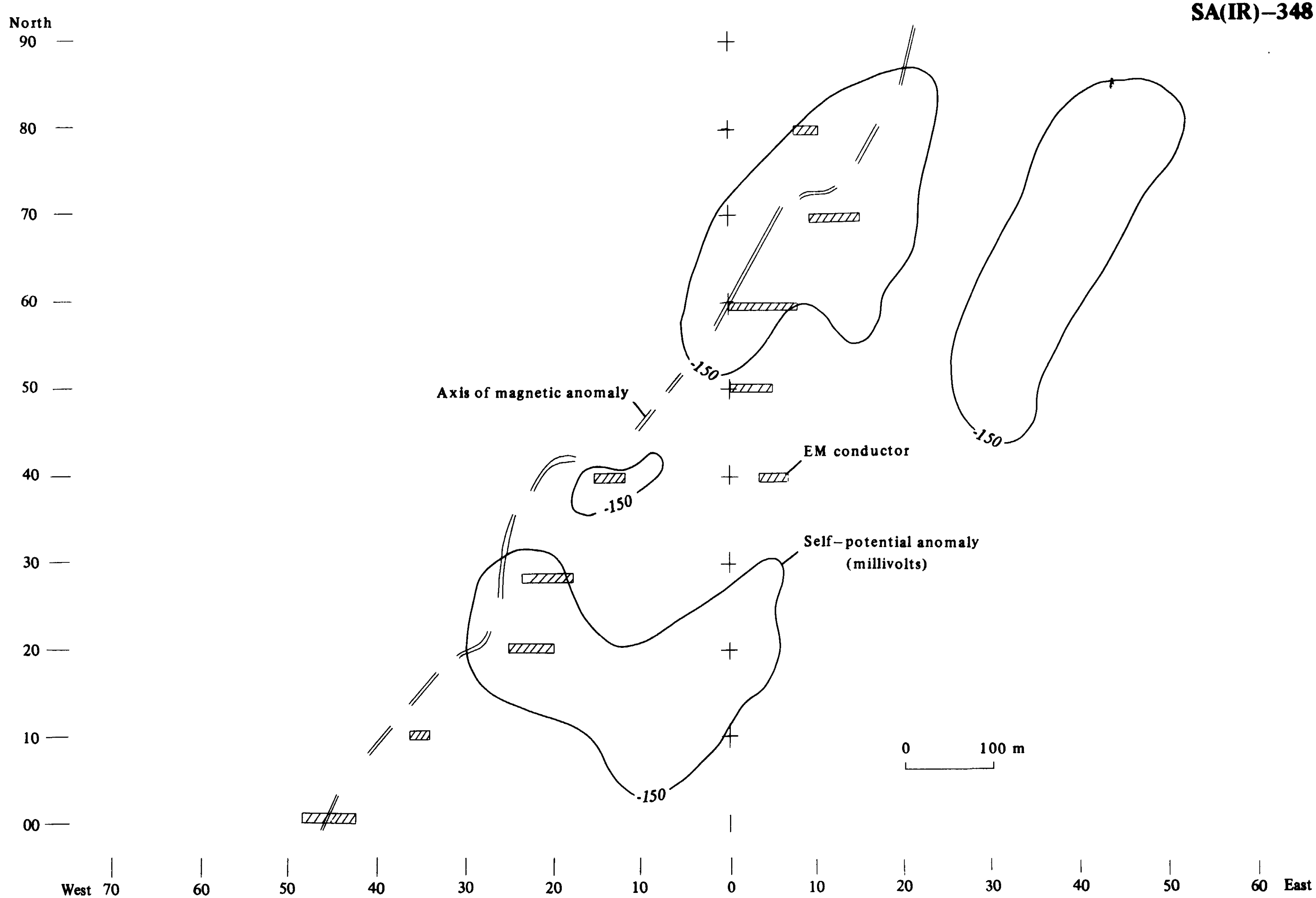

Figure 17.--Summary of relationships between different kinds of geophysical data in the B-25-26 target areas.

whether these were derived from weathered mafic rock or from weathered pyritiferous schists.

Previous geophysical investigation included the Ma'dan mine and showed no evidence of a conducting body at shallow depth (Flanigan, 1970). ARGAS (1978) made two EM and SP traverses over the Ma'dan mine, and SP values reported in excess of -180 mv lead the interpreter to suggest the possibility (at least) of graphite. The slingram data showed a strong anomaly that is centered (see fig. 18) at about station 460W (line L-1), dips slightly west at 70^{o} to 80^{o}, has a conductance about 30-40 mhos, and has a depth to top of less than 20 m. Figure 18 is helpful in visualizing the relationship between the airborne EM data, the ground EM data, the interpreted conductor, and the Ma'dan ancient mine and drill hole. This profile includes Line 1 of the 1978 ARGAS survey, and lies just south of the area discussed immediately below.

Figure 19 includes both SP data for lines run by ARGAS in the 1978 Phase 1 survey and additional data from the ARGAS Phase 2 survey. The SP data shows an intense anomaly running along a topographic low, about 200 m west of the axis of the Ma'dan mine (location of "Pit" on the figure). This anomaly reached -300 mv and may be caused by carbonaceous material. Carbonaceous samples collected on the surface, however, were not conductive. A sample collected by previous workers located "just west of the Ma'dan mine" was weakly conductive, nevertheless, having a conductivity of about 2 mhos. The SP values in the range of -200 to -300 mv does not rule out massive sulfides.

The EM results north of Ma'dan in area B-24 can be seen on figure 20. These data, especially the imaginary component, suggest a broad, shallow conductor trending north-south over the mapped area. The real component anomaly is coincident with the SP, and the imaginary component anomaly brackets it very closely.

Figure 21 shows a profile across line 190 N of B-24. The SP data show a -360 mv sharp-peak anomaly. The magnetic data has a range of about 300 gammas, but appears to be unrelated to the SP or EM conductors. The EM data allow us to characterize the conductor as being about 30 m wide, nearly vertical, buried only 5 to 10 m at most, and having a conductance of nearly 80 mhos. The character of the SP data, that is, sharp, steep gradients, is very similar to that seeallow us to characterize the conductor as being about 30 m wide, nearly vertical, buried only 5 to 10 m at most, and having a conductance of nearly 80 mhos. The character of the SP data, that is, sharp, steep gradients, is very similar to that seen in the SP data of Khayal al Masna'ah where graphitic schist was identified at the surface, and suggests that the geophysical anomalies in B-24 may be caused by graphitic schist.

The profile along line 250 N (fig. 22) of area B-24, similar to line 190N, has a -325 mv SP anomaly and a somewhat narrower conductor. The conductor dips about 60^{o} east, is buried more than 20 m, and has an estimated conductance of about 30 mhos. The same conclusions apply as for line 190 N.

Figure 23 shows the more revealing of the two profiles run over the Khayal al Masna'ah prospect in the northern part of area B-24. Line 00, presented here, crossed and was centered on the ancient mine site. The SP

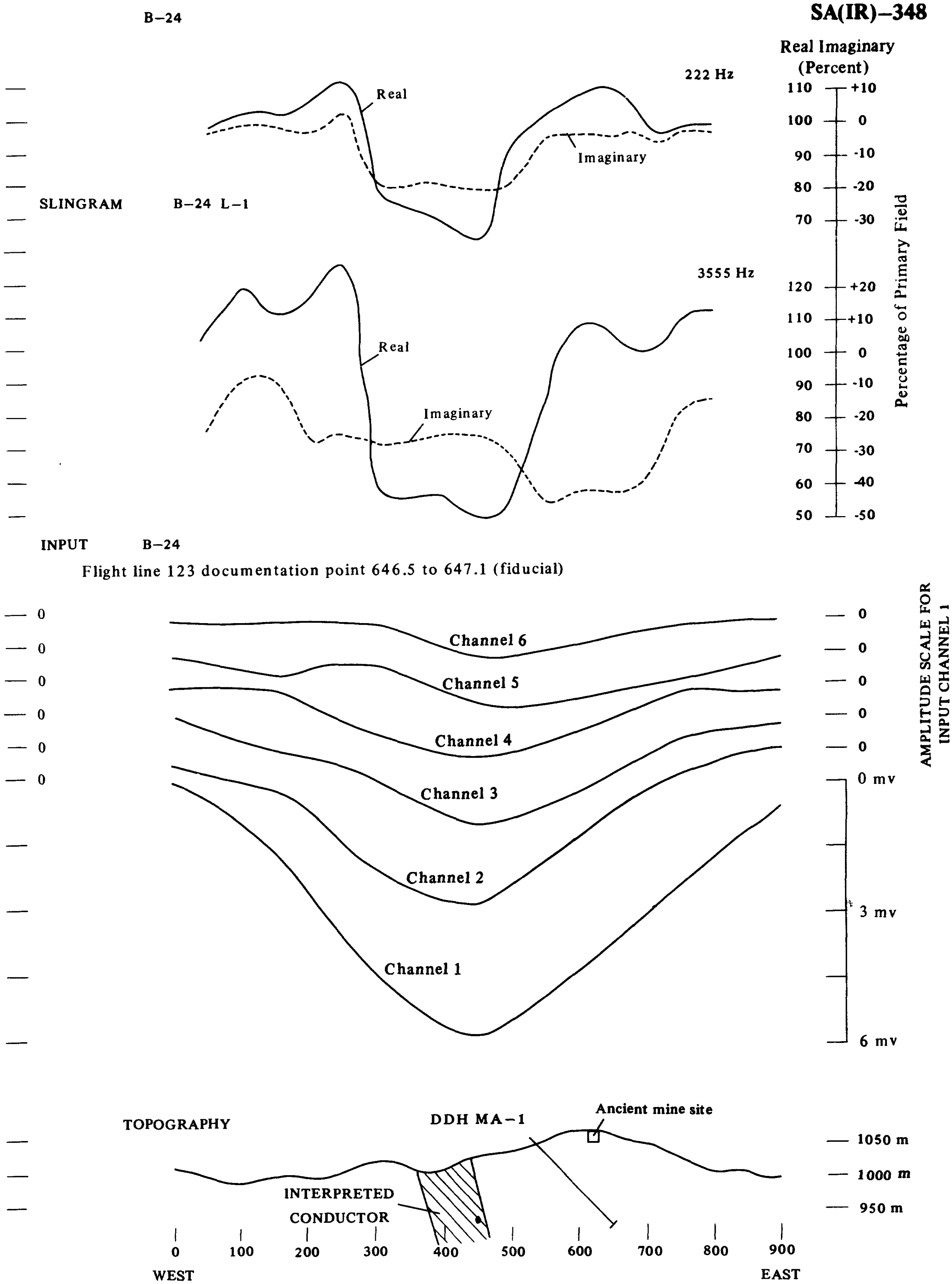

Figure 18.--Self-potential and electromagnetic profiles across the B-24 target area (Ma'dan mine). Data from the 1977 AEM INPUT survey is also shown in the lower part of the figure.

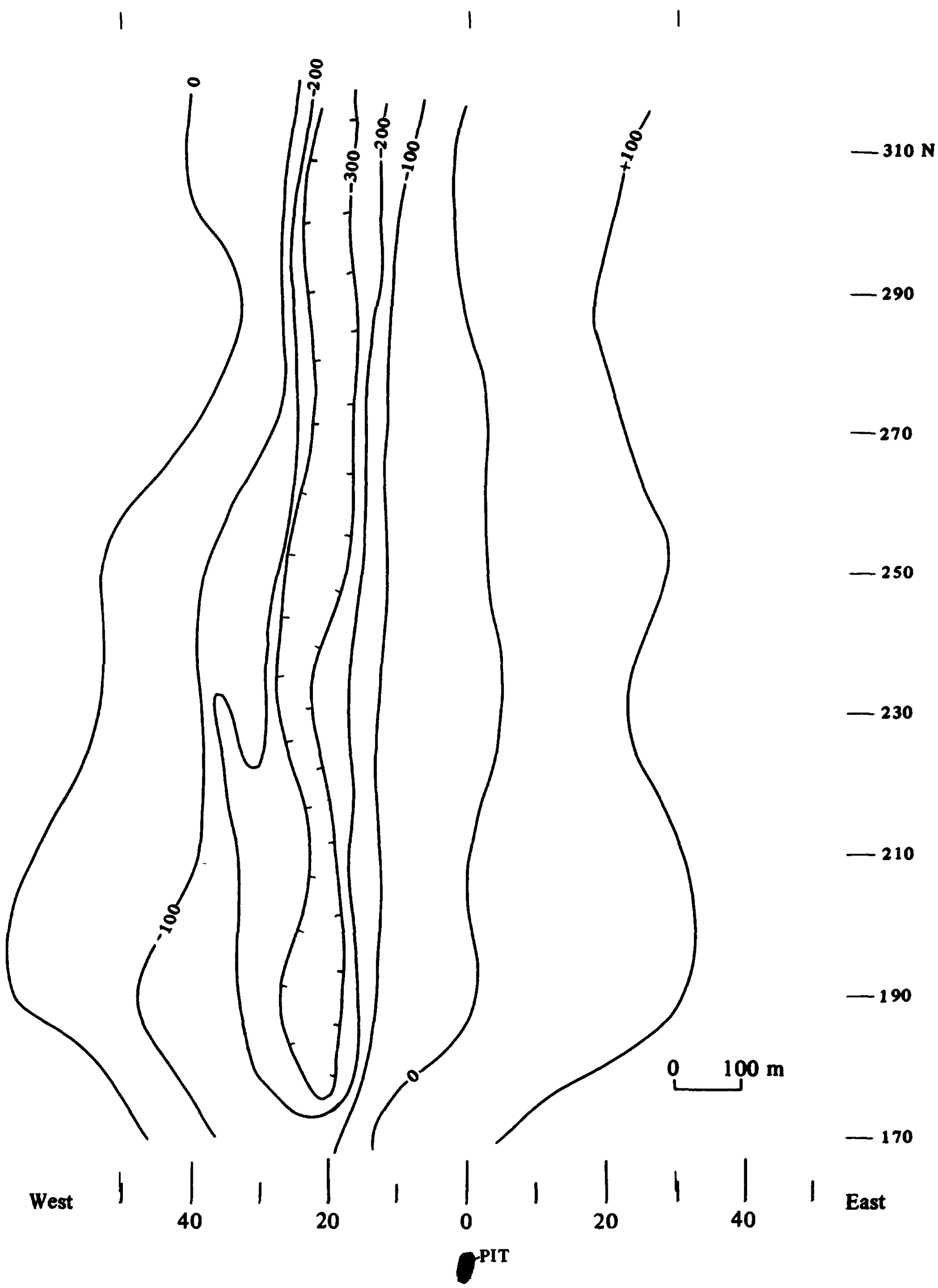

Figure 19.--Self-potential map of the B-24 area (Mahawiyah).

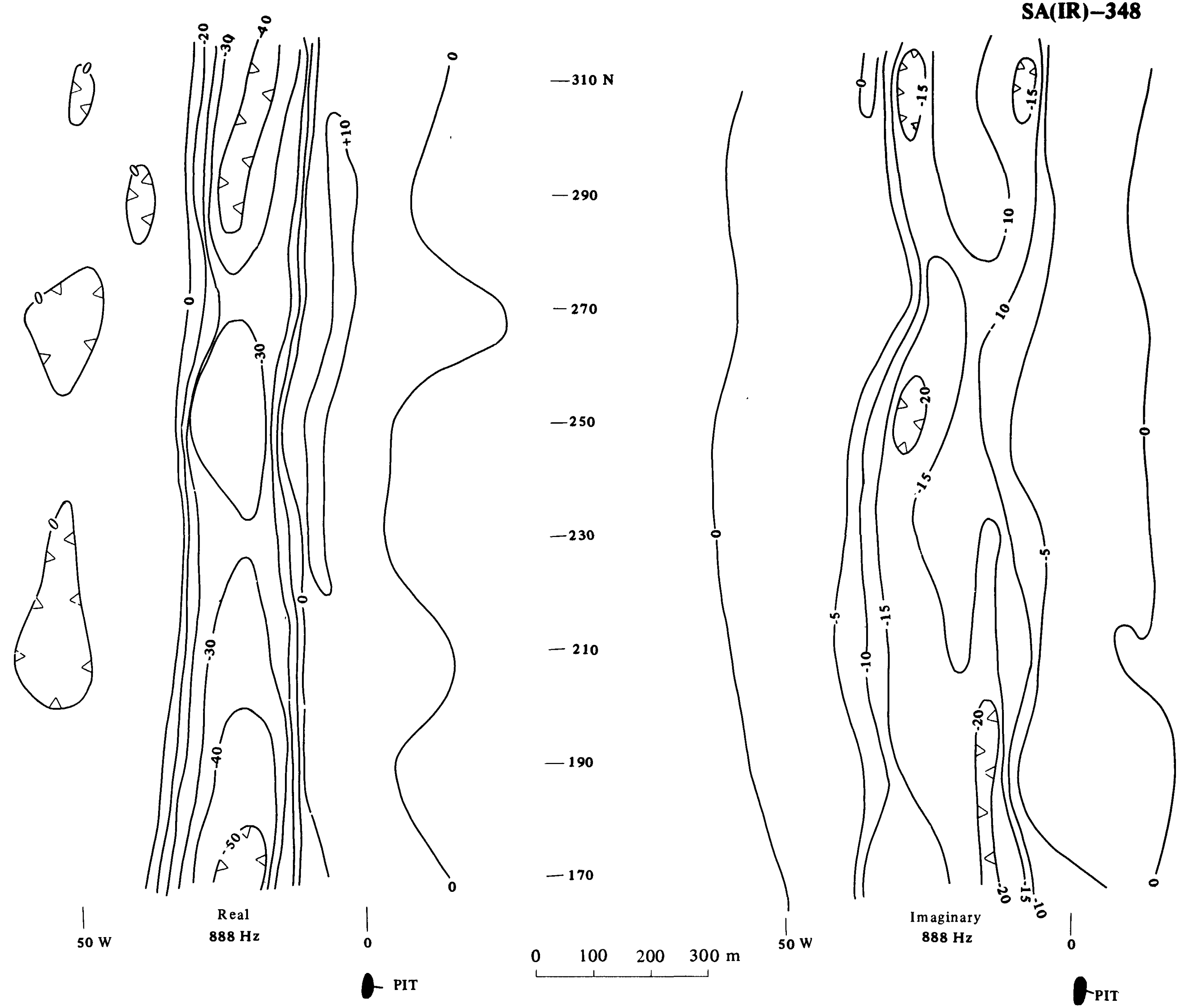

Figure 20.--Electromagnetic map of the B-24 area (Mahawiyah).

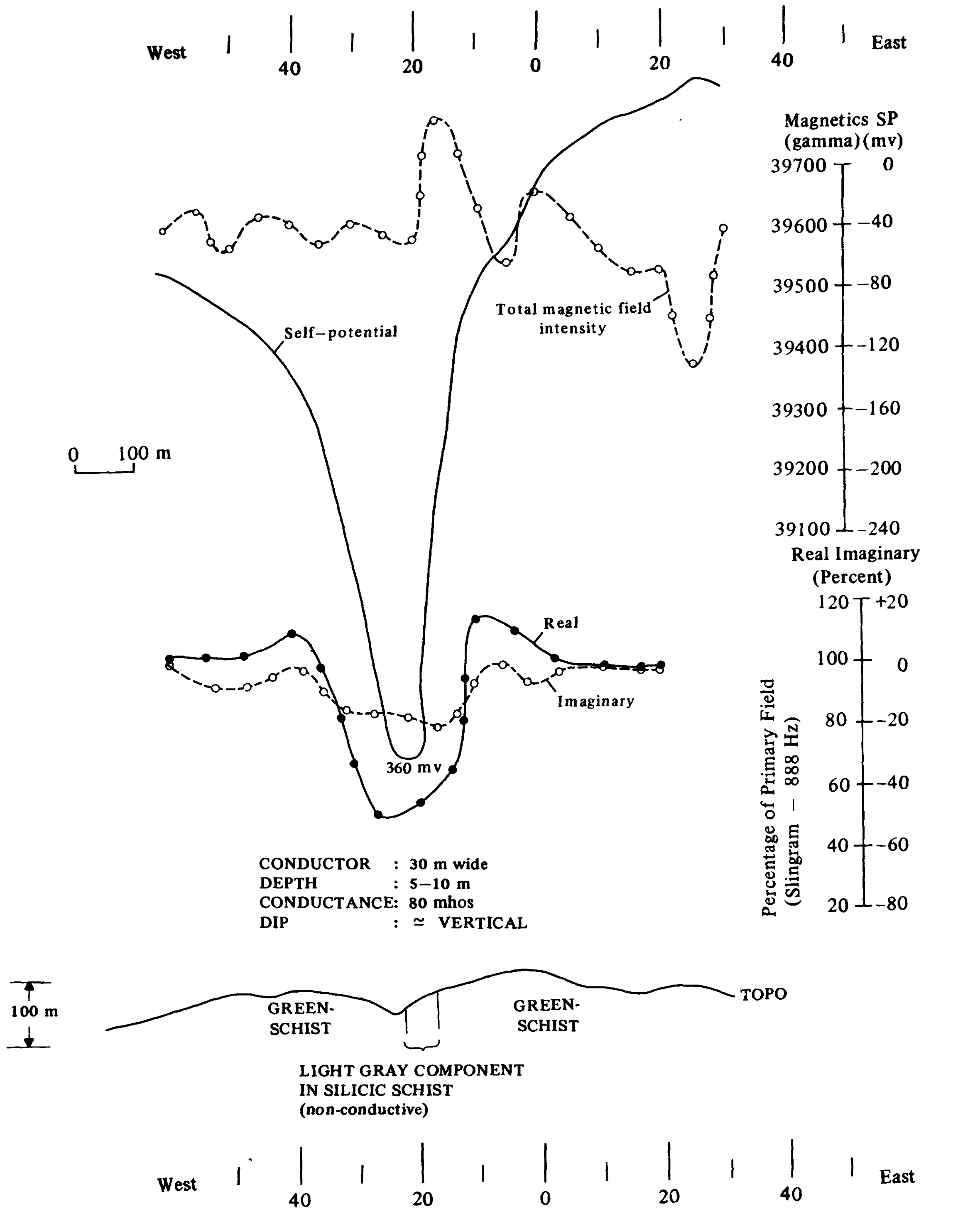

Figure 21.--Self-potential and electromagnetic profiles along line 190N in the B-24 area (Mahawiyah) showing the relationship of geophysical data to geology.

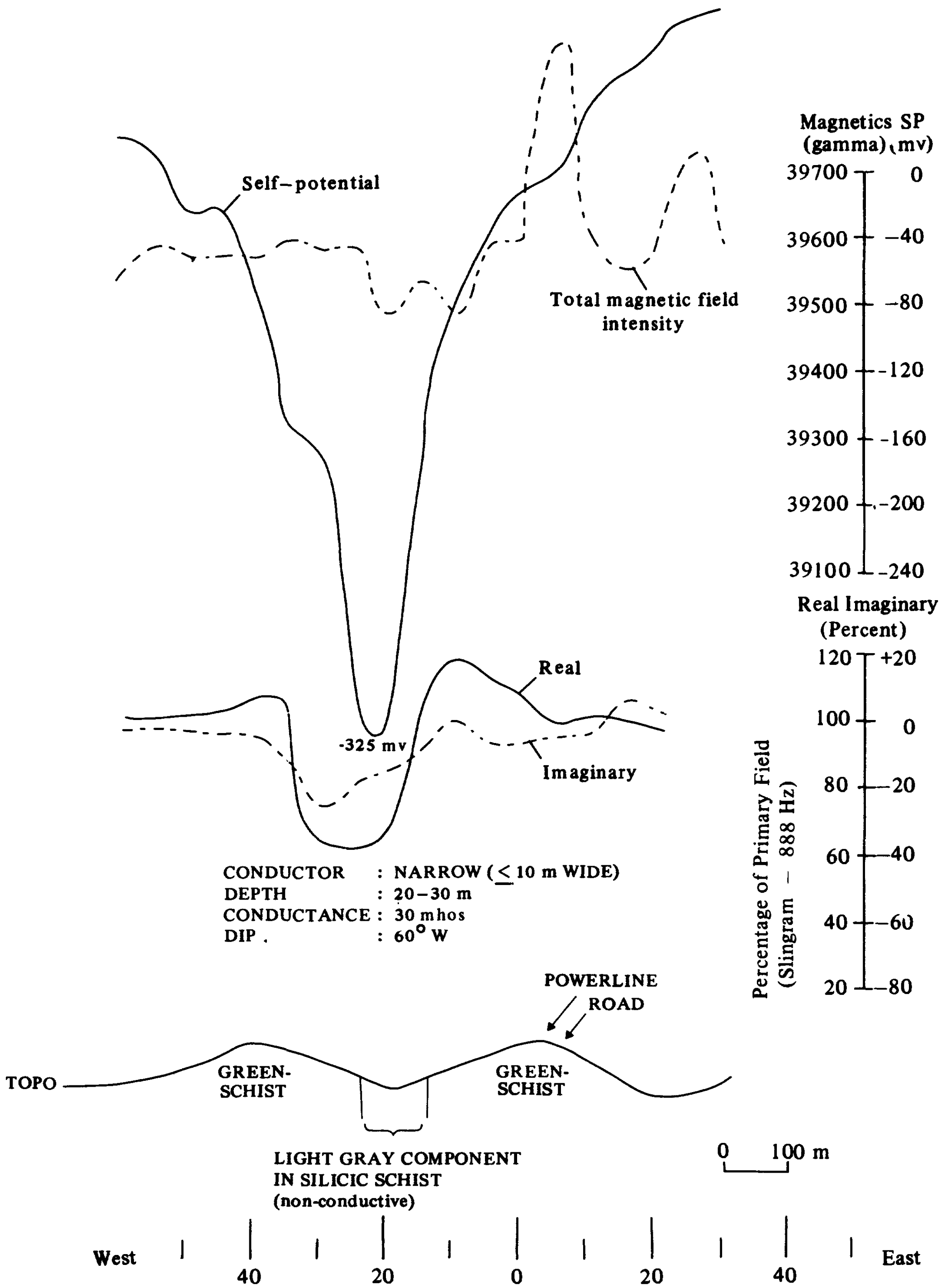

Figure 22.--Self-potential and electromagnetic profiles along line 250N in the B-24 area (Mahawiyah).

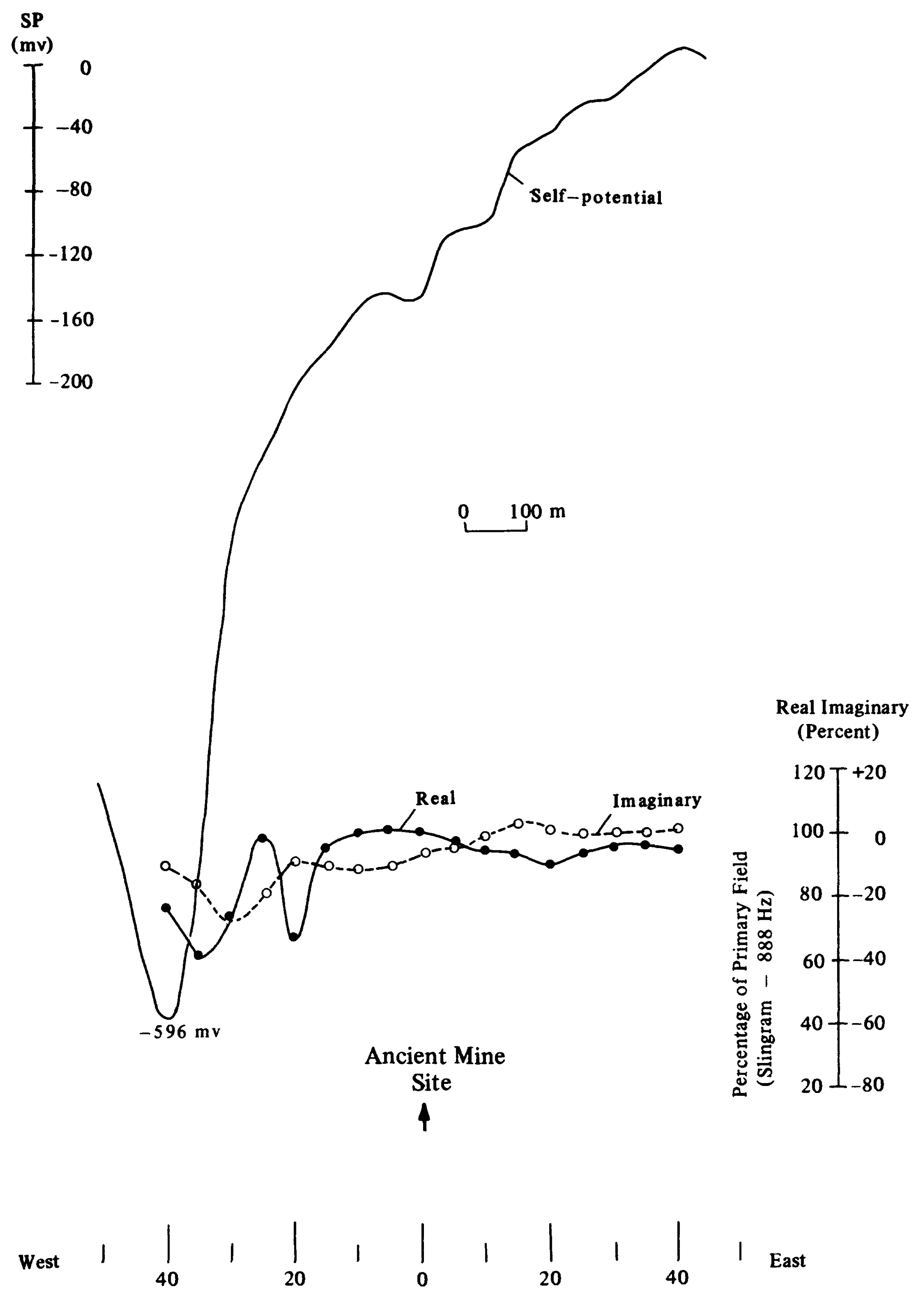

Figure 23.--Self-potential and electromagnetic profiles along line 00 in the B-24 area north (Khayal al Masna'ah)

data display an anomaly of -596 mv 400 m to the west, the magnitude of which excludes sulfides as a source. The EM data show some noise on the west end, uncorrelatable with anything even between phases; this lack of correlation is most probably due to the steep topographic gradient west of the ancient mine and the inability of the slingram operators to correct the coil tilts to the proper angle (>70 percent).

By way of summary, AEM target B-24 appears to be caused by conductive carbonaceous materials, but this interpretation is difficult to prove conclusively. Geochemical sampling should still be done, but only along a few profiles, for instance 150N, 190N, and 250N. It may be sufficient to note that there is no electrical expression at either ancient mine site, one of which has already been evaluated (Alcott, 1969) as sub-economic. No further geophysics is warranted or for that matter is possible, because a large powerline is being installed parallel to the B-24 EM anomaly.

B-35 area

The B-35 area is located about 17 km southeast of Mahawiyah village, in the southeast part of the Wadi Bidah area. The geology of the area is complex; in the broadest sense the main structural elements shift form north-south in the northwest part (called hereafter area A) to roughly east-west in the rest of the target area. Beyond this broad picture, no geology or geochemistry has been done in the area, except in connection with brief visits to several of the SP anomalies. The SP data collected in the B-35 area are shown in figure 24. The geophysical coverage of the B-35 area is reconnaissance in nature; however, figure 24 and following figures do reveal several trends of possible interest. For purposes of documentation, the area is divided into four parts: the northwest part, A; the west-central part, B; the east-central part, C; and the southeast part, D. Part A is difficult to explain. SP anomalies on lines 160N and 200N are intense. Line 180N gives almost no response. This same characteristic is seen in the EM data (figs. 25 and 26). The intense SP response exceeds -300 mv, but a visit to line 160N revealed no graphite (or gossan either). A silicic, gray rock similar in general appearance to those sampled at anomalies in the main B-35 area, turned out to be nonconductive (samples WB-3 to WB-6, table 2) and appears to be similar to carbonaceous schists in areas B-13, B-24, and B-29. We are unable, at the present time, to explain the source of the SP-EM anomalies.

Area B has two anomalous areas (line 90N, station 5W, and line 110N, station 40W) that exceed -300 mv, the former is continuous across four separate profiles. No source could be found on the ground for this latter anomaly, though there are some thin outcrops of very weak gossan that have short strike length. The most likely "graphitic" sample collected here turned out to be nonconductive.

Area C has the most intense and longest SP anomaly, running at least 1.3 km in strike in a northeastern direction. The high point of this anomaly (line 70N, station 75E) is more than -500 mv., and it seems likely that it is not caused by sulfides because of the high amplitude of the SP values. All of these SP anomalies, by the way, are good conductors.

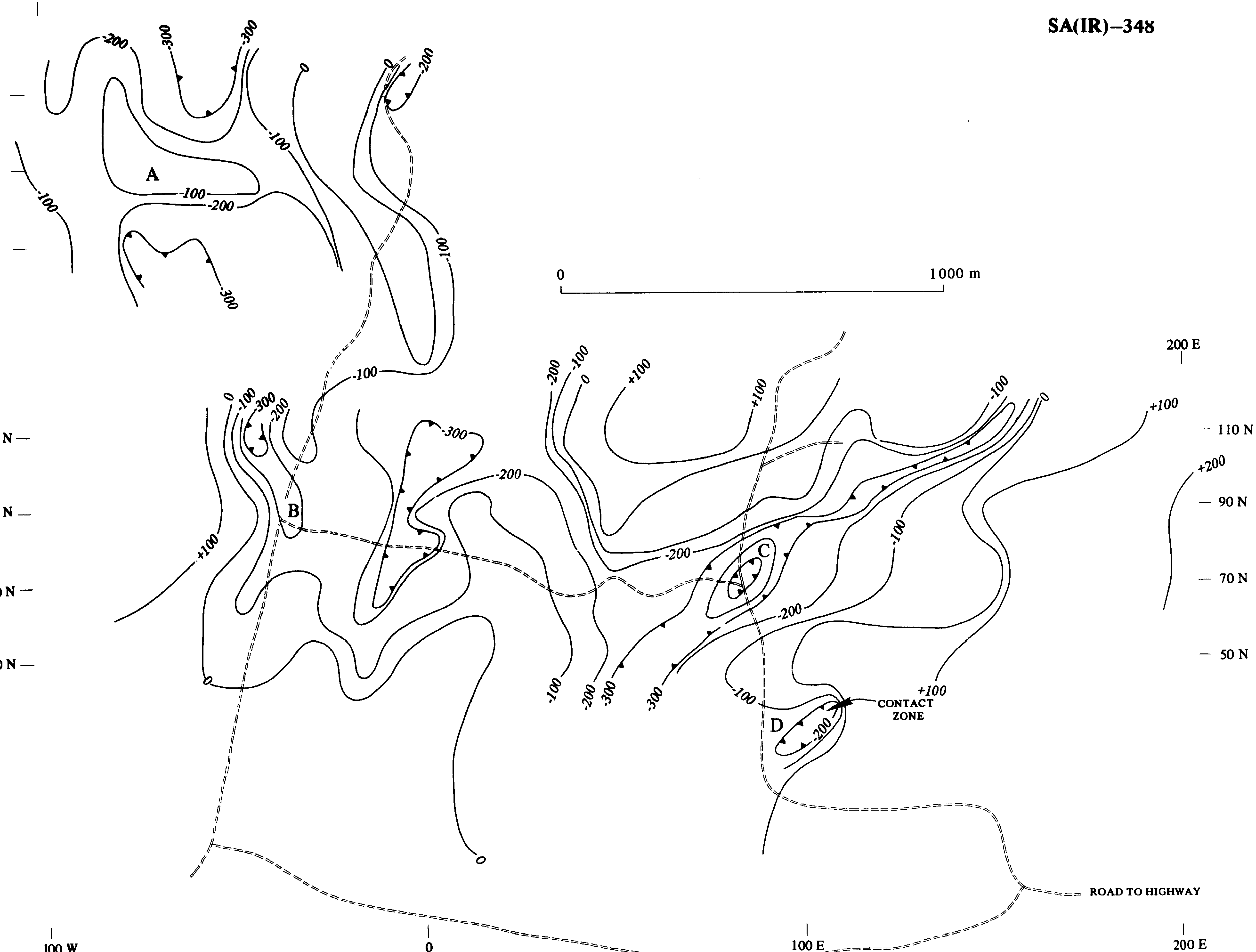

Figure 24.--Self-potential map of the B-35 area.

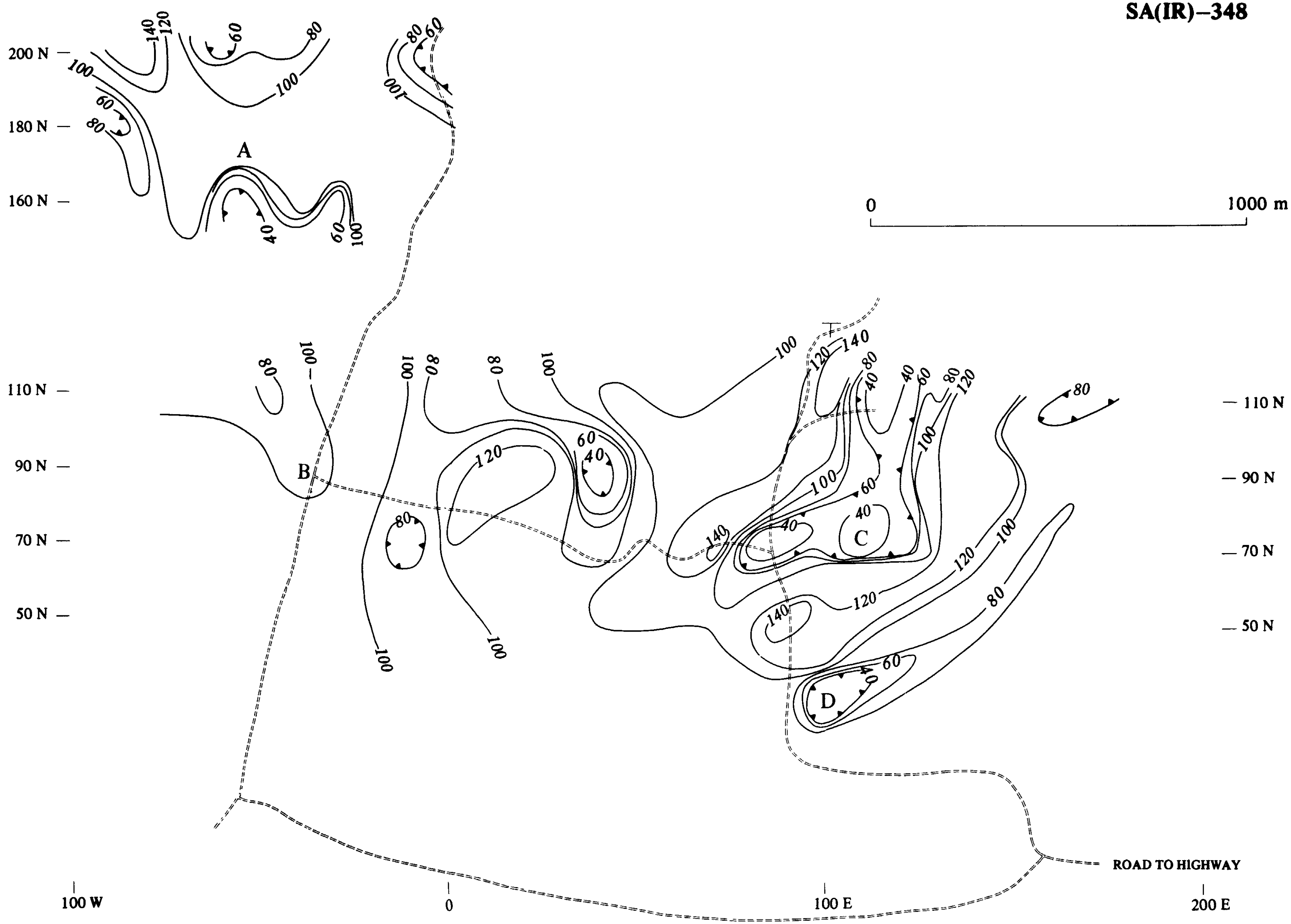

Figure 25.--Real component (in-phase, 888 Hz) electromagnetic map of the B-35 area.

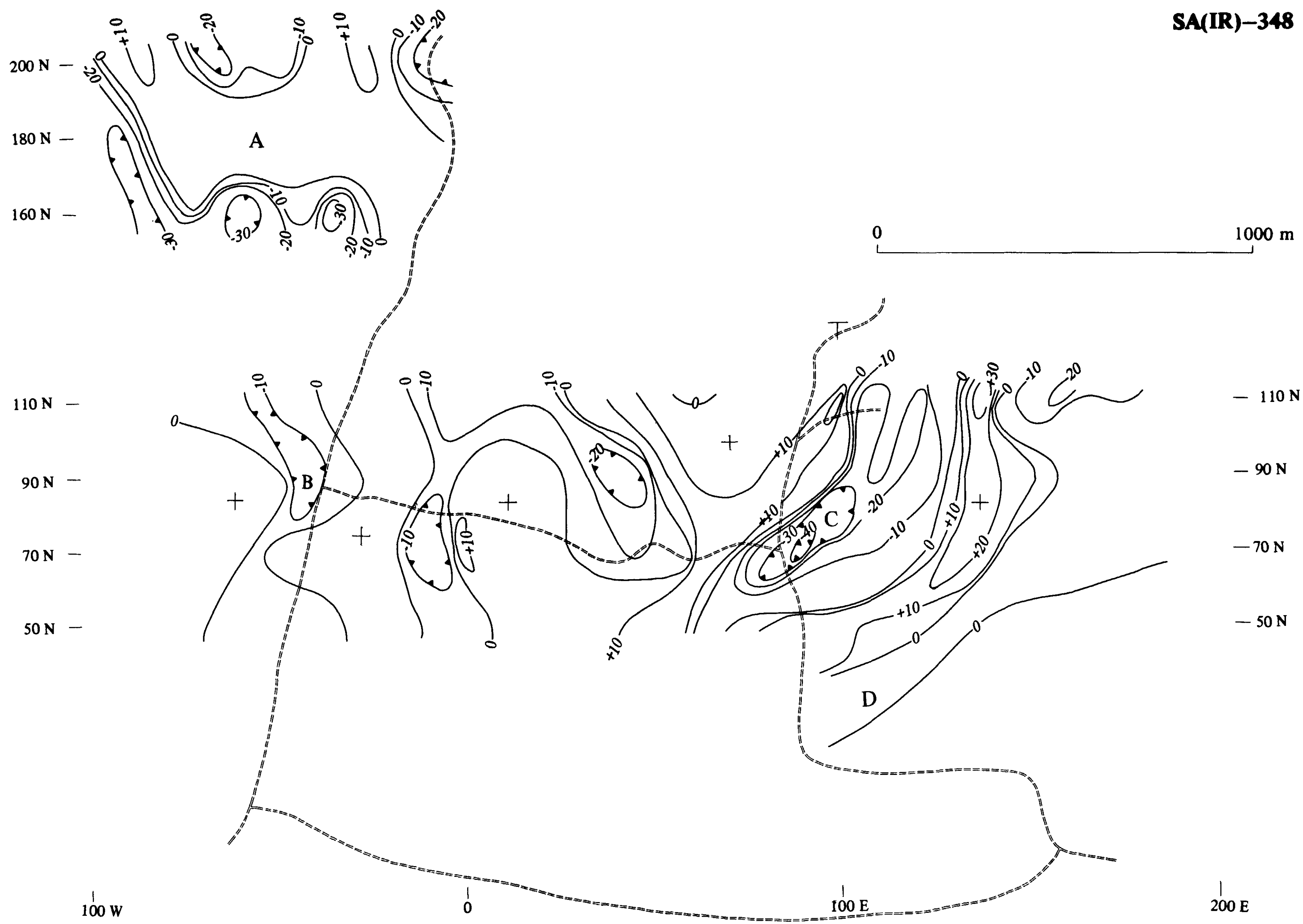

Figure 26.--Imaginary component (out-of-phase, 888 Hz) electromagnetic map of the B-35 area.

Area D has the most promising SP anomaly, and will be discussed later in detail in relation to figure 27. Figures 25 and 26 show the EM real and imaginary component data respectively. These results mirror the SP data almost exactly, except that in area B a barely discernible, right-hand, horseshoe-shaped part of the eastern (more intense) anomaly is the better conductor; it is centered about line 90N at station 40E.

Figure 27 displays the SP, EM, and some geologic information for the for the south end of profile line 100E, covering the anomaly of interest in area D. This anomaly is on line 100E at about stations 25N to 30N. The SP data show a spike of -256 mv, and a narrow conductor less than 10 m wide. The conductor is at least 30m deep, and has a conductance of 25-30 mhos. This anomaly is interesting because it lies on a contact between metabasalts on the north and felsic, silicic schists on the south. A possible "graphite schist" collected near the contact was nonconductive in laboratory tests. The SP readings are very high for a sulfide source, but a drill hole might be warranted at this anomaly if only to test the best but representative SP-EM anomaly in area B-35.

The anomalous area farther north, around station 80N, is part of the anomaly in area C and shows two SP anomalies, the highest of which reaches -285 mv.

By way of summary, from the geophysical point of view the data are insufficient to make a thorough study of area B-35. Geochemical sampling coordinated around the existing geophysical information, if totally negative in results, might justify dropping this target from further consideration, or at least reducing its priority. In the northeastern part of the target area, a substantial ancient gold mine was discovered (called Wadi Hamdan, by Ron Worl, oral commun.) by independent means. A reconnaissance geophysical profile might be worthwhile over this deposit to see if distinctive geophysical signatures will be found.

Al Khadra area

The Wadi al Khadra area is located about 5 km southeast of the B-35 area, and its southern border is about 14 km north of the village of Al Bahah. The area was not included in the original Wadi Bidah AEM survey in order to have rectangular boundaries.

The rocks in the area do contain carbonaceous material, and unweathered sulfide samples were not found; therefore no laboratory conductivity tests were made. The mineralization appears to follow a highly sheared contact zone between diorite (itself sheared and strongly foliated) on the east and agglomerates and silicic volcanic tuffs on the west.

Preliminary geophysical data showed almost negligible EM results, but they did show a substantial and encouraging SP anomaly (fig. 28). This SP anomaly is approximately 1 km in strike length, passing just to the strike length, passing just to the east of the ancient mine. The anomaly exceeds -100 mv in three locations and exceeds -150 mv in two of those, one being in close proximity to the ancient mine. The anomaly trend is roughly N.15°W., beginning at or just south of station 25E, line 00N. An important element of

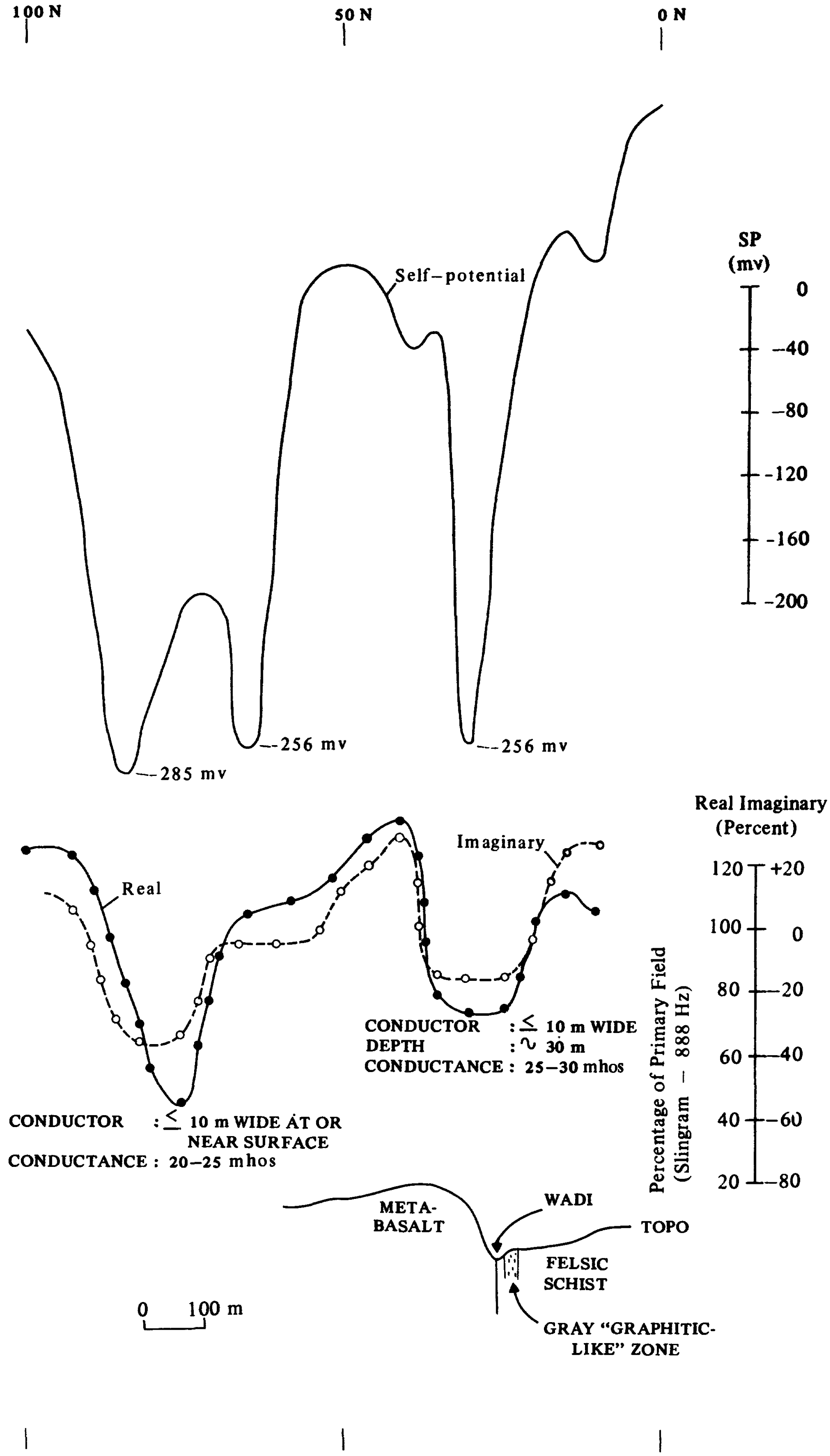

Figure 27.--Self-potential and electromagnetic profiles along line 100E in the B-35 area showing relationship of geophysical data to geology.

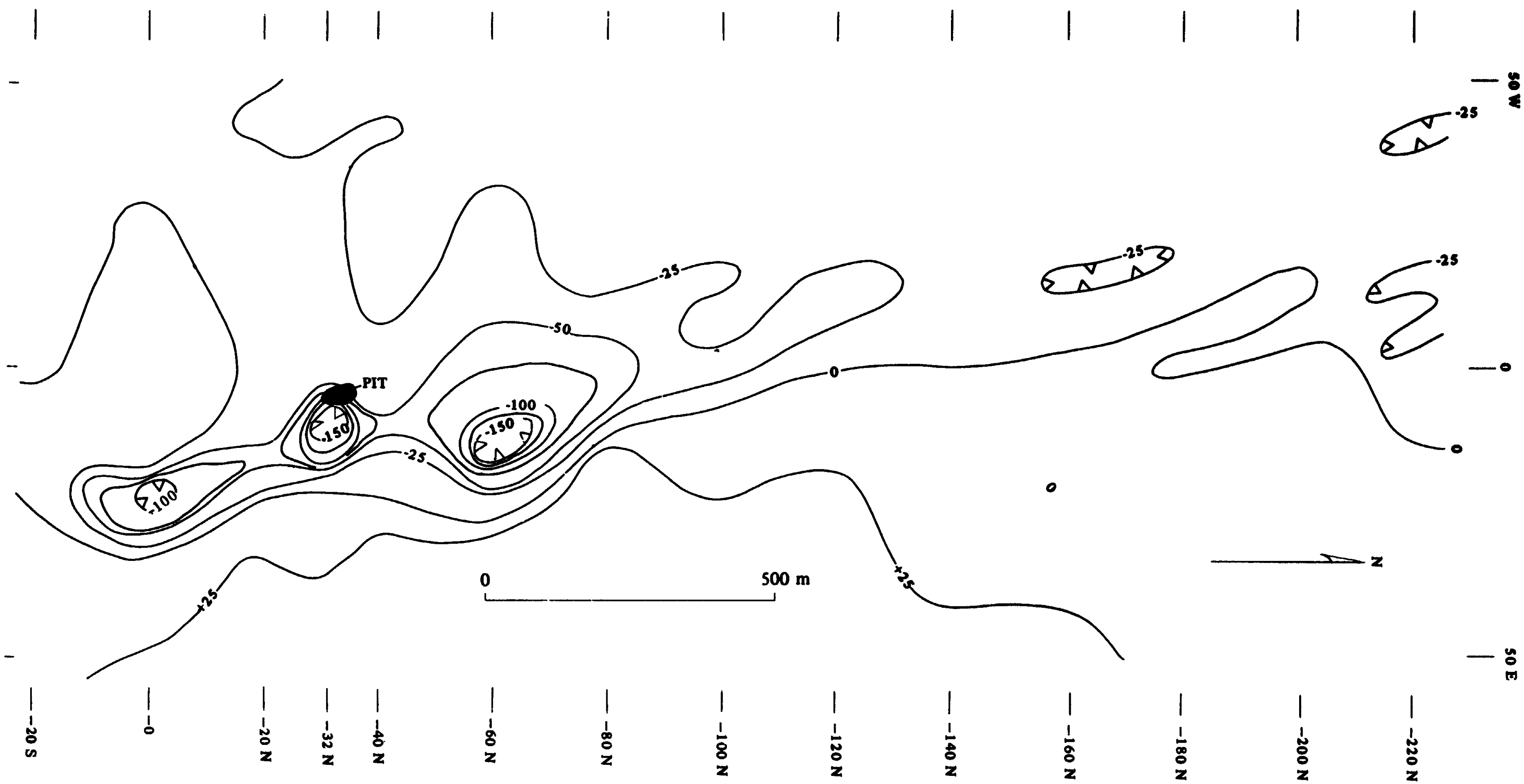

Figure 28.--Self-potential map of the Al Khadra area.

the anomaly is the good response on line 60N, at station 10E. There is a right-lateral offset in the SP source between the ancient mine and line 60N, perhaps with as much as 100 m horizontal displacement that corresponds to offset of the gossan-bearing contact zone. This offset should be considered in subsequent evaluation of the mineralization. North of line 100N, the area is electrically dead.

The magnetic data (fig. 29) are suspect because enormous drifts were encountered during the survey; at least one magnetic storm was recorded at the Riofinex base station in Jiddah during this survey. A magnetite-rich gabbro outcrop seems to be confirmed at line 180N, station 35E. Another possible magnetite-rich locality at station 00, line 00N might also have contributed to the drift in the data because it was used as a reference base station. An apparent gradient lends support to SP data that indicate a possible fault somewhat beyond the north end of the ancient mine (PIT on fig. 29). The main conductor north of line 80N seems to be followed approximately by a weak magnetic high (about 200 gammas).

Figure 30 shows results in a profile across the ancient mine on line 32N. No magnetic data exists for this profile. A -210 mv SP anomaly, coincident with a weak conductor, is just east of the pit. This weak conductor is located at the sheared contact zone described earlier. Its conductance is only about 1 mho, and it is buried 15 to 20 m.

Figure 31 shows a slightly better conductor at the SP anomaly (-200 mv) on line 60N. This conductor, which is coincident with some gossan stringers at the sheared contact-zone, is narrow, perhaps at the most 10 m wide, dips roughly 60° east, and has a conductance of about 35 mhos, which is moderate to good. The reason for the low amplitude EM anomlay is that the top of the conductor is buried 50-60 m deep. This apparent deep conductor is highly encouraging, and, in consideration of the copper stain seen at the ancient mine, might be justification for a drill hole.

In summary, this prospect looks good. The EM data imply that the sulfides may be disseminated in the vicinity of the ancient mine, and dipole-dipole IP profiles along lines 00N, 32N, and 60N should be made to try to characterize the two-dimensional conductor at depth and test for disseminated sulfides. The dipole length on this IP survey should be no more than 100 m at maximum, and no less than 50 m; the latter would optimize horizontal resolution, the former would optimize the depth penetration consistent with acceptable resolution. Geochemical results are encouraging, and if the IP proves interesting, at least two drill holes are necessary to test this target.

CONCLUSIONS AND RESULTS

Target area B-29 (Rabathan) gave highly satisfactory geophysical results, and the known ore resources may be substantially extended if additional drilling confirms that certain geophysical anomalies are caused by the presence of sulfides. The advantages of the systematic geophysical and geochemical investigations in the Rabathan area may have been understated.

Area B-13 was covered on only a reconnaissance basis, but the area is favorably located along geological and geophysical trends from target area B-29. Subsequent geophysics and drilling will depend heavily on the results of the systematic geochemical sampling, because there are many SP-EM anomalies and no conductive rocks found to explain them.

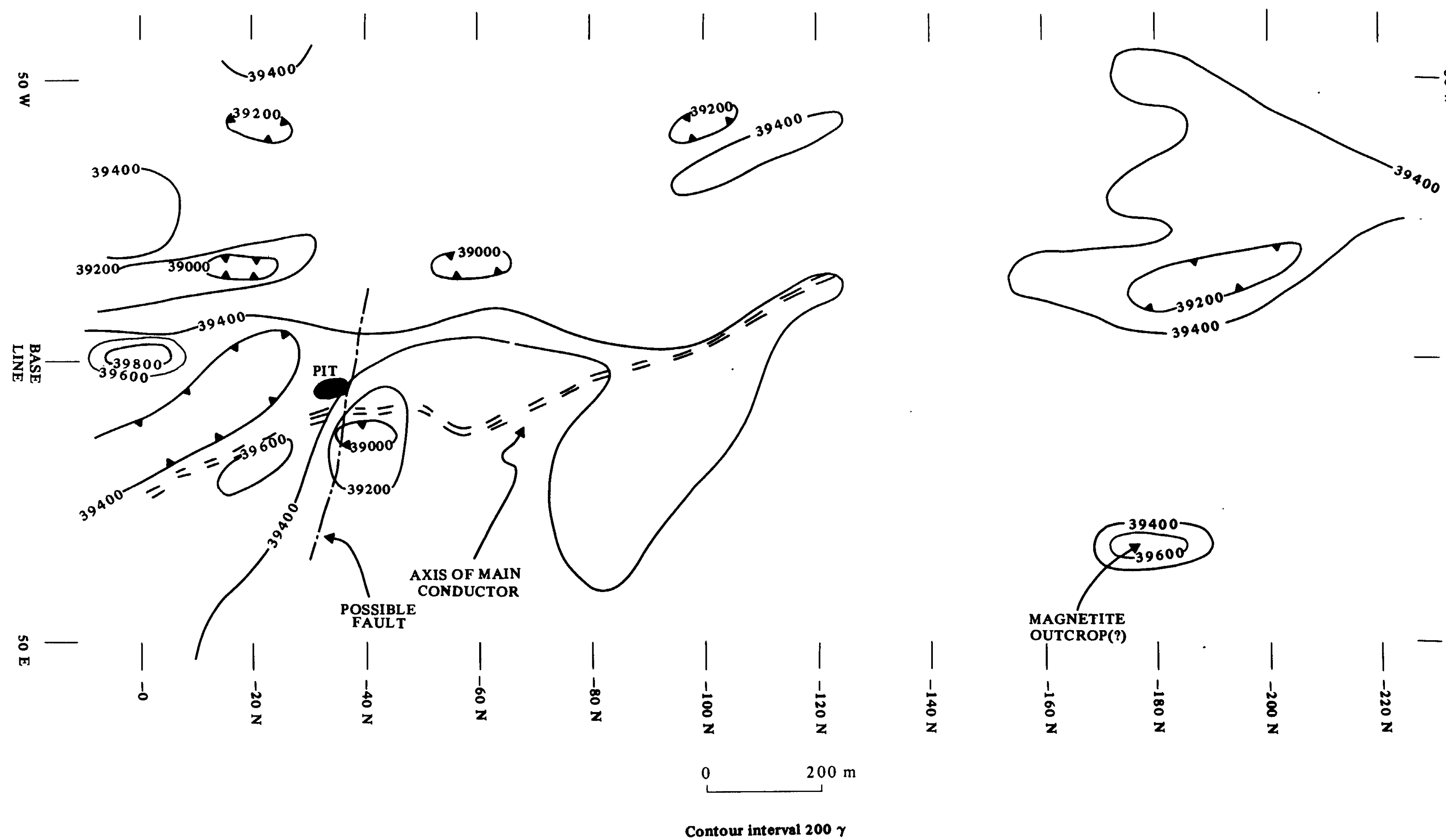

Figure 29.--Electromagnetic map of the Al Khadra area.

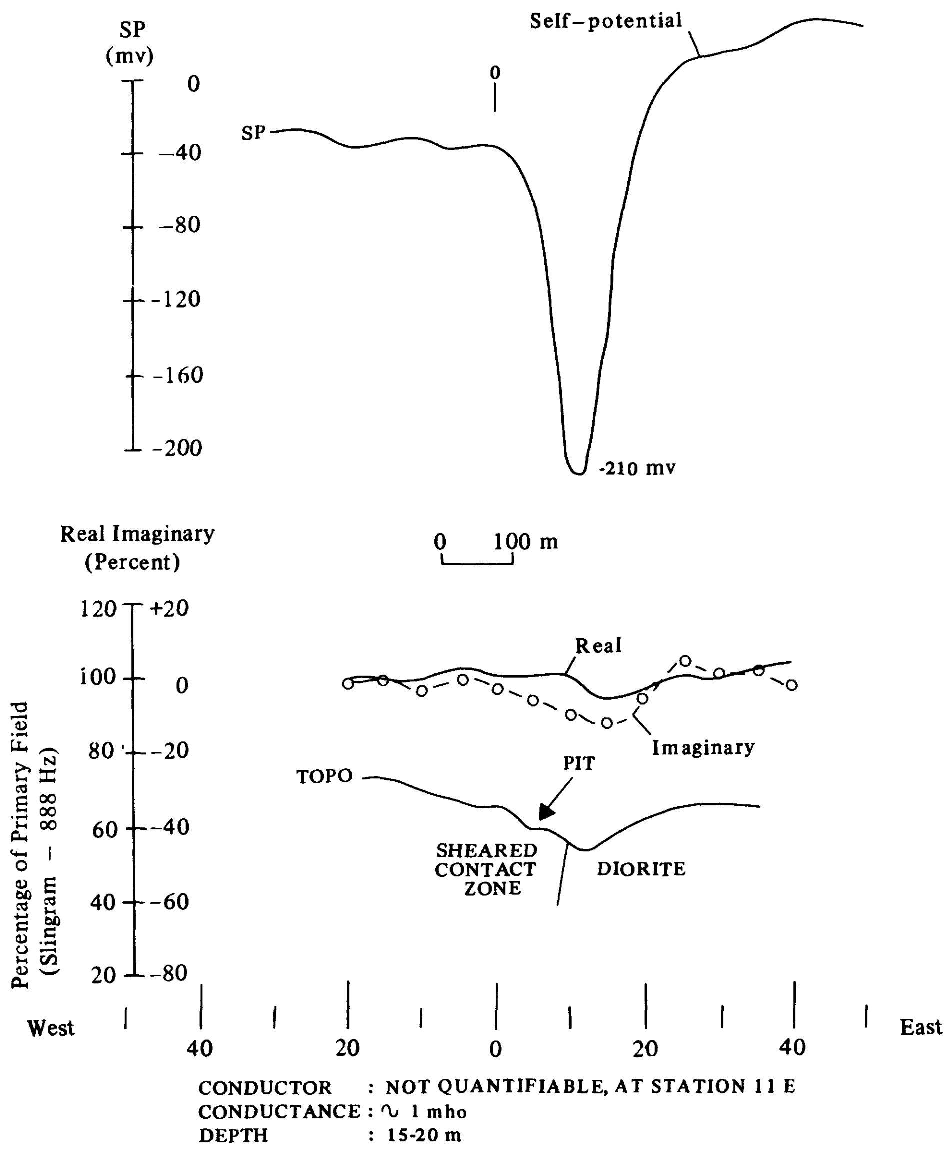

Figure 30.--Self-potential and electromagnetic profiles along line 32N of the Al Khadra area showing relationship of geophysical data to geology.

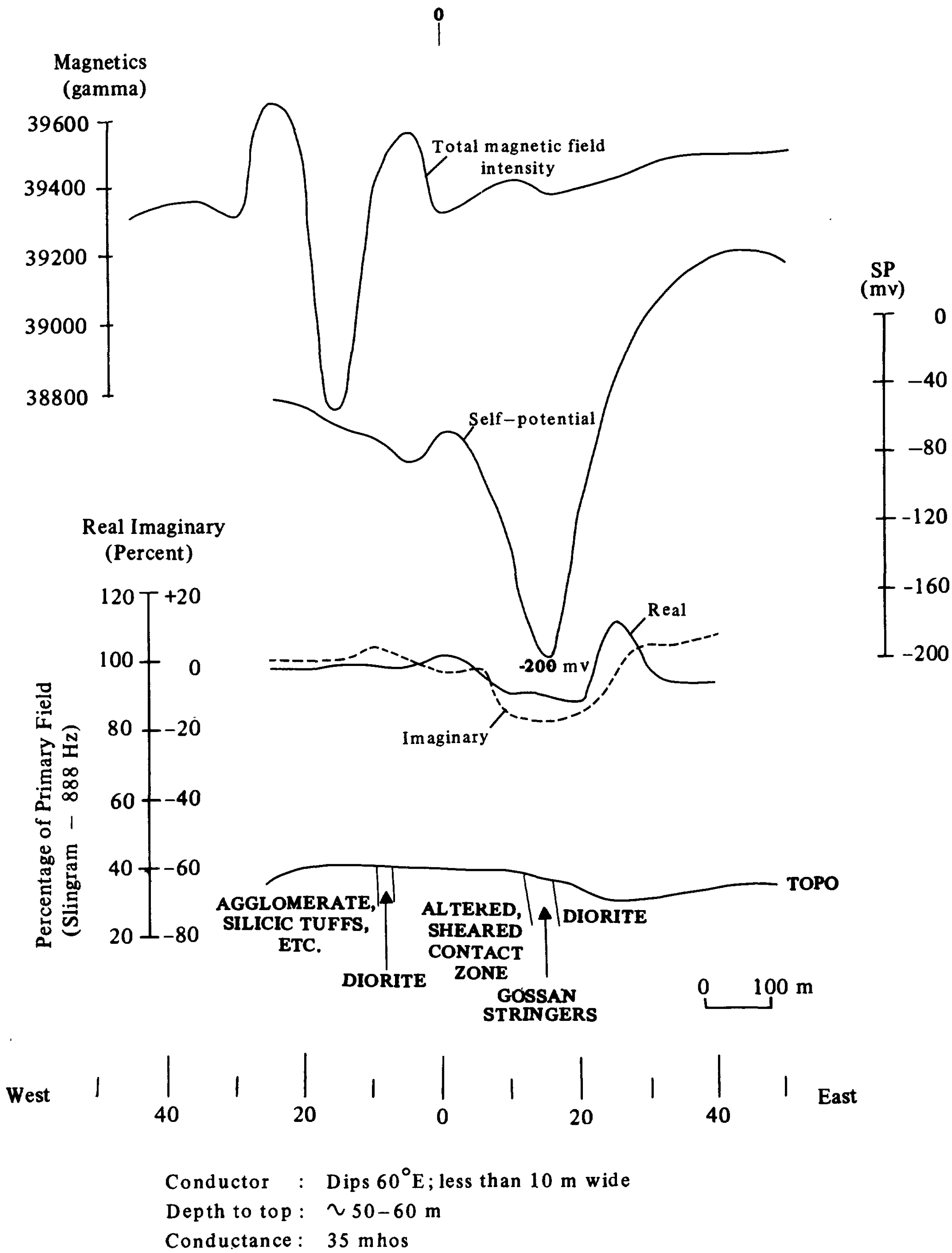

Figure 31.--Self-potential and electromagnetic profiles along line 60N of the Al Khadra area showing relationship of geophysical data to geology.

Areas B-25 and 26 and Al Khadra also are high-potential targets, and we suggest that at least two drill-holes will be needed to check anomalies in each area. Geochemical sampling could miss a mineralized body, and drillholes in each should be considered even in the face of discouraging geochemical results.

Areas B-24 and B-35 are the least encouraging of the area investigated during phase 2, but there is a moderate potential for mineralization in area D of B-35.

RECOMMENDATIONS

An additional field season of work should be carried out to cover targets not yet examined and to follow up geochemical results in targets that have been examined. Fill-in EM and SP might be called for in areas B-13 and B-35. A limited IP survey should probably be considered in the Wadi al Khadra area, and also perhaps on the B-25-26 target, along profile lines already found to be anomalous using SP.

The nature of the conductors at B-13, B-35, and B-24 should be investigated, perhaps by drilling as a last resort. B-35 and B-13, at least, cannot be discounted in the light of the present geophysical data.

AEM anomalies not examined in either Phase 1 or Phase 2 should be examined by reconnaissance EM and SP and geochemical sampling. These anomalies should include: B-31 (good gossan, good amplitude ratio in the AEM data, and on strike with B-29), B-35 A (gossan, good amplitude ratio), B-44 A (gossan, ancient mine), and B-45 (gossan with copper stains). In addition, Class 2 priority targets should be examined by one or two reconnaissance geologic-geophysical profiles (B-15, B-21, B-6, and B-39).

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