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GROUND-FOLLOWUP STUDIES OF THE 1977 AIRBORNE ELECTROMAGNETIC SURVEY IN THE ASSIFAR AND MULHAL AREAS, WADI BIDAH DISTRICT, KINGDOM OF SAUDI ARABIA

by

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CONTENTS

Page

ABSTRACT.. 1

INTRODUCTION...................................... 1

Purpose... 1
Data storage...................................... 2
Location.. 2
Previous investigations........................... 2

PRESENT INVESTIGATIONS............................ 4

Assifar area...................................... 4
Anomaly B-37...................................... 8
Mulhal No. 2...................................... 9

SUMMARY OF GROUND-FOLLOWUP STUDIES................ 10

CONCLUSIONS....................................... 16

REFERENCES CITED.................................. 17

APPENDIX 1. Data profiles from Assifar study area...... 19
2. Data profiles from Mulhal No. 2 study area...... 42

ILLUSTRATIONS

[Plates are in back pocket]

Plate 1. Map showing locations of airborne electromagnetic anomalies detected in the 1977 airborne input survey, Wadi Bidah district

2. Maps showing in-phase and out-of-phase electromagnetic response (888 Hz), self-potential response, and location of interpreted geophysical anomalies in the Assifar area

3. Maps showing in-phase and out-of-phase electromagnetic response (888 Hz) and self-potential response, Mulhal No. 2 area

Figure 1. Index map of western Saudi Arabian showing location of the Wadi Bidah district......... 3

2. Plots of electromagnetic/self-potential and magnetic responses along traverse 215 S, Assifar area.............................. 7

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ABSTRACT

Parts of four airborne electromagnetic (AEM) anomalies were selected for study in order to determine the cause of high conductivity of Precambrian rocks underlying extensive areas in the southern Wadi Bidah district, Kingdom of Saudi Arabia. In the Assifar area, which contains an ancient mine or prospect having the same name, geophysical data suggest that a mineralized body may lie beneath and immediately south of the ancient workings. Many other conductive zones detected during the course of the geophysical survey are thought to be related to metavolcanic rocks containing carbonaceous materials. Detailed geologic mapping, and possibly diamond core drilling, will be necessary to fully evaluate the area.

In the Mulhal No. 2 area, located about 2 km south of the Mulhal ancient mine, geophysical studies suggest that mineralized rocks extend about 500 m along strike beneath outcrops of gossanous material.

A brief review of the AEM ground-followup studies in the Wadi Bidah district suggests that most, if not all, of the AEM conductors are carbonaceous rocks. Secondary causes of conductivity are intense faulting and shearing.

INTRODUCTION

Purpose

This report presents results of part of the geophysical studies conducted during 1979-80 field season in the Wadi Bidah district, Kingdom of Saudi Arabia, including reconnaissance geophysical surveys conducted in the southern part of the district to locate and delineate the geophysical characteristics of anomalies detected by the 1977 airborne electromagnetic (AEM) survey of the district. In addition, results of studies in the Mulhal No. 2 (MODS 02702) area are presented. Results of other geophysical work conducted during the 1979-80 field season have been presented by Flanigan and others (1982).

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

Data storage

Mineral localities referred to in this report are recorded in the Mineral Occurrence Documentation System (MODS) data bank and identified by a unique five-digit sample number. No new MODS entries were made as a result of this study. Inquiries regarding this data bank may be made through the Office of the Technical Advisor, Saudi Arabian Deputy Ministry for Mineral Resources, Jiddah.

No data files were established for this report.

Location

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

Previous investigations

Many scientists have contributed to the present geologic understanding of the Wadi Bidah district through geologic, geochemical, and geophysical studies. Only a few are mentioned in this report; for a more complete list, refer to Kiilsgaard and others (1978), Flanigan and others (1981, 1982) and Smith and others (unpub. data, 1982).

In the middle to late 1960's, Earhart and Mawad (1970) conducted reconnaissance geologic mapping, geochemical sampling, and diamond core drilling at several of the more promising prospects in the district. Their work indicates that although there are several massive sulfide deposits in the district, they are marginal both in grade and tonnage. Subsequent studies by Jackaman (1972), Roberts and others (1975), and Roberts (1976) suggest two possible genetic origins. Earhart and Mawad (1970) and Jackaman (1972) both proposed a volcanogenic origin for the deposits, whereas Roberts and others (1975) and Roberts (1976) suggested a postvolcanic-replacement origin. Kiilsgaard and others (1978) indicated that the massive sulfide deposits may well be volcanogenic in origin and that the rocks have undergone

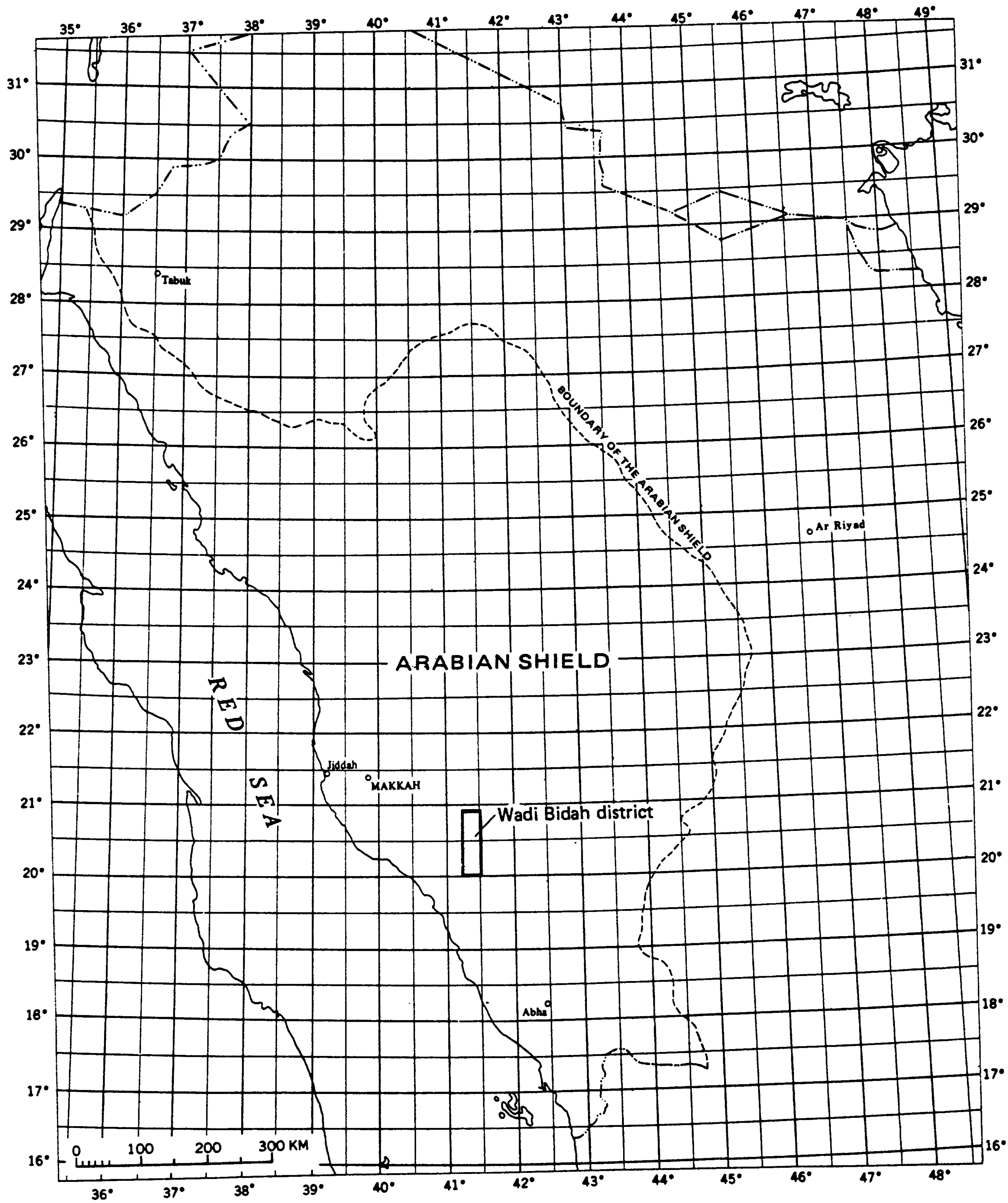

Figure 1.--Index map of western Saudi Arabian showing location of the Wadi Bidah district.

varying amounts of postdepositional remobilization along shear and fracture zones.

Between 1972 and 1976, the work of Earhart and Mawad (1970) was expanded upon when detailed geologic, geochemical, and diamond core drilling studies were made at the Sha'ab at Tare (MODS 00464), Gahab (MODS 00468), and Rabathan (MODS 00463) prospects (Kiilsgaard and others, 1978). In both the earlier and later phases of geologic investigations, a limited amount of geophysical work was done in support of these studies. Most of this work is summarized by Kiilsgaard and others (1978).

In 1977, a districtwide AEM survey was made using a flight-line spacing of about 250 m. This AEM survey delineated more than 50 discrete electromagnetic (EM) conductors ranging from a few hundred meters to more than 20 km in strike length (Wynn and Blank, 1979). In 1978, ground-followup investigations of the sources of the EM anomalies were made in both reconnaissance and detailed modes. Results of these latest studies are reported by Flanigan and others (1981, 1982; 1982), Smith and others (unpub. data, 1982) and Worl and Wynn (unpub. data).

PRESENT INVESTIGATIONS

Assifar area

The Assifar area, so named for the Assifar ancient mine (MODS 01341; Greenwood, 1975), covers parts of AEM anomalies B-42, B-44, B-45 and B-46 (Geoterrex Limited, 1977). The area is located about 30 km northwest of the town of Al Bahah and is accessible by road from the At Taif-Al Bahah highway (plate 1).

The area is underlain by predominantly fine clastic metasedimentary rocks consisting mostly of siltstone, chert, and argillite that grades into both siltstone and chert in some places. Minor amounts of volcanic rock (mostly andesite porphyry flows, dikes, and sills) are also present. Smith and others (unpub. data, 1982) suggested that the structural fabric of the area is complex, such that extensive mapping would be required to understand the local structure and geologic relationships. The most noteworthy structural feature, however, is the pronounced difference between the strike of layered rocks west of the Assifar ancient mine (N. 5° W.) and that of the rocks east of the mine (N. 20° E.).

Twenty reconnaissance traverse lines were made across the area to establish ground control for geophysical, geologic, and geochemical studies (plate 2). Slingram-electromagnetic (EM) and self-potential (SP) measurements were made by the Arabian Geophysical and Surveying Company (ARGAS) under contract to the USGS through the Directorate General of Mineral Resources (DGMR). In addition, magnetic measurements were made over the area by Mohamed Nur Jama (USGS). The geophysical data from these surveys are included in this report as appendix 1.

EM and SP data were compiled in contour maps and are shown on plate 2, along with a comprehensive interpretive map showing the location and apparent width of the rock unit containing the source of the EM and SP response. Local magnetic anomalies interpreted as indicating near-surface concentrations of magnetic minerals are shown on the interpretive map as arrows. Local geology, as mapped by Smith and others (unpub. data, 1982) forms the base for the interpretive geophysical map.

The interpreted location and width of the EM conductor is based on one-half the coil spacing (50 m) from each side (zero or inflection point) of the EM response. Where the individual conductor could not be resolved, the zone containing the multiple conductors is shown. The location and width of the SP response are based on the width of the half-amplitude of the SP response. As is the case for the EM interpretation, if multiple SP sources combine to give a complex response, the entire zone is indicated on the interpretive map.

Several EM-SP anomalies were detected along each traverse. Most of the anomalies are complex; that is, the responses indicate interaction between two or more conductive sources spatially located such that their individual responses cannot be resolved at the 200-m coil separation used for the slingram-EM survey. Semiquantitative estimates of conductance and depth to the conductor are not considered valid in areas that produce such complex responses, and, in many cases, estimates of conductor width and location are only approximate. However, because the SP data indicate a broad SP response having several peaks or minima located over the source rocks, it is possible to partially resolve the EM data, at least qualitatively, by using the SP minima as the location for the source rocks.

The amplitudes of the SP anomalies range from -200 to -450 mV, the highest values occurring over rocks that almost certainly contain a large percentage of carbonaceous material. Given the apparent complex structure of the host rocks, most of the SP anomalies are coincident with an EM conductor, except in a few cases that will be discussed later.

From the Assifar ancient mine eastward (between traverses 215 S and 5 S), most of the geophysical anomalies lie along the crest of a east-trending anticline (plate 2). On the northern limb of the anticline, the EM anomalies in particular follow a northeast-trending dikelike outcrop of cherty manganese-iron oxide metasedimentary rocks. A similar lens of metasedimentary rocks on the southernmost limb of the anticline has no geophysical anomalies associated with it. According to Smith and others (unpub. data, 1982) both exposures of the cherty manganese-iron oxide lens are of the same formation, and, although moderately high copper values are associated in places with the northern exposure, no significant gossans are exposed. Two small gossans are associated with the formation at the southern exposure. Although it appears that the cherty manganese-iron oxide formation is the source of the observed geophysical anomalies, it is not known why the formation produces strong EM-SP responses in some places and little or no response in others. Several possibilities are suggested below.

From traverse 50 S to 100 S (500-m strike length) and northwest of the base line, strong complex EM-SP responses are observed. A second area of high EM-SP response is between traverses 135 S and 215 S (800-m strike length). Both of these zones of high EM-SP response are just south of a major fault zone. The conductive zones may represent areas of concentrated shearing along the fault zone, areas of remobilized mineral concentration along the more highly sheared parts of the fault zone, or the response of carbonaceous rocks lying beneath the manganese-iron oxide formation. A similar manganese-iron oxide zone in the Rabathan area having high EM-SP responses was tested by diamond core drilling (RAB-2), and carbonaceous schist was found to be the source of the anomalies (Flanigan and others, 1982). However, a drill hole (R-3) located several hundred meters to the south tested the same zone and intersected a small massive sulfide body (Earhart and Mawad, 1970).

Traverse 215 S crosses the area of the ancient Assifar mine (fig. 2). Based on the in-phase response along the traverse, three zones of high conductivity can be delineated. The zones are each as wide as 100 m and are centered 100 m west, 275 m east, and 600 m east of the base line. Because the last zone is not completely traced out, its location is not shown on figure 2. The EM anomaly located 100 m west of the base line has an associated SP response of about -200 mV. A second SP anomaly (25 m east of base line) is thought to be associated with the ancient mine workings; no EM conductor is associated with this SP response. There is a good possibility that a mineralized body lies at depth in the area of this SP anomaly. A third SP anomaly is 150 m east of the base line at station 275 E and is offset northwest from the associated EM anomaly. It seems likely that both the SP and EM responses are related to the same geologic source, but only very tentative relationships can be surmised because of limited knowledge of the local geologic and structural control. A fourth SP anomaly of about -100 mV is near the end of traverse 215 S at station 600 E. Again, the fact that the

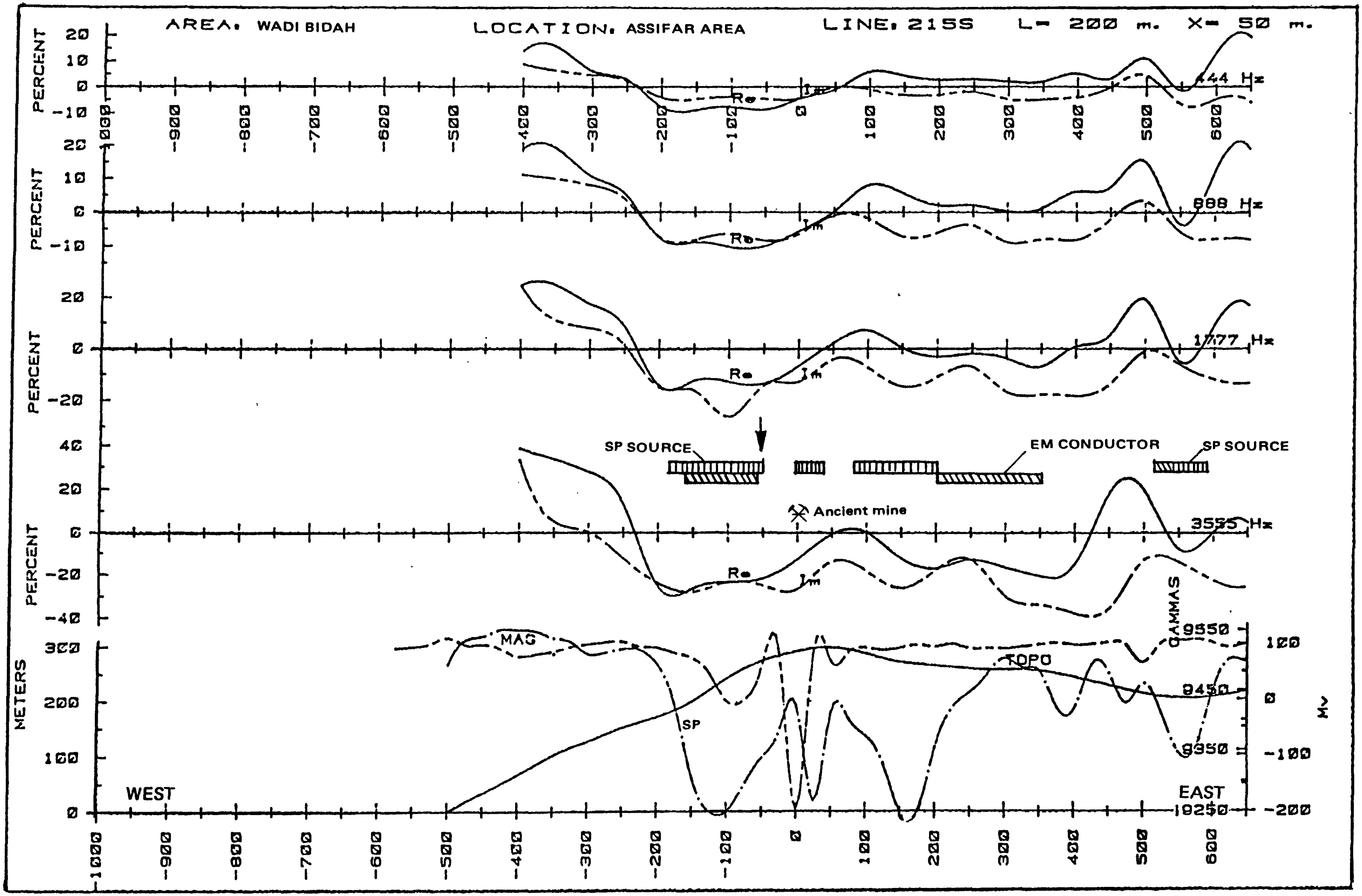

Figure 2.--Plots of electromagnetic/self-potential responses along traverse 215 S, Assifar area. Re, real or in-phase EM response; Im, imaginary or out-of-phase electromagnetic response. The downward-pointing arrow indicates the interpreted location of a local magnetic anomaly. For detailed explanation, see appendix 1.

SP response is offset northwest of the associated EM conductor indicates either a very complex geologic and structural environment or separate geologic sources for the two responses.

In the area west of the Assifar ancient mine (AEM anomaly B-42), three or more EM anomalies were detected on each traverse by the ground survey. Because many of the EM conductors are less than 200 m apart, they form complex anomaly patterns and the interpreted position and apparent width of the source conductors are at best only approximate. Although some of the more isolated conductors may be traced from traverse line to traverse line, on the basis of their characteristics it is nearly impossible to trace many of the anomalies with a reasonable degree of certainty. Nearly all of the EM anomalies are in areas of metasedimentary rock, predominantly chert and grading into argillite. Associated SP anomalies range from -200 to -400 mV. Although it is difficult to recognize carbon in hand samples, the amplitude of the SP response suggests that carbon composes a high percentage of the cherty metasedimentary rocks in the conductive zones below the weathered layer. The EM-SP anomalies may correlate at least in part with manganese-iron oxide zones, as seen on traverses 10 N, 40 N, 95 N, 115 N, and 135 N; however, as in the eastern half of the Assifar area, no major gossans are associated with this unit and copper and precious metal values are low (Smith and others, (unpub. data, 1982)

Results of the geochemical and geological observations suggest a very complex environment almost certainly involving carbonaceous rocks, and there is no strong evidence to suggest that any of the EM conductors are associated with sulfide-mineralized rocks in the western part of the Assifar area.

Anomaly B-37

AEM anomaly B-37 located north of the Assifar area was visited in a brief geologic reconnaissance (plate 1). Rocks in the area are mostly fine grained, bedded metasedimentary clastic rocks and calcareous mudstones. Black shales ranging to carbonaceous shales underlie much of the area. In most places, carbonaceous rocks form wadi bottoms and are the loci of shear zones. Some evidence of mineralization is indicated by malachite staining and at least one ancient prospect pit. Two north-northwest-trending geophysical traverses were made at the northern and southern ends of AEM anomaly B-37. The data produced (not included in this report) are of little value in locating the AEM anomaly for two reasons: first, the profiles are parallel with the strike of the AEM anomaly and do not appear to have crossed it and, second, the data were collected in an area crossed by recently constructed power lines and hence show only power-line response. Because of the negative geochemical results, further geophysical work was abandoned.

Mulhal No. 2

Mulhal No. 2, named by Smith and others (unpub. data, 1982) lies about 2.5 km north of Bilajimah (AEM anomalies B-25 and B-26; plate 1). No airborne electromagnetic anomaly was detected over the area probably because the survey aircraft was too high above the ground to record a response. A gossan crops out intermittently in an area more than 375 m long; host rocks are mostly quartz crystal pumice tuff interlayered with thin andesite beds. A syntectonic felsic intrusion lies about 1 km west of the gossan, and in the gossan zone aplite dikes extend outward from the intrusion.

Five geophysical traverses, each 500 m in length, were made across the gossan outcrop area. The geophysical data profile plots are included in this report as appendix 2. Anomalous SP values form a pattern that closely follows gossan outcrops over a length of at least 500 m along strike (plate 3). The amplitude of the SP response is less than -100 mV, a value which almost certainly precludes the presence of carbonaceous rocks as the source of the anomaly. As seen in profile form (appendix 2), the anomalous SP zone forms a broad response, several hundred meters long, coupled with several discrete minima; this pattern suggests multiple source zones, as would be expected over a shallow, vein-type mineral deposit.

The EM data (plate 3) reflect a multiple source response similar to that of the SP data. The interpreted widths of the conductors suggest the primary conductive zone is between 75 and 100 m wide and dips steeply to the east. Depth to the top of the EM conductor is estimated to be 20 m. The EM data profile (appendix 2) indicates a moderate in-phase (real) and out-of-phase (imaginary) EM response over the gossan outcrop area and suggests that a moderate to good conductor lies beneath the gossan.

The geophysical response of the Mulhal No. 2 area is quite similar to that recorded over the Sha'ab at Tare prospect (plate 1), which is considered to be a low-grade massive sulfide deposit (Kiilsgaard and others, 1978). It seems very likely that further exploration in the Mulhal No. 2 prospect area would confirm the interpreted presence of a massive sulfide body at depth. Inasmuch as all of the known deposits of copper in the Wadi Bidah district are of low grade and limited in size, it seems most likely that such a body would be similar in size and grade.

SUMMARY OF GROUND-FOLLOWUP STUDIES

The ground-followup studies of the 1977 AEM survey of the Wadi Bidah district included three phases: 1977-8 (phase 1 studies), 1978-9 (phase 2), and 1979-80 (phase 3). Classification of the 51 AEM anomalies was based partly on the pre-survey knowledge of the mineral potential of the source areas and partly on how readily apparent the source of the AEM anomaly was (Flanigan and others, 1981, 1982). In general, the ground-followup studies included a brief geologic examination of the source area by a geologist-geophysicist team and limited geochemical sampling in at least those anomalous areas for which the source rock was not readily apparent. Based on these reconnaissance studies, the work was expanded in areas believed to have fair mineral potential to include reconnaissance geophysical traverses, which would accurately locate the anomalous AEM zones on the ground, to be followed by a somewhat closer examination by the exploration team. In two areas considered to have a somewhat greater mineral potential, detailed, geologic, geochemical, and geophysical studies were made, followed in two of the areas by diamond-core drilling and reexamination by the exploration team.

The following listing of the AEM anomalies, including some pertinent facts about each, summarizes the ground-followup studies of the 1977 AEM survey in the Wadi Bidah district (plate 1).

AEM anomaly B-1

This anomaly represents a conductive zone probably related to the contrast in conductivity between a major fault zone and surrounding country rocks. No gossan development or other signs of mineralized rocks were observed (ARGAS, 1978; Flanigan and others, 1981, 1982).

AEM anomaly B-2

Reconnaissance geophysical surveys located an EM conductor, but no further followup studies, such as geologic mapping or geochemical sampling, were made. The zone contains the ancient mine of Mulgatah (MODS 00467); see previous reports on the area by Earhart and Mawad (1970) and Kiilsgaard and others (1978). Phase 1 ground-followup studies were discussed by ARGAS (1978) and Flanigan and others (1981, 1982).

AEM anomaly B-3

A long linear anomaly on the eastern side of Wadi Bidah is partly covered in the north by a thin layer of volcanic flow rocks. The zone is formational, following quite closely the meandering channel of Wadi Bidah, and most probably reflects conductive sediments in the wadi itself or possibly high conductivity along a major fault zone thought to control the location of the wadi. The anomaly area is believed to have little or no mineral potential.

AEM anomaly B-4

This westward extension of anomaly B-3 is most likely related to the same source rocks, and it is thought to have little mineral potential.

AEM anomaly B-6

The anomaly lies within a north-trending zone, 1 to 2 m long, of quartz-sericite schist; a small gossan, from 4 to 5 m wide and about 100 m long, was found in the zone. The area is accessible by helicopter only. Geochemical sampling results, the limited gossan exposure, and difficult access discouraged further work at this site. Although the gossan outcrop is small, mineralization at depth cannot be ruled out.

AEM anomalies B-7 and B-8

Two reconnaissance geophysical traverses were made at each of these anomalies (ARGAS, 1978; Flanigan and others, 1981, 1982). Both anomalies are on strike with anomaly B-1 and probably reflect the same shear or fault zone. Geochemical sampling produced negative results.

AEM anomaly B-9

This anomalous area is associated with Gahab prospect (MODS 00468). No further work was done as part of this study; see Kiilsgaard and others (1978) for a discussion of this prospect.

AEM anomaly B-10

This anomaly is thought to be related to the same major fault zone as anomalies B-1, B-7, and B-8.

AEM anomaly B-11 and B-18

Two geophysical profiles were made that cross both anomalies (Flanigan and others, 1981, 1982). No geochemical samples were taken, mineralized rocks are not evident on the surface, and no gossans are present in the area.

AEM anomaly B-12

This anomaly is thought to be formational and is most probably related to carbonaceous rocks similar to those in the anomaly B-13 area (see below).

AEM anomaly B-13

This anomaly is formational and extends at least 20 km in strike length. The conductive zone is composed of at least three individual conductors. The area has been studied in some detail and was discussed by Smith and others (unpub. data, 1982) and Flanigan and others (1982).

AEM anomaly B-14

This anomaly was visited briefly by an exploration team; carbonaceous schist is thought to be the source of the EM conductors. Geochemical sampling produced negative results, and no further work is thought worthwhile.

AEM anomaly B-15

A geologic examination within the anomalous area indicated a zone of highly altered schist from 5 to 10 m wide; some siliceous gossanous material with abundant limonite is present for a strike length of more than 100 m. Geochemical sampling indicated negative results, and no further work is thought worthwhile.

AEM anomaly B-16

This area contains highly weathered, dark-gray schist having much the same appearance as rocks seen in the B-14 area. Carbonaceous schists are the most probable source of the EM conductor. Geochemical results were negative.

AEM anomaly B-17

A brief geologic visit revealed no obvious reason for this anomaly. A zone of altered schist, about 40-50 m wide, with abundant limonite might be the possible source. No visible signs of mineralized rocks were seen, and the geochemical sampling results were negative; therefore, no further work is thought worthwhile.

AEM anomaly B-18

See discussion of anomalies B-11 and B-18.

AEM anomaly B-19

This anomaly is associated with the Sha'ab at Tare prospect. Previous work at this site was described by Earhart and Mawad (1970) and Kiilsgaard and others (1978).

AEM anomaly B-20

Anomaly B-20 is many tens of kilometers in strike length and is on the western edge of the Wadi Bidah AEM survey. It is thought to be formational, but no geologic reconnaissance was made in the area during these investigations.

AEM anomaly B-21

A brief geologic visit revealed a 100-m-wide zone of dark-gray to black carbonaceous schist, thought to be the source of the anomaly.

AEM anomaly B-22

The rocks in the area are predominantly metasedimentary rocks of volcanic origin(?); geochemical sampling produced negative results. Carbonaceous rocks are the most probable source of the EM conductors.

AEM anomaly B-23

Dark-green chlorite schist forms resistant ridges in the center of the anomalous area, and there is no apparent reason for the anomaly. Ground-geophysical methods are needed to determine the exact location of the AEM anomaly, but because little evidence of surface mineralization was seen and no anomalous metallic minerals were found by geochemical sampling, no further work at the site is thought worthwhile.

AEM anomaly B-24

Carbonaceous schist is thought to be the major source of anomaly B-24. Previous work in the southern end of the anomaly was discussed by Allcott (1970) and Flanigan and others (1982).

AEM anomalies B-25 and B-26

Studies of these anomalies included reconnaissance and detailed mapping, geochemical sampling, and geophysical surveying, accompanied by two drill holes. The results were discussed by Flanigan and others (1981, 1982) and Smith and others (unpub. data, 1982).

AEM anomaly B-27

This anomaly was not investigated. An ARGAS report (1980) indicated a series of reconnaissance traverses over AEM anomaly B-27; these were, in fact, made over the Mulhal No. 2 prospect discussed earlier in this report.

AEM anomaly B-28

The B-28 anomaly is a single-line AEM anomaly at the southern end of anomaly B-13. It has not been located using ground-EM methods. Its close proximity to anomaly B-13 suggests that it may be related to carbonaceous rock, but this relationship is not known for certain.

AEM anomaly B-29

Results of geologic, geochemical, and geophysical studies and diamond drilling were discussed by Flanigan and others (1981, 1982) and Smith and others (unpub. data, 1982).

AEM anomaly B-30

In a visit to the area, the exploration team found dark-gray schist that is very likely carbonaceous in content. Because no evidence of mineralization was seen and the geochemical sample results were negative, no further work is thought worthwhile.

AEM anomaly B-31

Anomaly B-31 lies along strike to the south of anomaly B-29 and is most likely related to shear zones and carbonaceous rocks similar to those at anomaly B-29. No work was undertaken in the ground-followup program because it was not expected to yield positive results.

AEM anomaly B-32

A brief geologic visit indicated that the rocks in the area are mostly dark gray to green chloritic schist. The most likely source of the anomaly is carbonaceous-bearing schist. The geochemical samples yielded no anomalous metallic values, and no further work is thought worthwhile in the area.

AEM anomaly B-33

A geologic reconnaissance of this weak airborne EM anomaly revealed no obvious source for the anomaly. The geochemical sampling produced no anomalous metallic values, and no other work is thought worthwhile in the area.

AEM anomalies B-34, B-35 and B-35A

Reconnaissance geophysical traverses located airborne EM anomalies, and detailed mapping by Kiilsgaard and others (1981, 1982) revealed that carbonaceous rocks correlate with conductive zones delineated by the geophysical methods.

AEM anomaly B-36

Anomaly B-36 was not investigated but perhaps should be included in future exploration of the area, especially if a relationship is found between AEM anomalies and nearby mineralization.

AEM anomaly B-37

Reconnaissance geophysics surveys were not successful in delineating the airborne anomaly, as discussed in this report.

AEM anomaly B-38

This anomaly is very near anomaly B-37 and may well be part of the same conductive zone as B-37. However, few indications of mineralized rocks were seen and the geochemical sampling results were not encouraging; therefore, no further work is recommended in this area.

AEM anomaly B-39

A geologic traverse in the B-39 area suggests that dark-gray fine-grained metavolcanic rocks predominate. A zone of highly altered schist, 50 to 70 m wide, crosses the area and marks the loci of a major fault zone. No gossans or other surface indications of mineralized rocks were observed. Geochemical analysis of selected samples from the area produced negative results; no further work is thought worthwhile.

AEM anomaly B-40

Dark-gray quartz-sericite schist, which may contain significant amounts of carbonaceous material, is the most probable source of the EM anomaly. Geochemical results were negative, and no further work is planned.

AEM anomaly B-41

Anomaly B-41 was not visited; it is on strike with anomaly B-42 and is most likely also related to carbonaceous rocks.

AEM anomalies B-42, B-44 and B-45

Results of geologic, geochemical, and geophysical investigations in the northern parts of these anomalies were discussed earlier in this report.

AEM anomalies B-43, B-46 to B-51

These anomalies are thought to be related to formational and cultural sources rather than to mineralized zones; however, no work has been done to confirm this assumption.

CONCLUSIONS

Detailed geologic, geochemical, and geophysical studies in the Assifar area indicate moderate to low potential for economic mineralization. Self-potential values, coupled with moderate metallic contents of geochemical samples, suggest a possible mineralized zone beneath and immediately to the south of the Assifar ancient mine. Electromagnetic and self-potential anomalies detected with ground-geophysical methods are spatially associated with manganese-iron oxide-bearing metasedimentary rocks that may be the source of the geophysical anomalies. However, it seems much more likely that carbonaceous rocks not recognized at the surface are the source of the conductive zones producing the anomalies.

Geophysical data in the Mulhal No. 2 area are spatially associated with gossan outcrops and moderate geochemical copper contents and suggest the possibility of mineralized rocks at depth over a strike length of 500 m. An exploratory drill hole is necessary to ascertain this assumption.

By far the highest percentage of the 51 airborne electromagnetic anomalies detected during the 1977 AEM survey in the Wadi Bidah district are caused by a very high content of carbonaceous material in some lithologic units.

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Appendix 1.--*Data profiles from Assifar study area*

Explanation

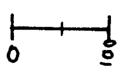
L = 200 m. — Slingram coil separation, in meters

x = 50 m. — Slingram measurement interval, in meters

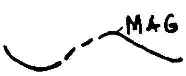
Real or in-phase electromagnetic (EM) response, in percent of the primary field

Imaginary or out-of-phase EM response, in percent of the primary field

444 Hz — Frequency of measured EM response



Slingram traverse showing station locations in meters



Total-intensity magnetic response, in gammas

Self-potential (SP) response, in millivolts, measured in reference to a single fixed electrode

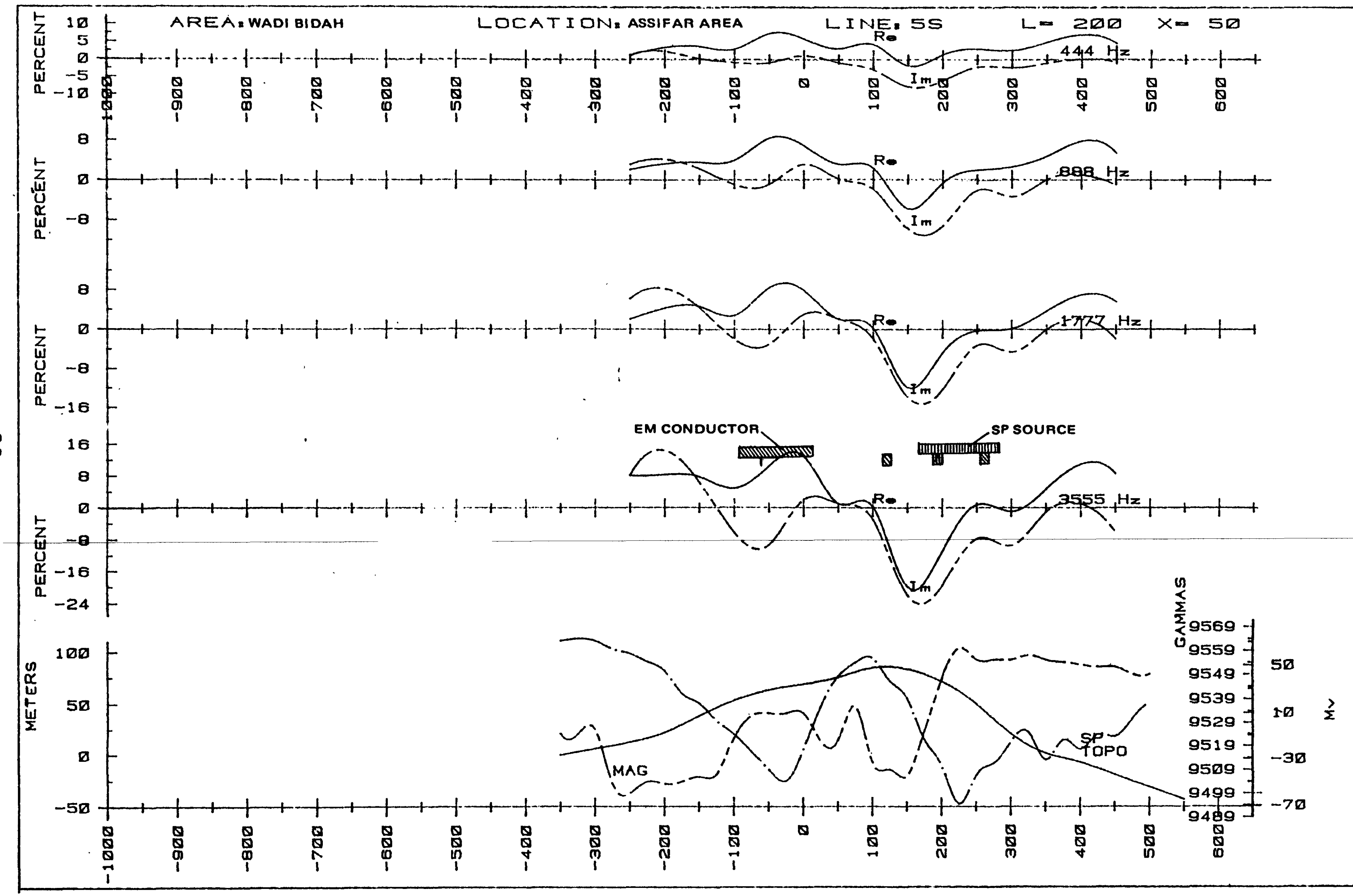
Altitude along geophysical traverse, in meters, measured from an arbitrary base elevation

Interpreted EM conductor, showing approximate location and width of anomalous zone

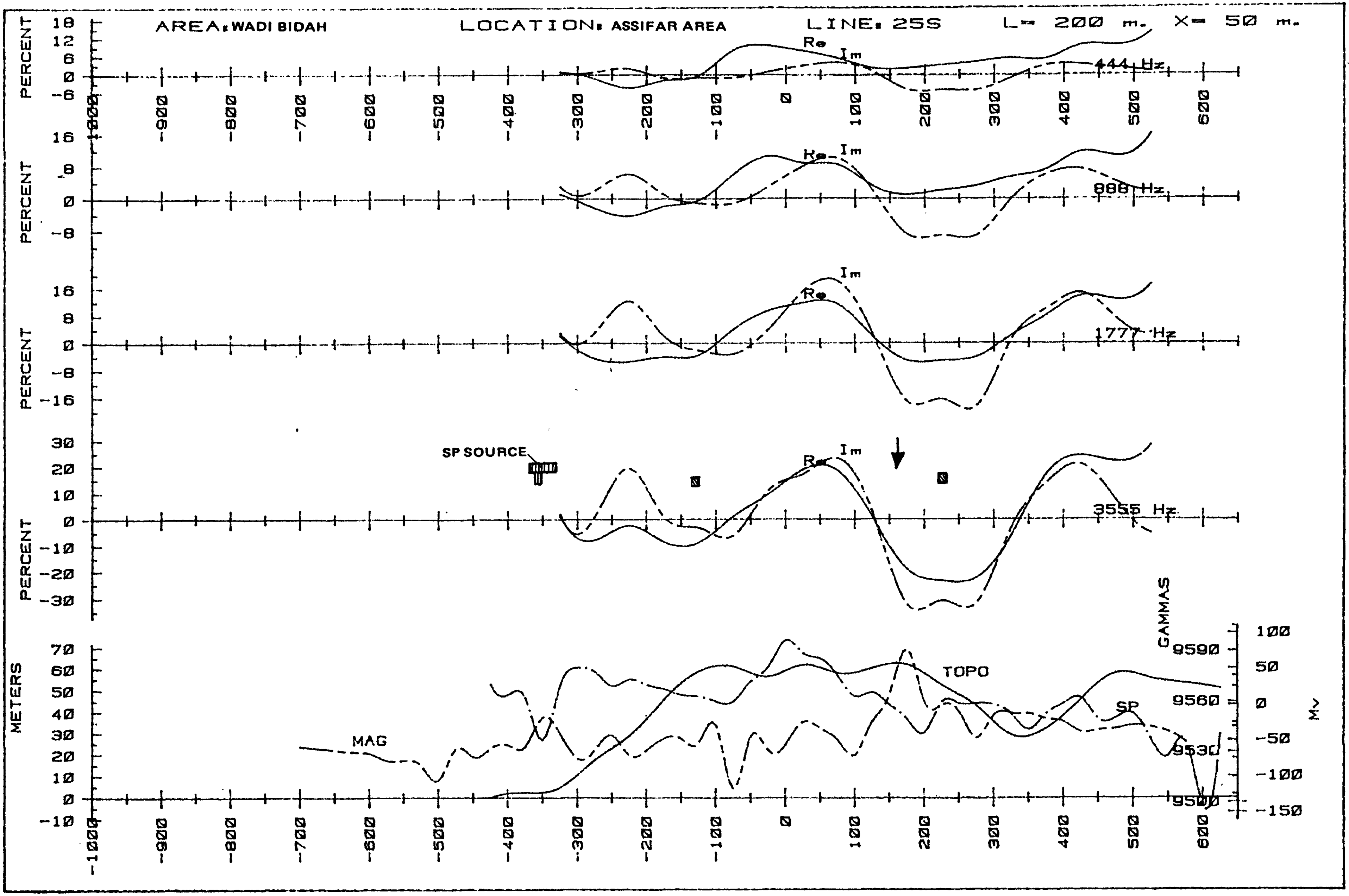
Interpreted SP source, showing approximate location and width of anomalous zone

Interpreted location of local magnetic anomaly

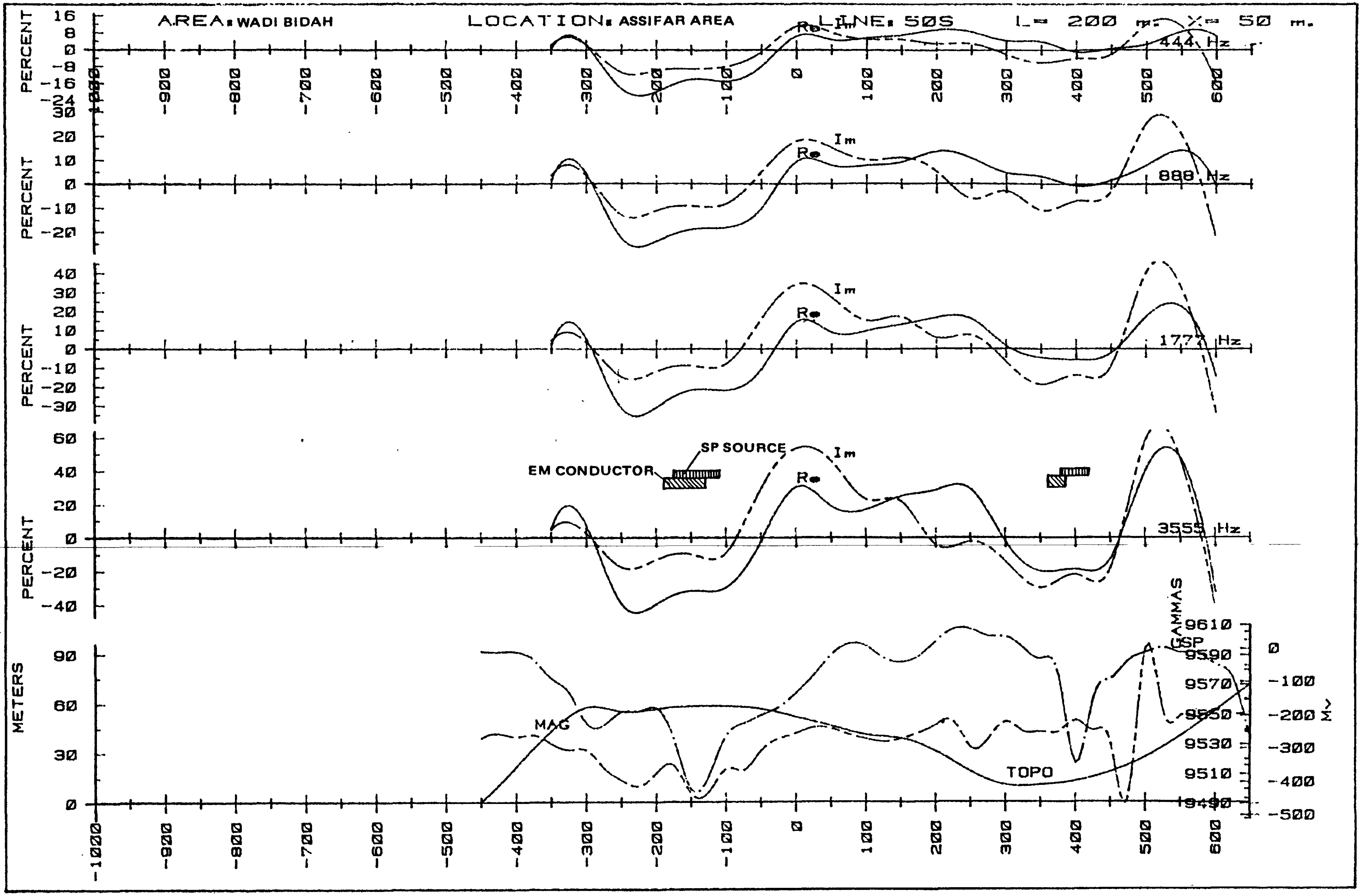
Appendix 1.--*Data profiles from Assifar study area*--Continued



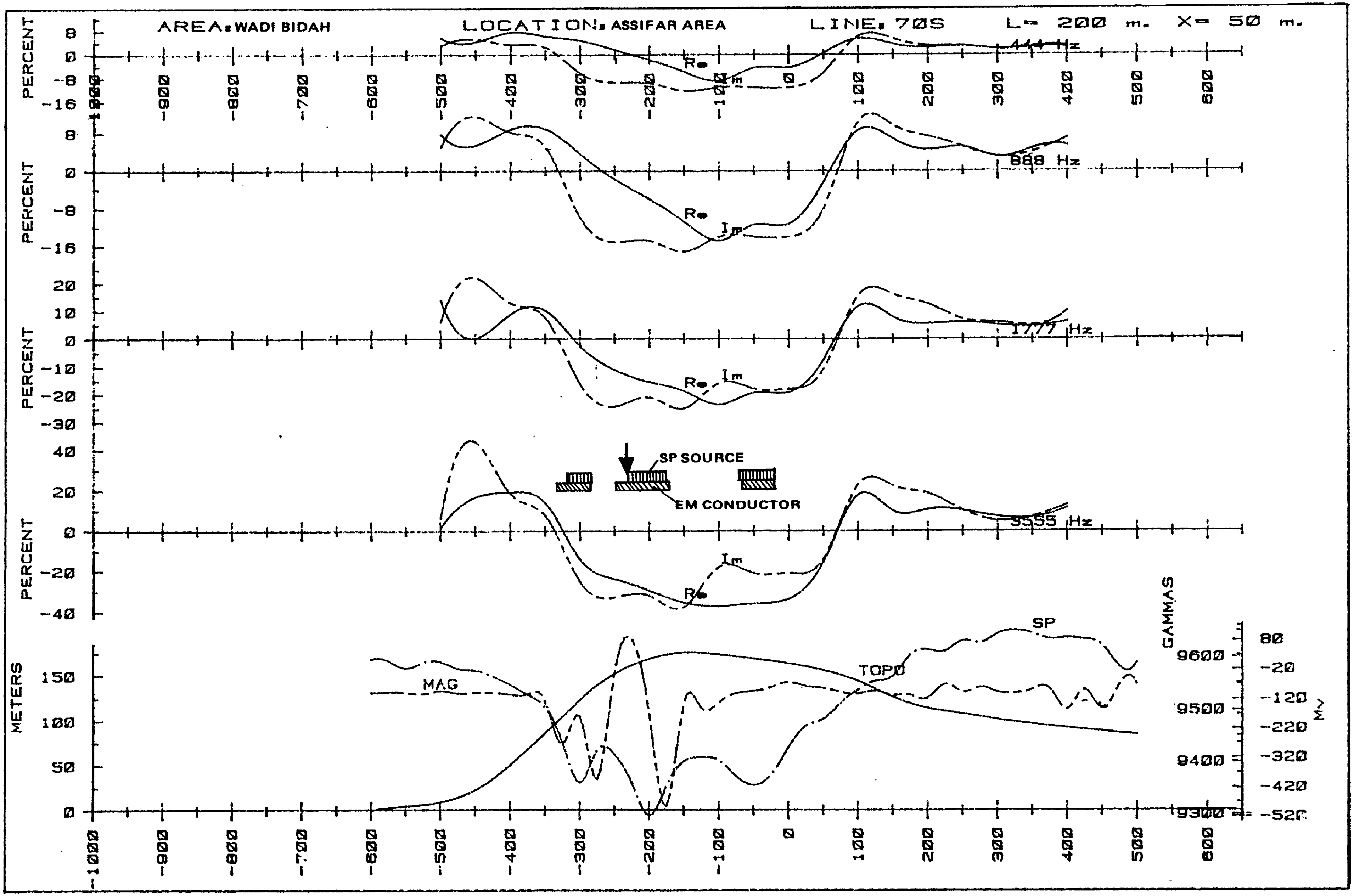
Appendix 1.--*Data profiles from Assifar study area*--Continued



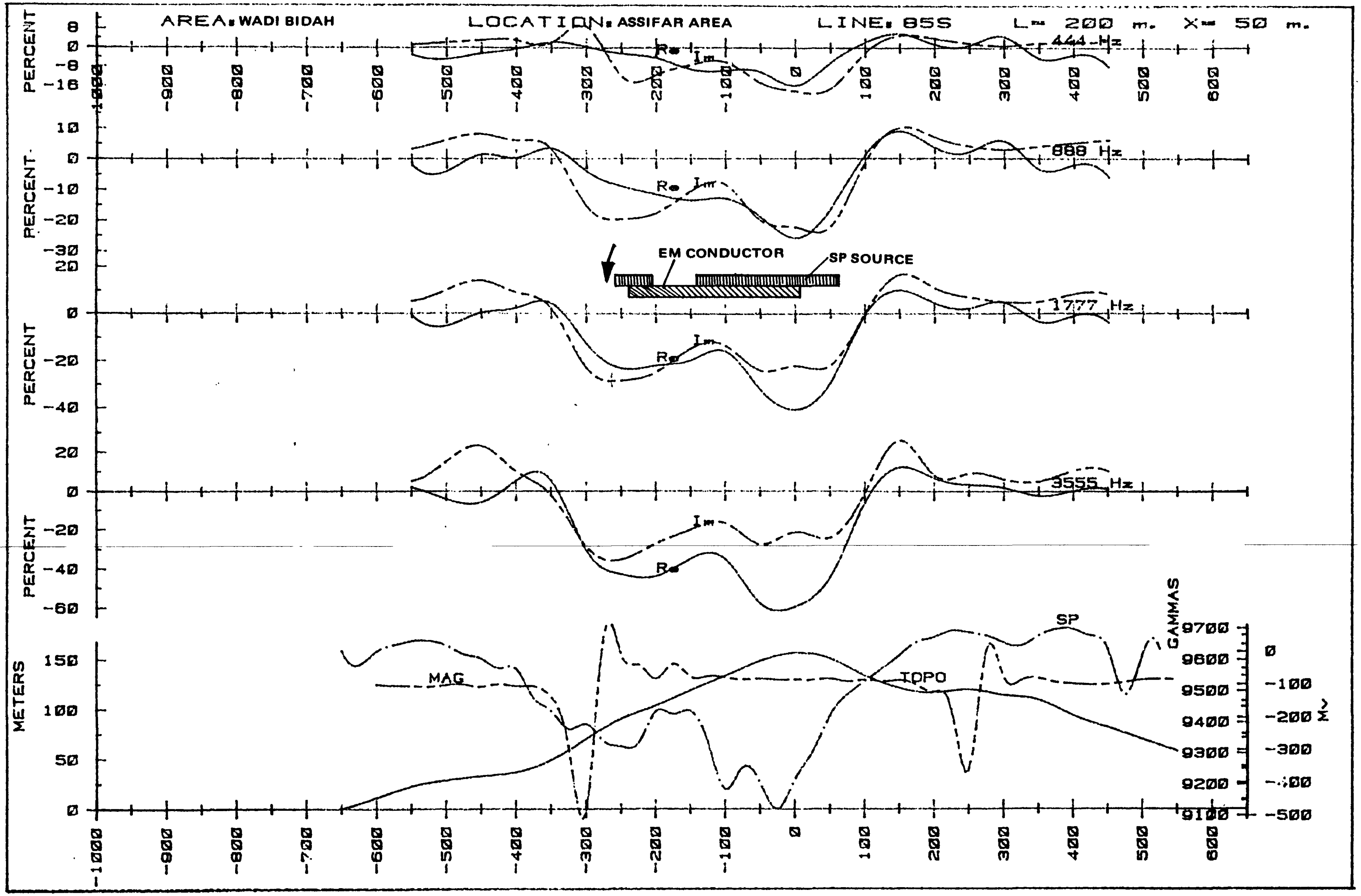
Appendix 1.--*Data profiles from Assifar study area*--Continued



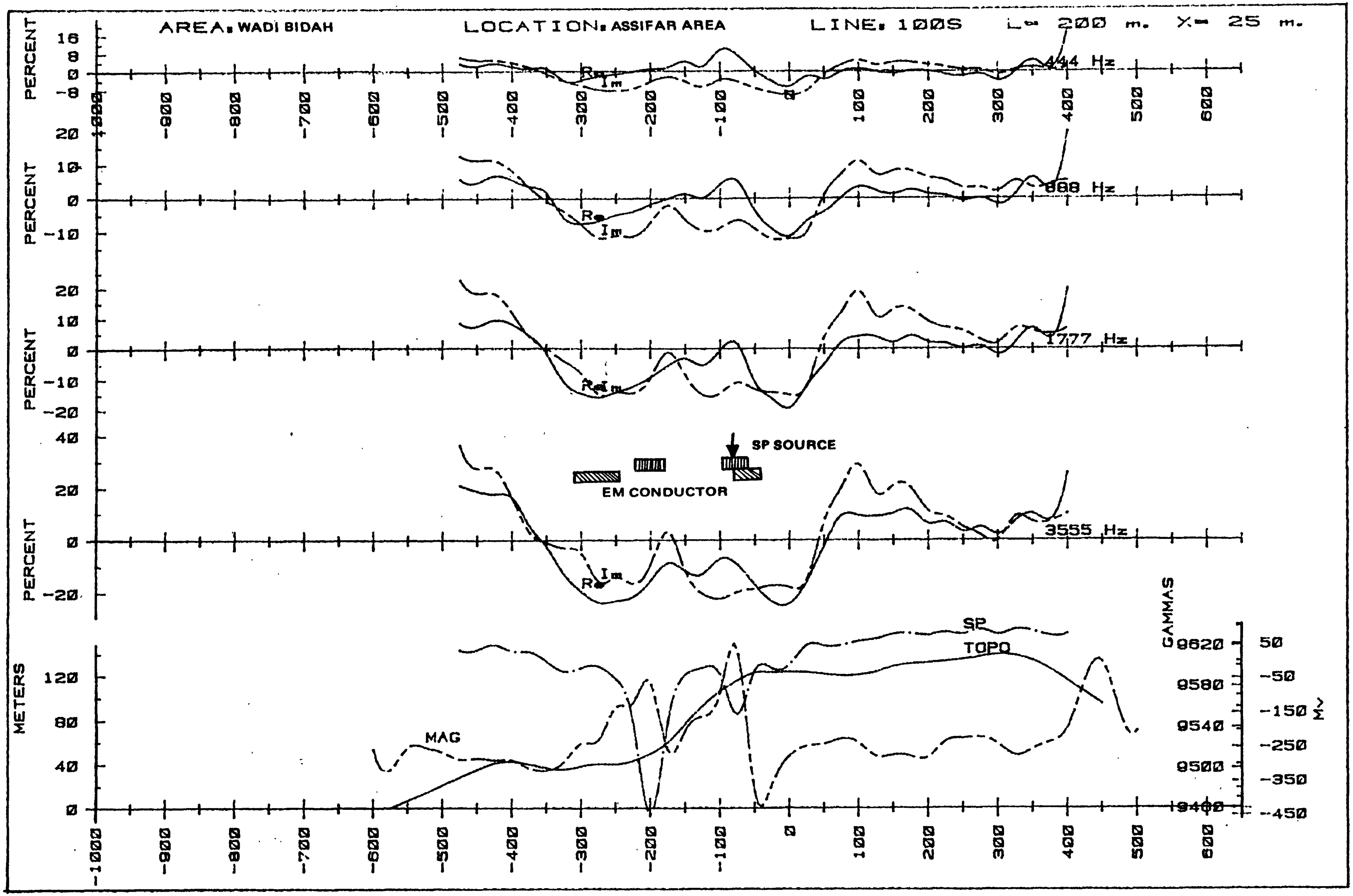
Appendix 1.--*Data profiles from Assifar study area*--Continued



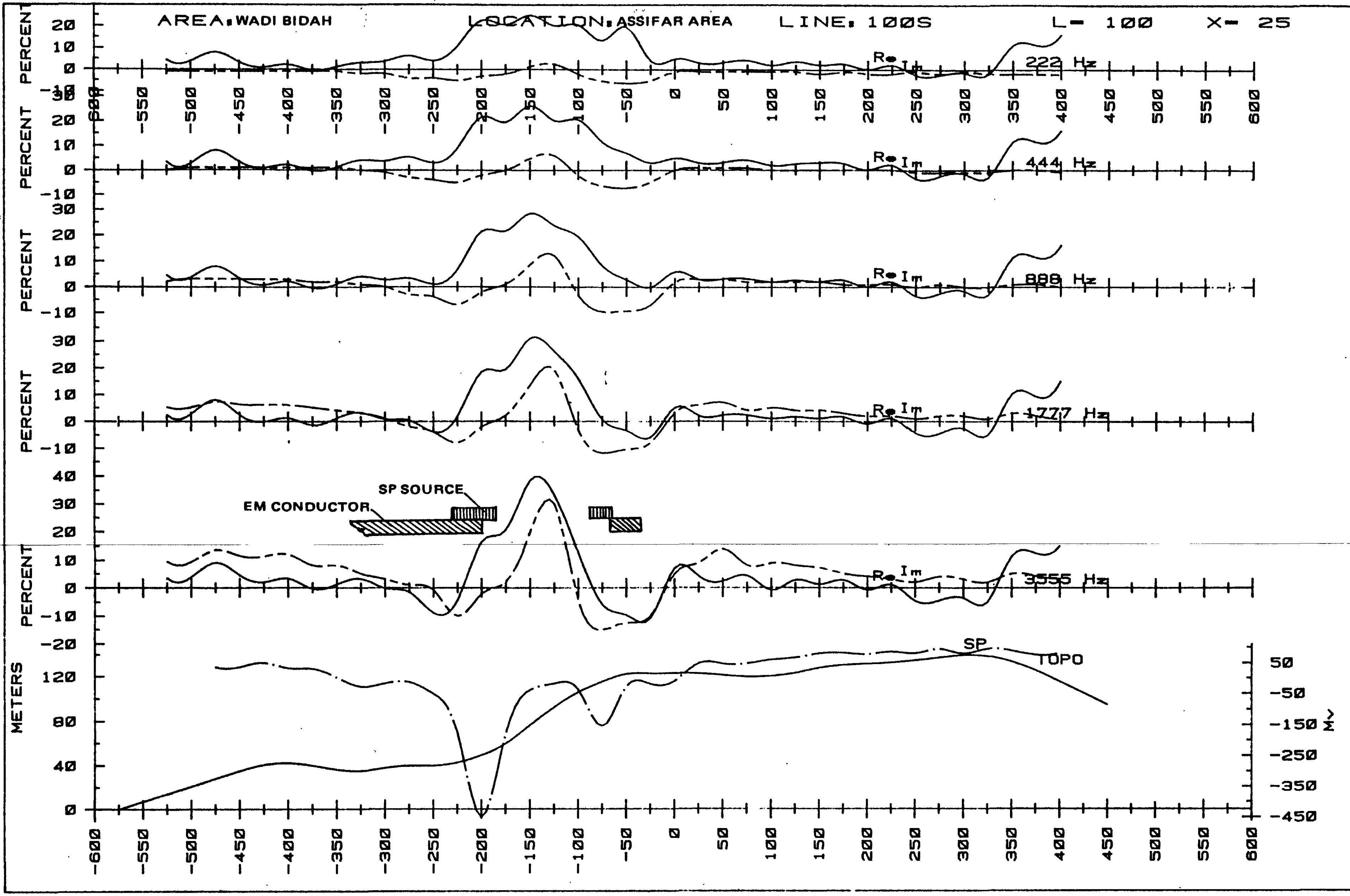
Appendix 1.--*Data profiles from Assifar study area*--Continued



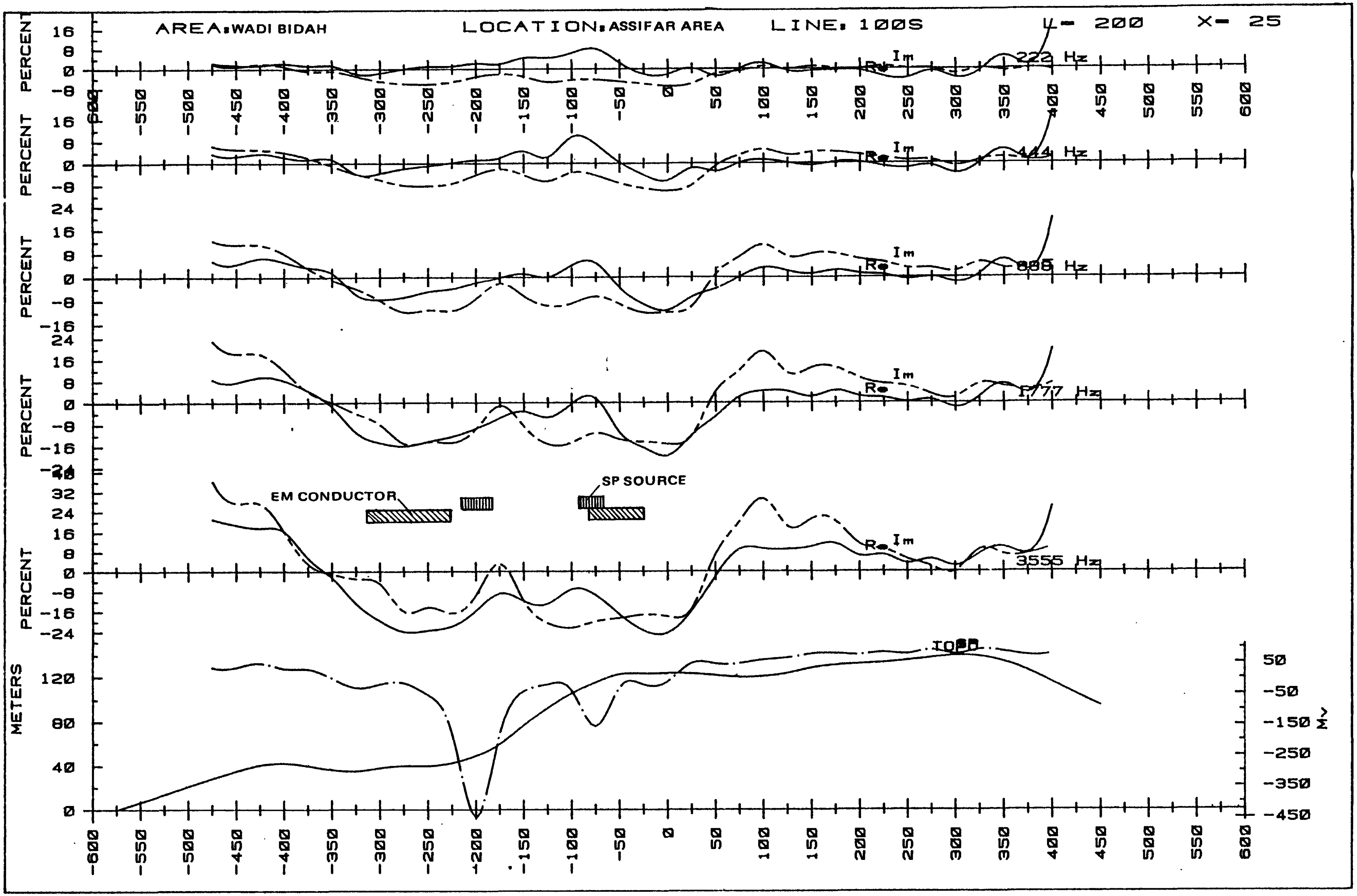
Appendix 1.--*Data profiles from Assifar study area*--Continued



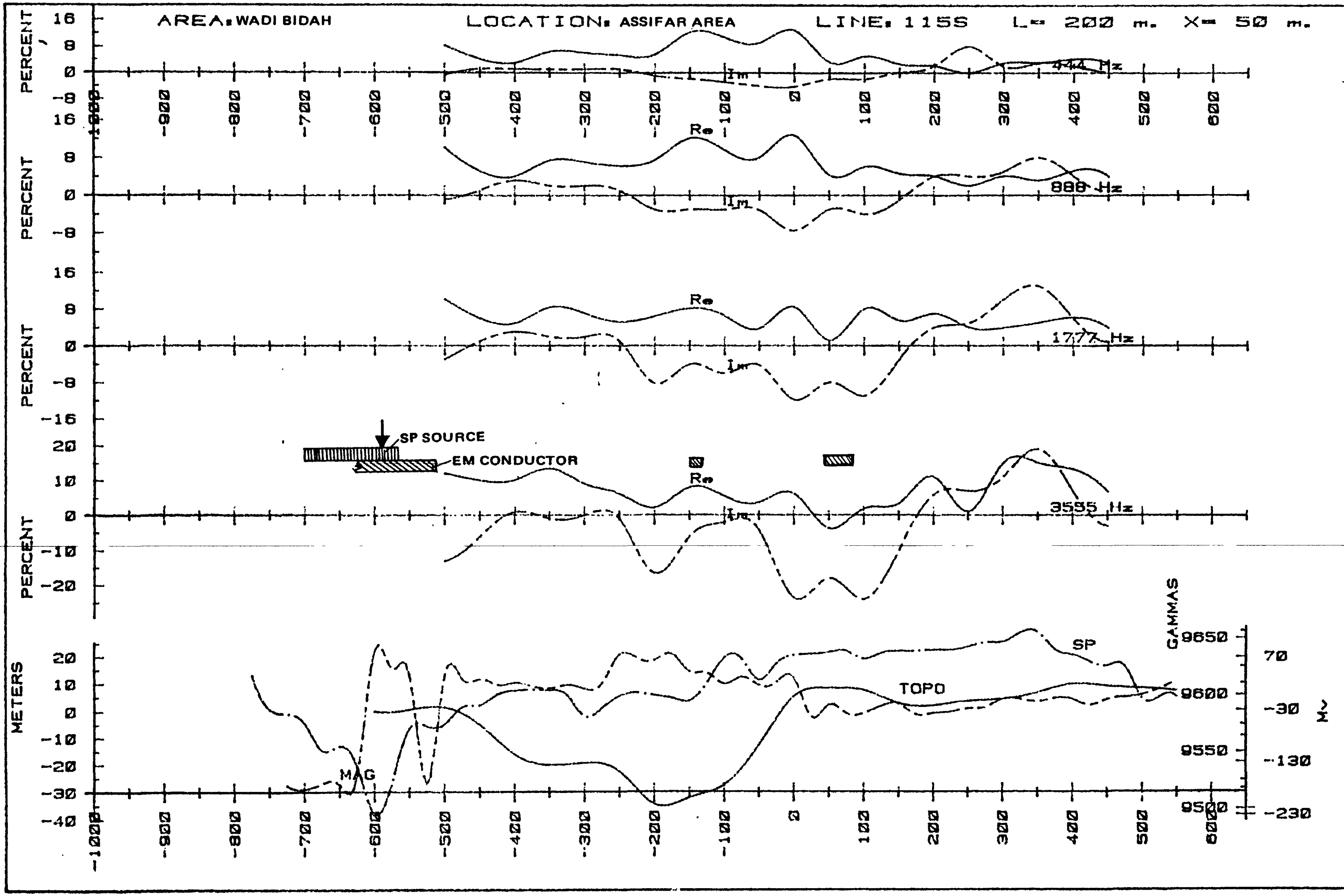
Appendix 1.--*Data profiles from Assifar study area*--Continued



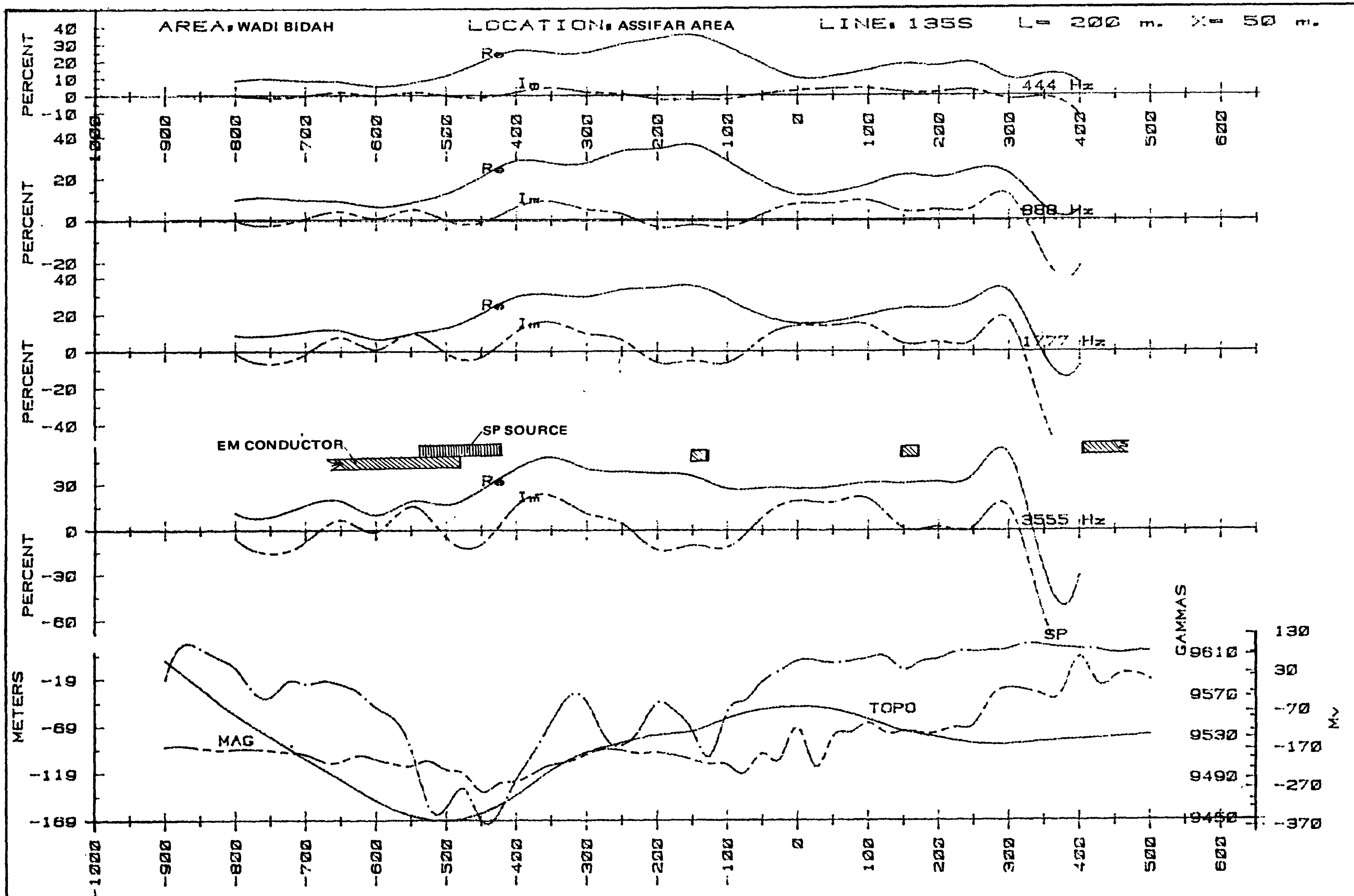
Appendix 1.--*Data profiles from Assifar study area*--Continued



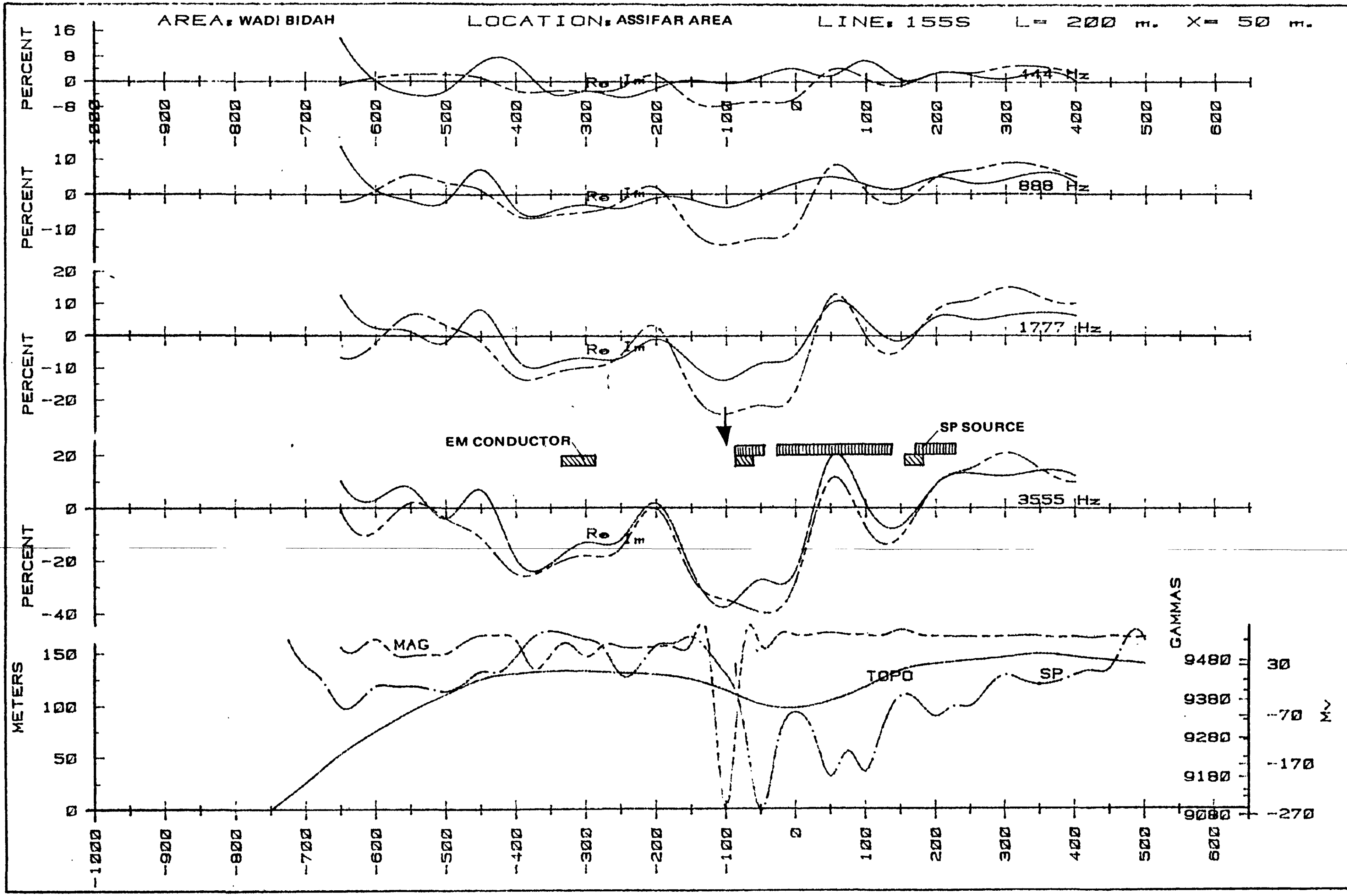
Appendix 1.--*Data profiles from Assifar study area*--Continued



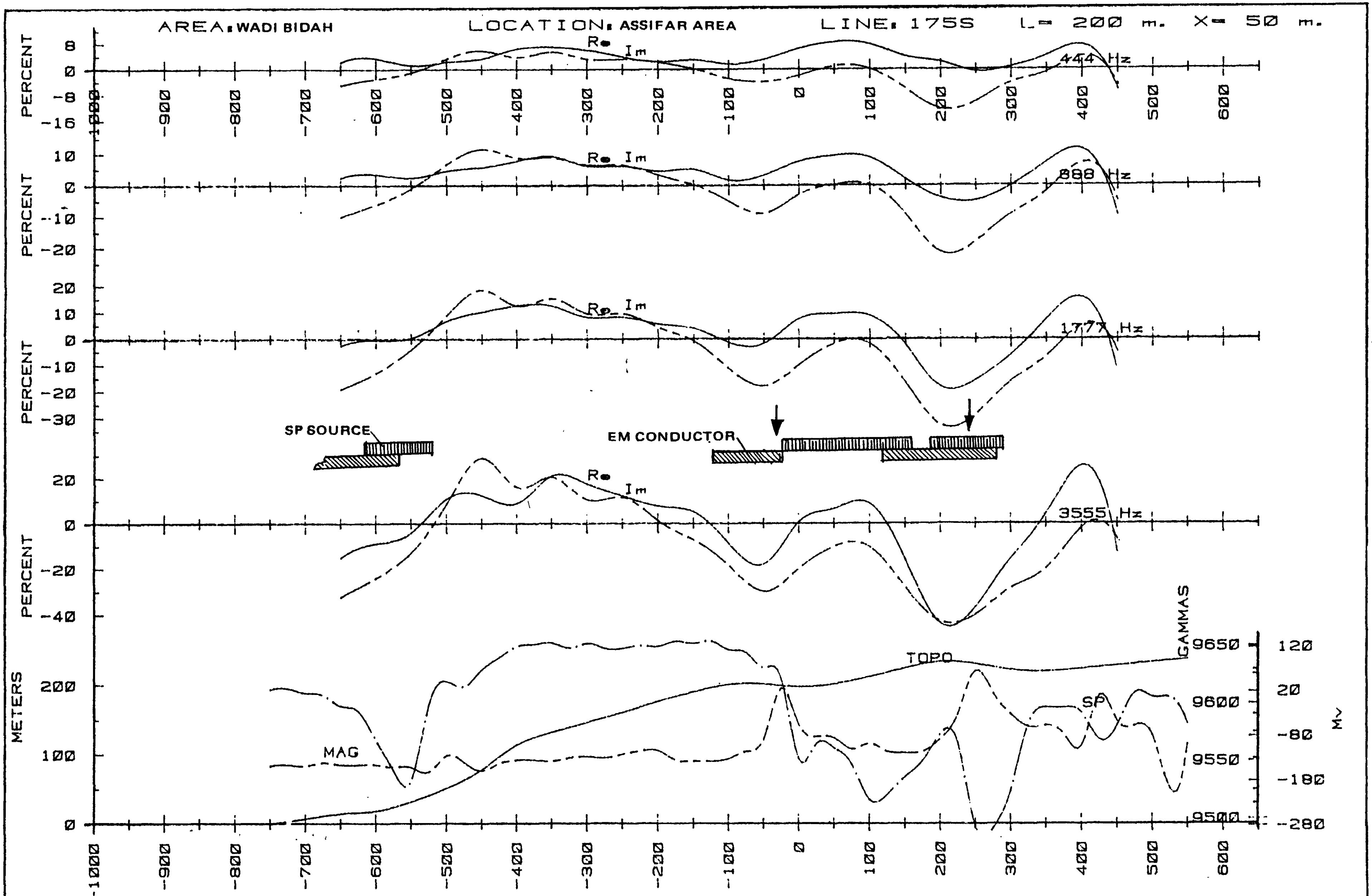
Appendix 1.--*Data profiles from Assifar study area*--Continued



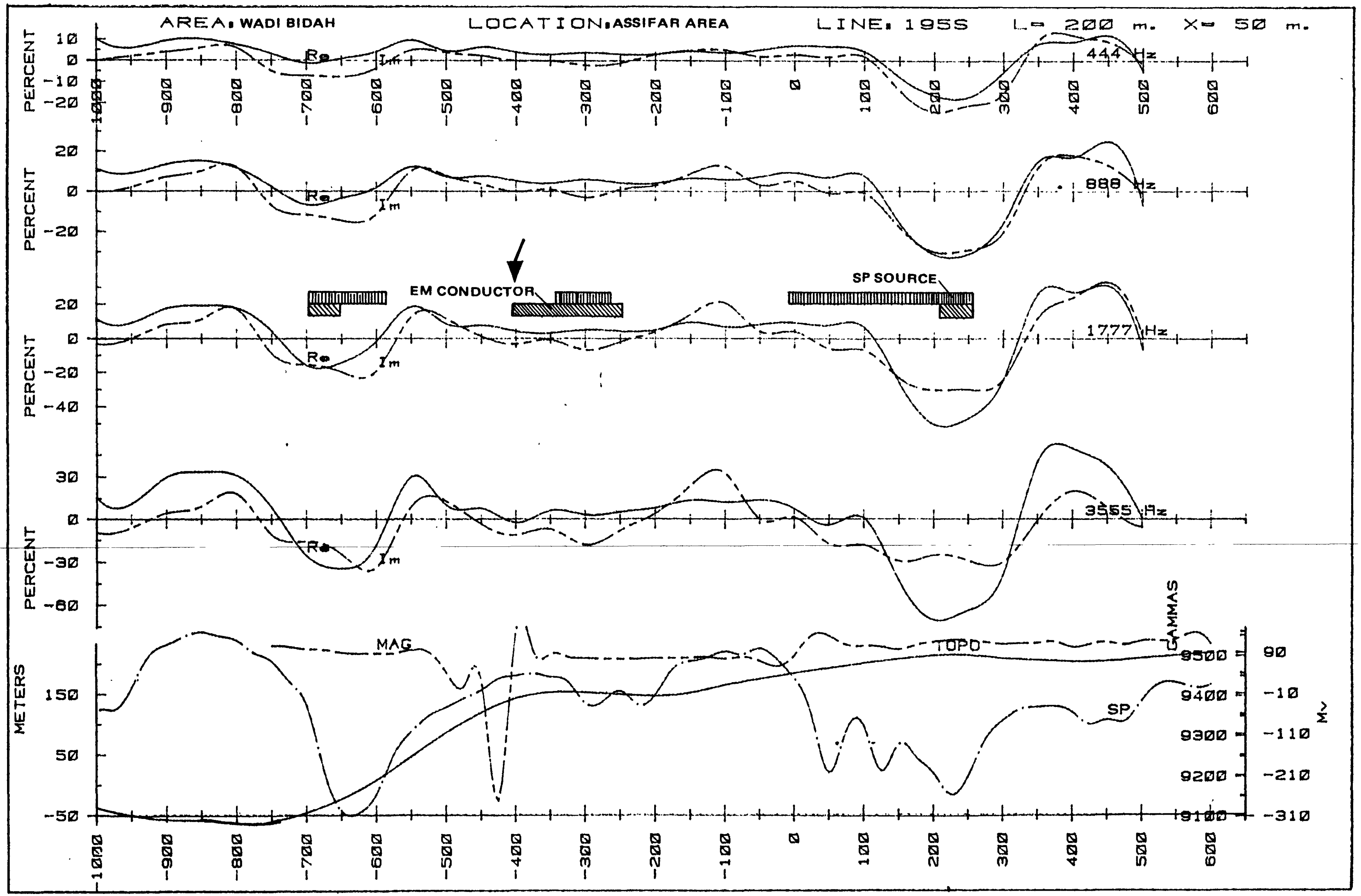
Appendix 1.--*Data profiles from Assifar study area*--Continued



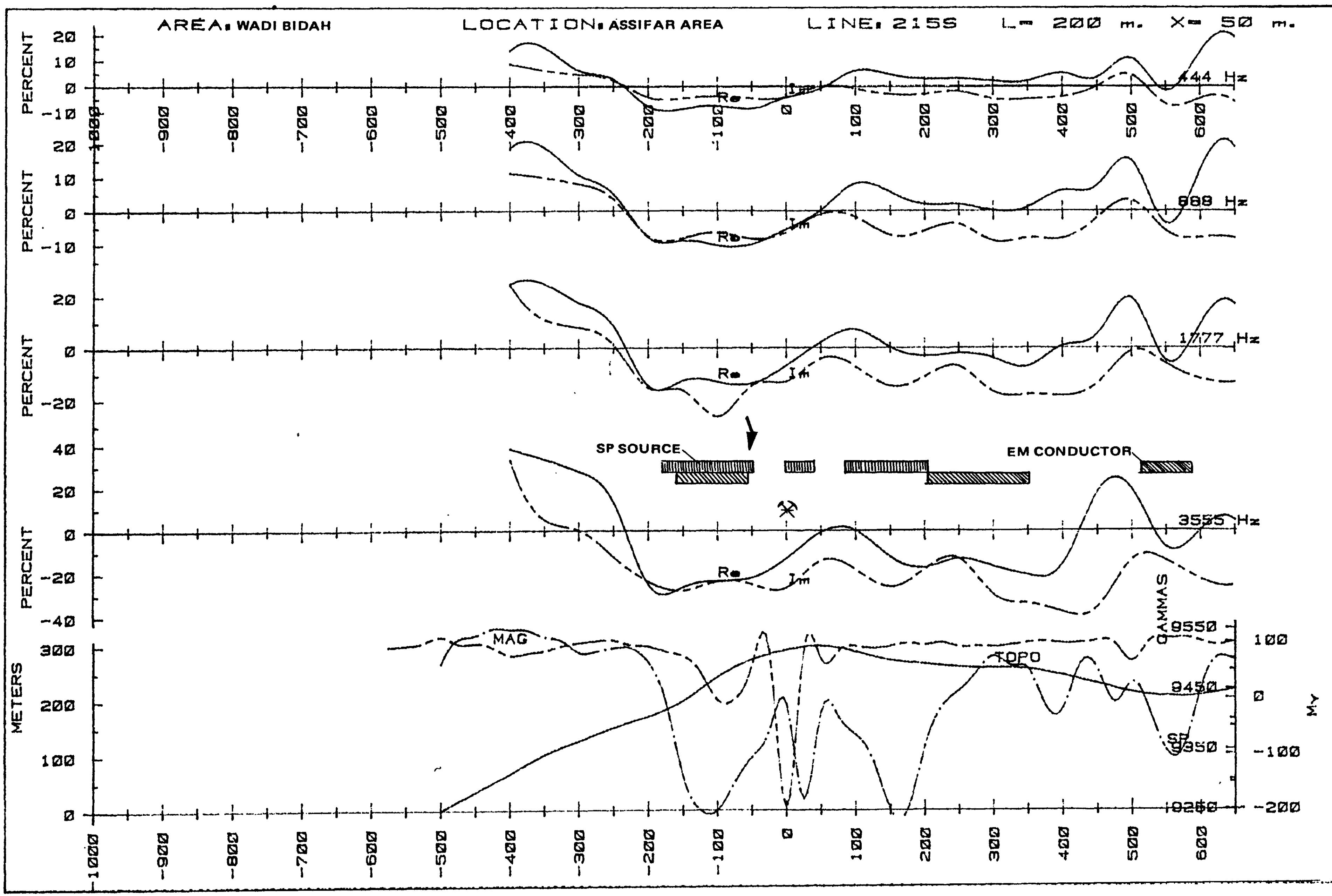
Appendix 1.--*Data profiles from Assifar study area*--Continued



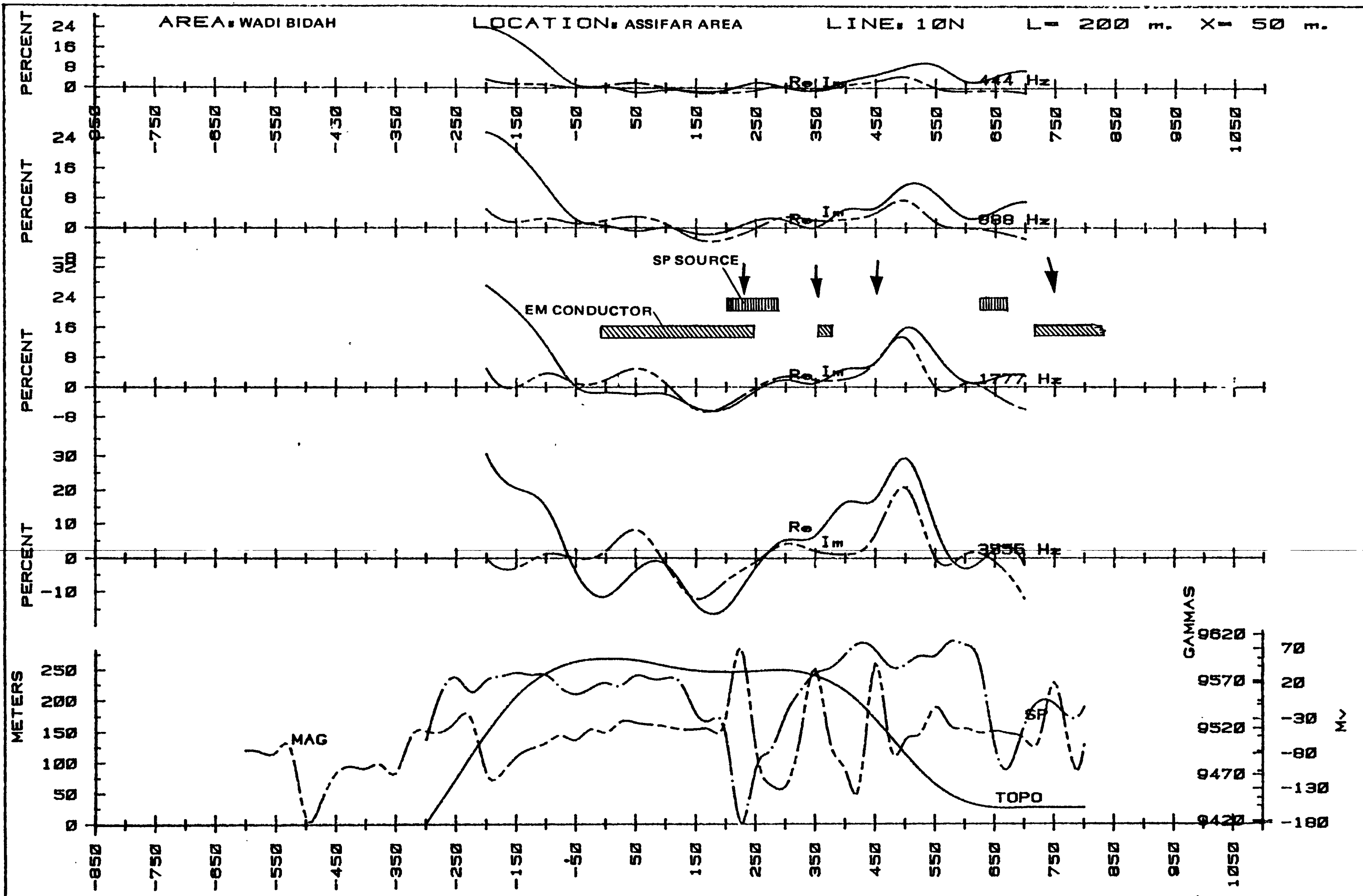
Appendix 1.--*Data profiles from Assifar study area*--Continued



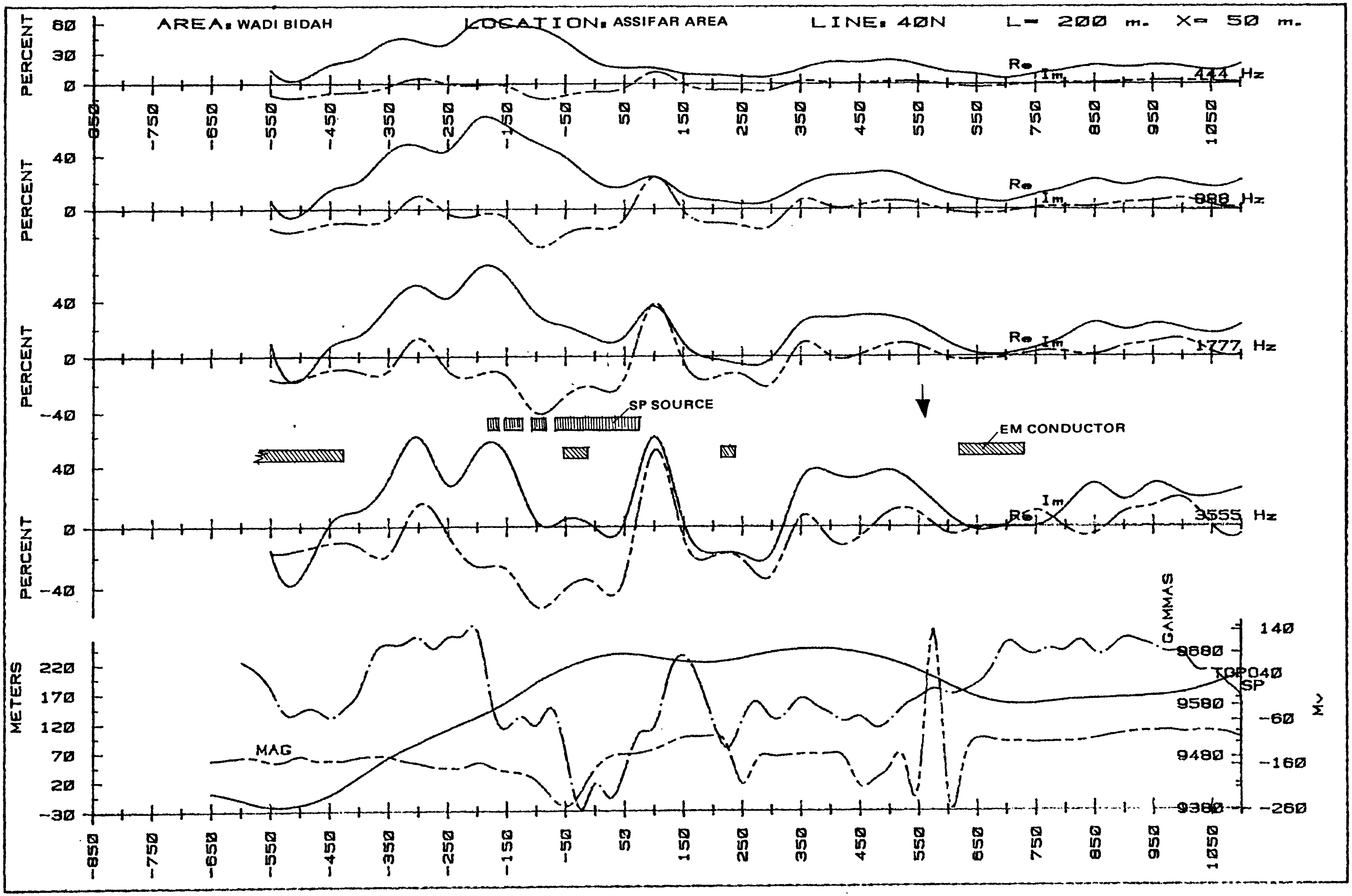
Appendix 1.--*Data profiles from Assifar study area*--Continued



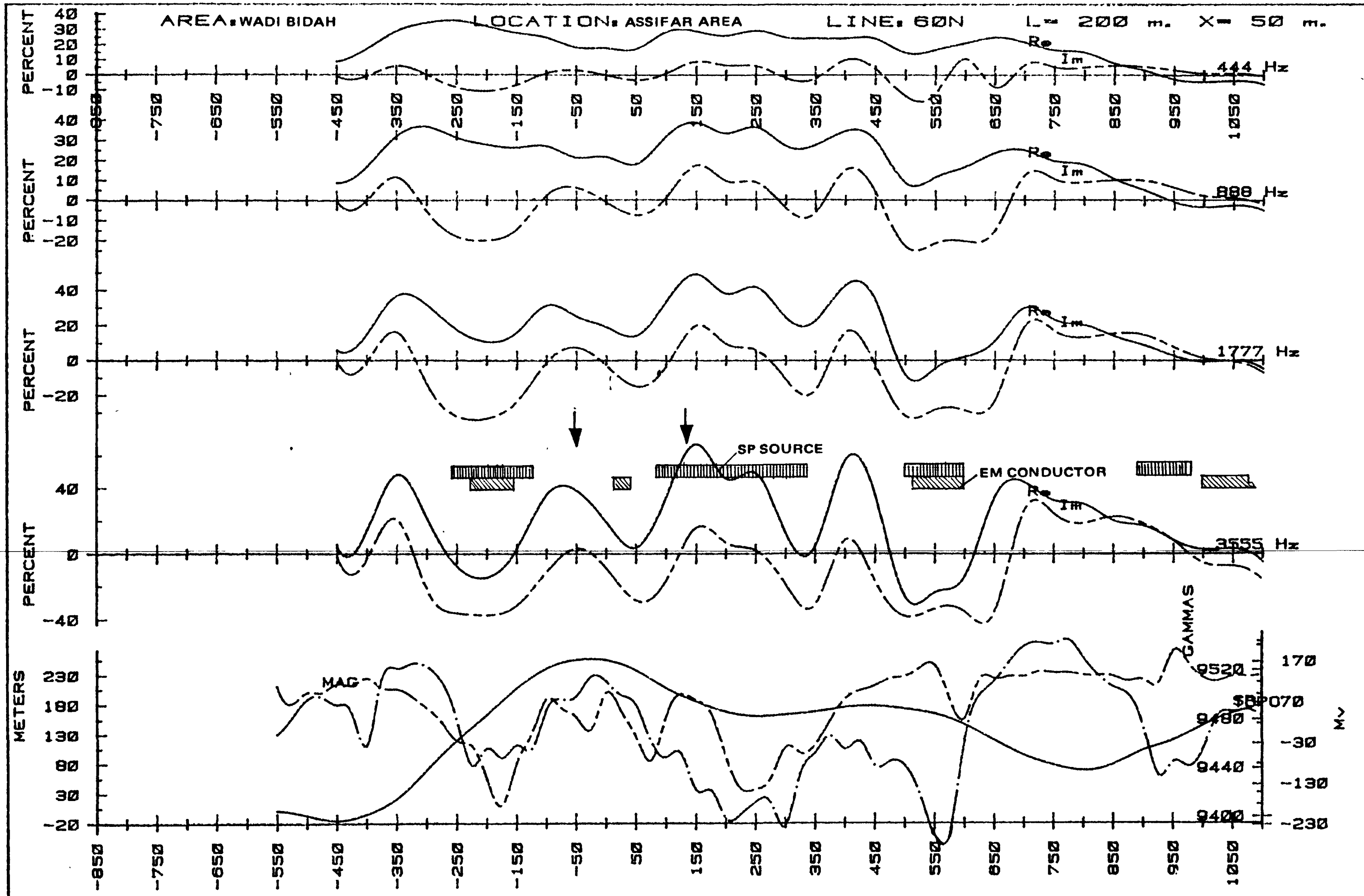
Appendix 1.--*Data profiles from Assifar study area*--Continued



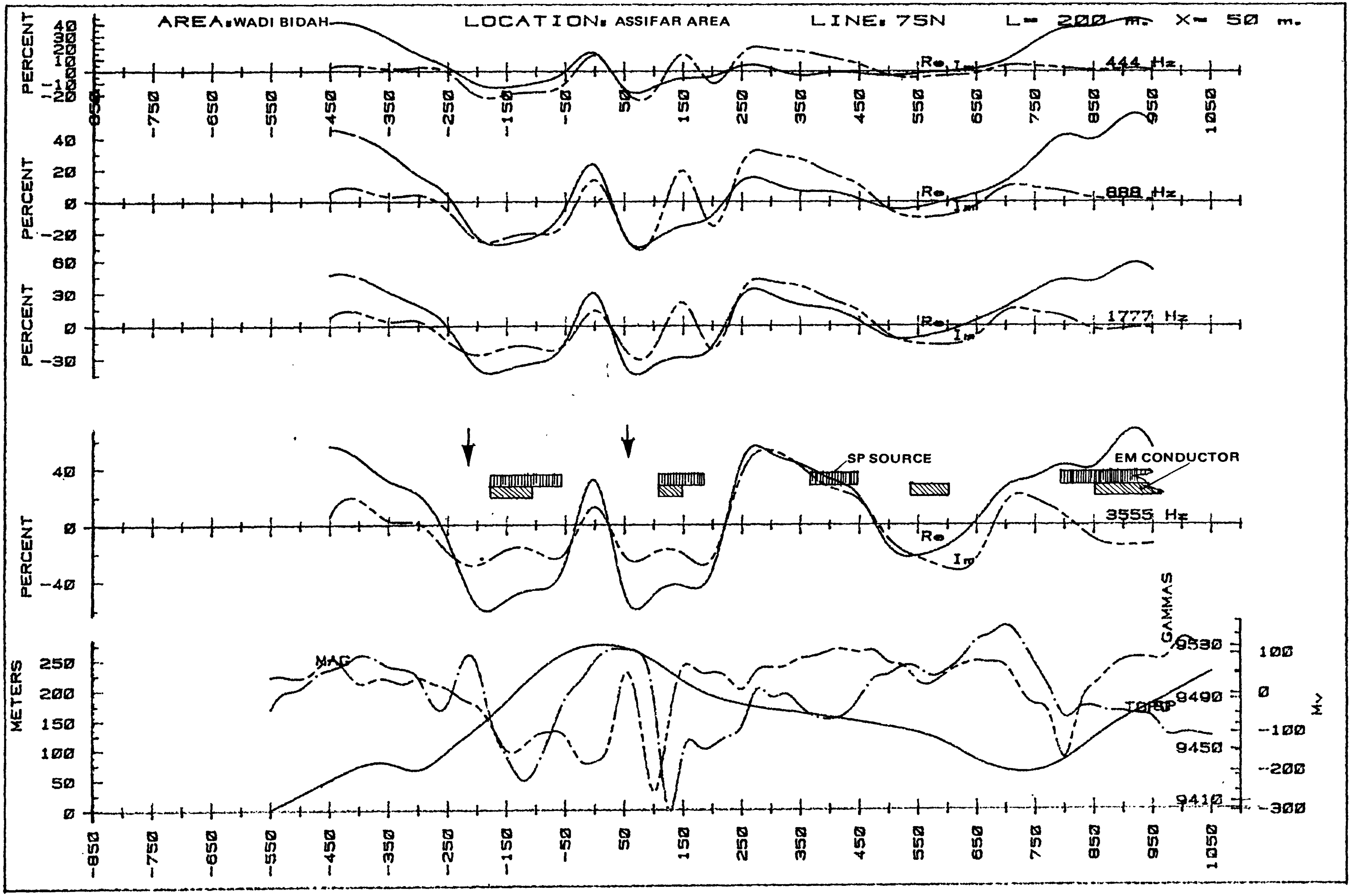
Appendix 1.--*Data profiles from Assifar study area*--Continued



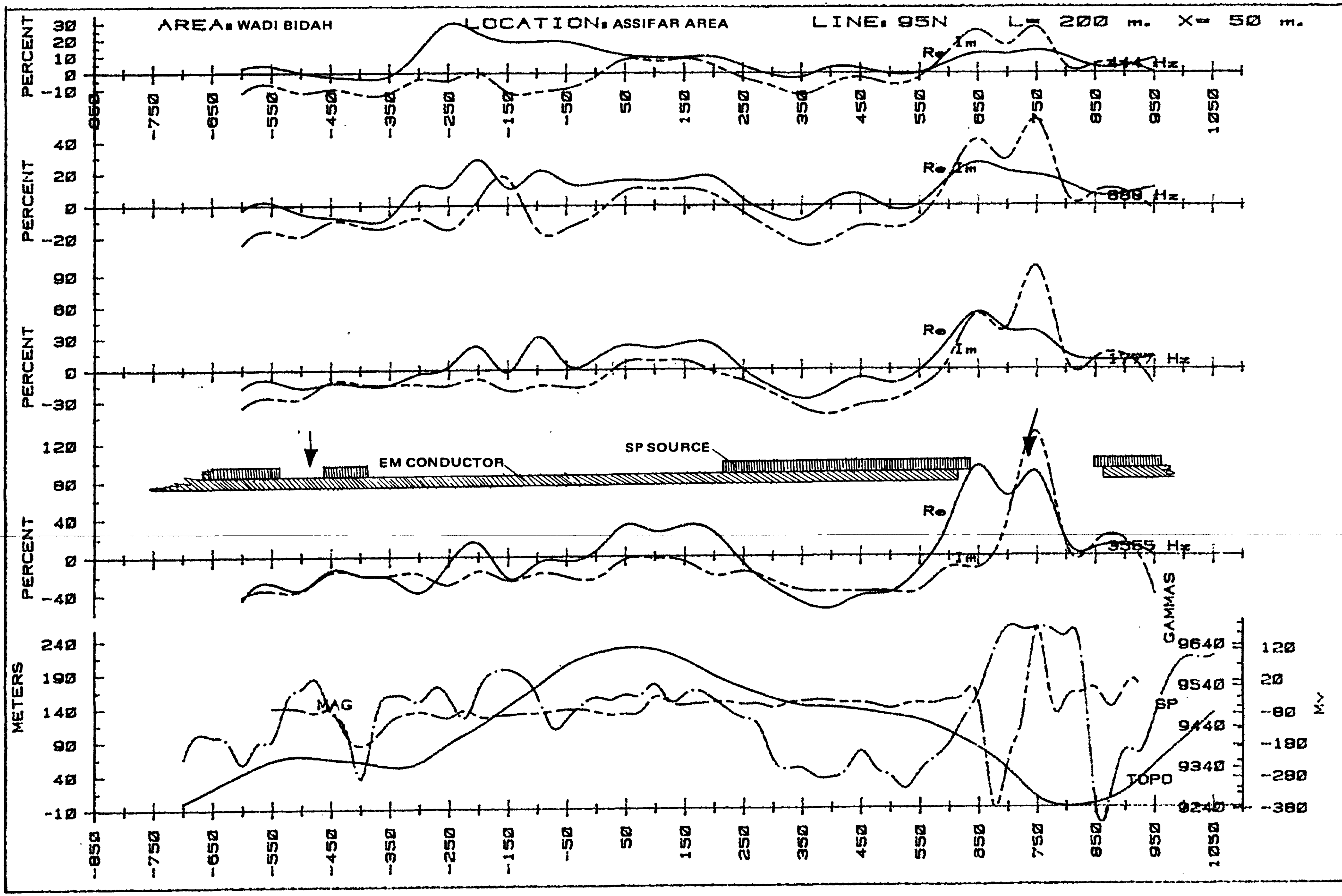
Appendix 1.--*Data profiles from Assifar study area*--Continued



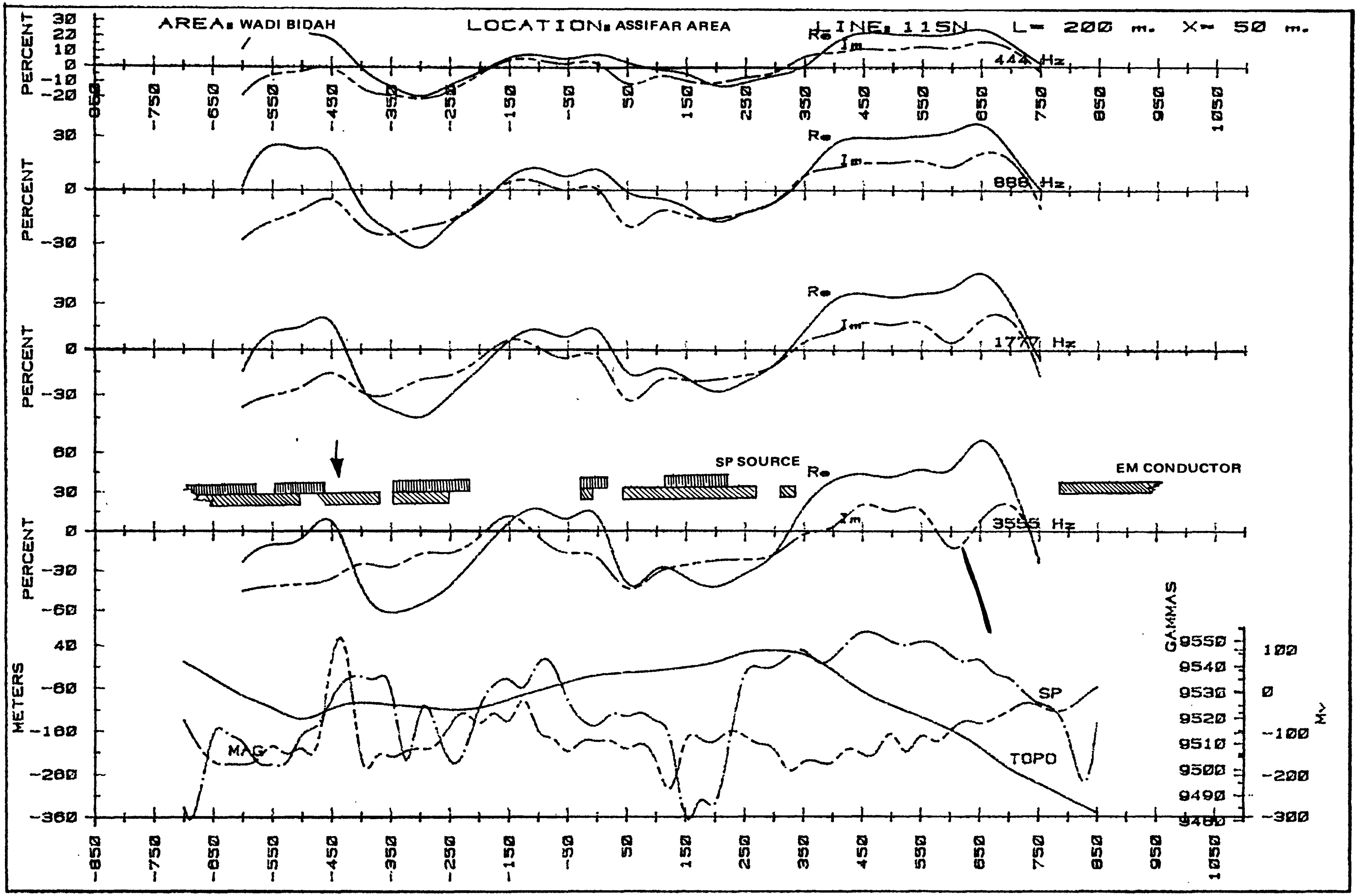
Appendix 1.--*Data profiles from Assifar study area*--Continued



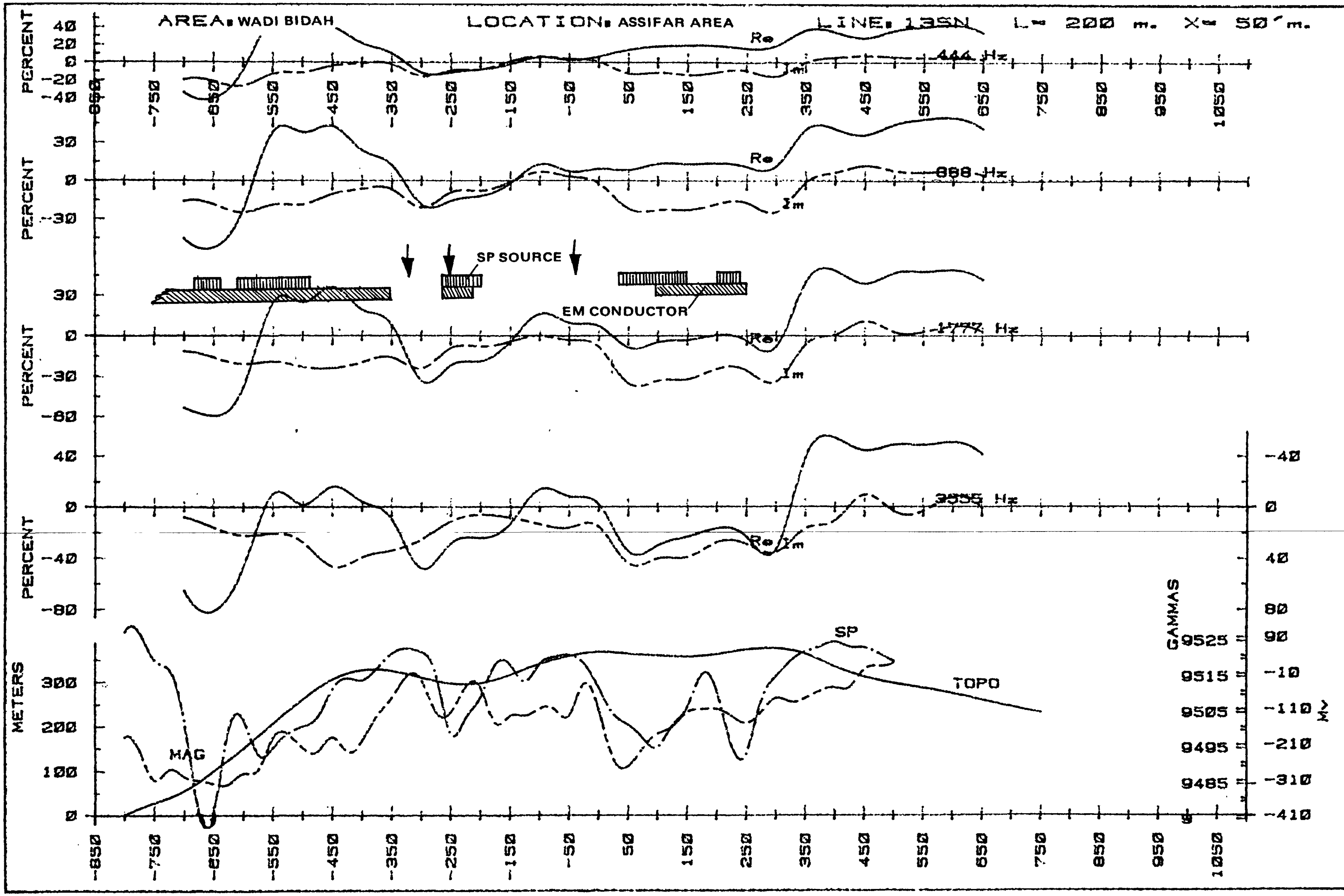
Appendix 1.--*Data profiles from Assifar study area*--Continued



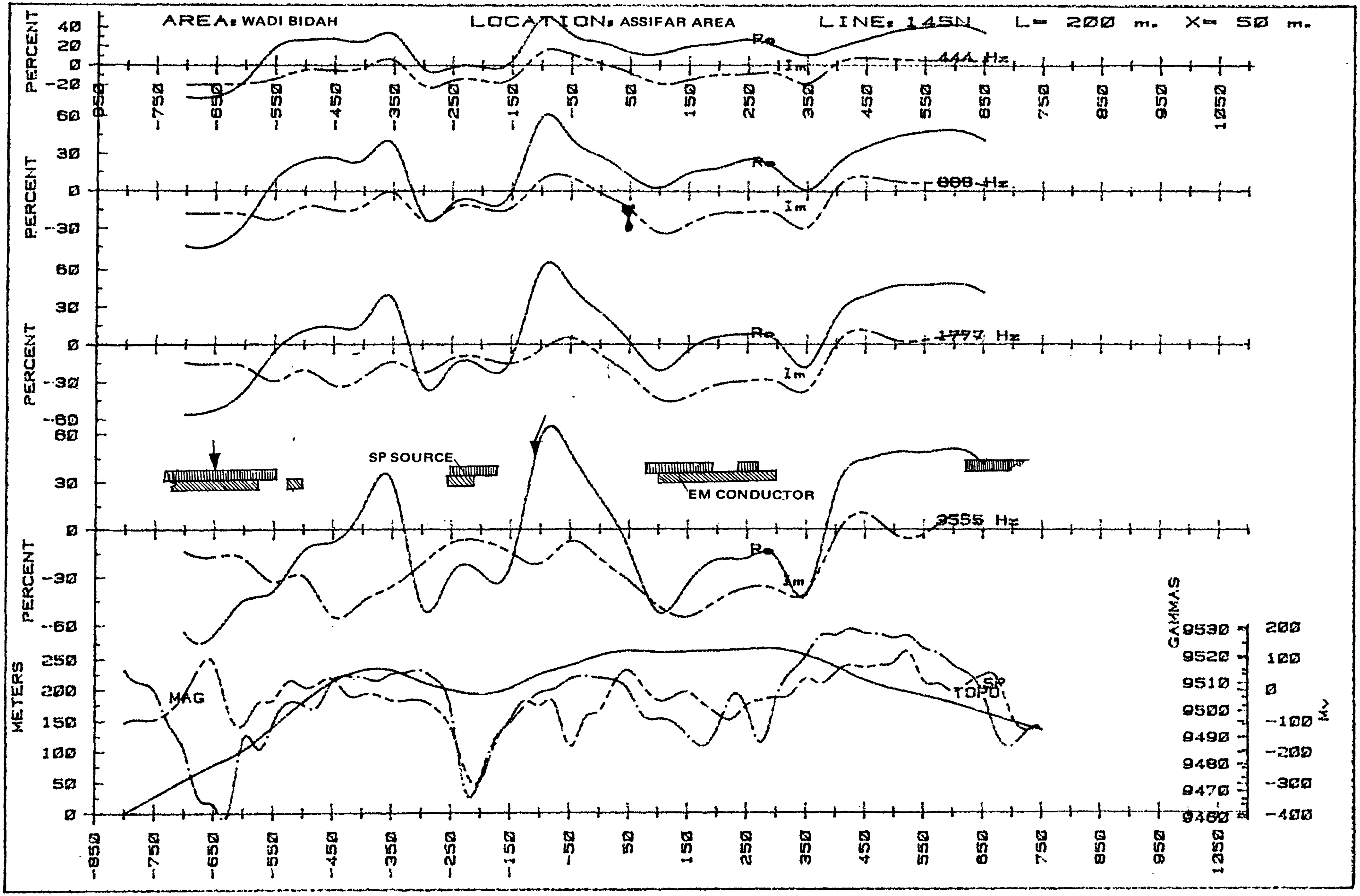
Appendix 1.--*Data profiles from Assifar study area*--Continued



Appendix 1.--*Data profiles from Assifar study area*--Continued



Appendix 1.--*Data profiles from Assifar study area*--Continued

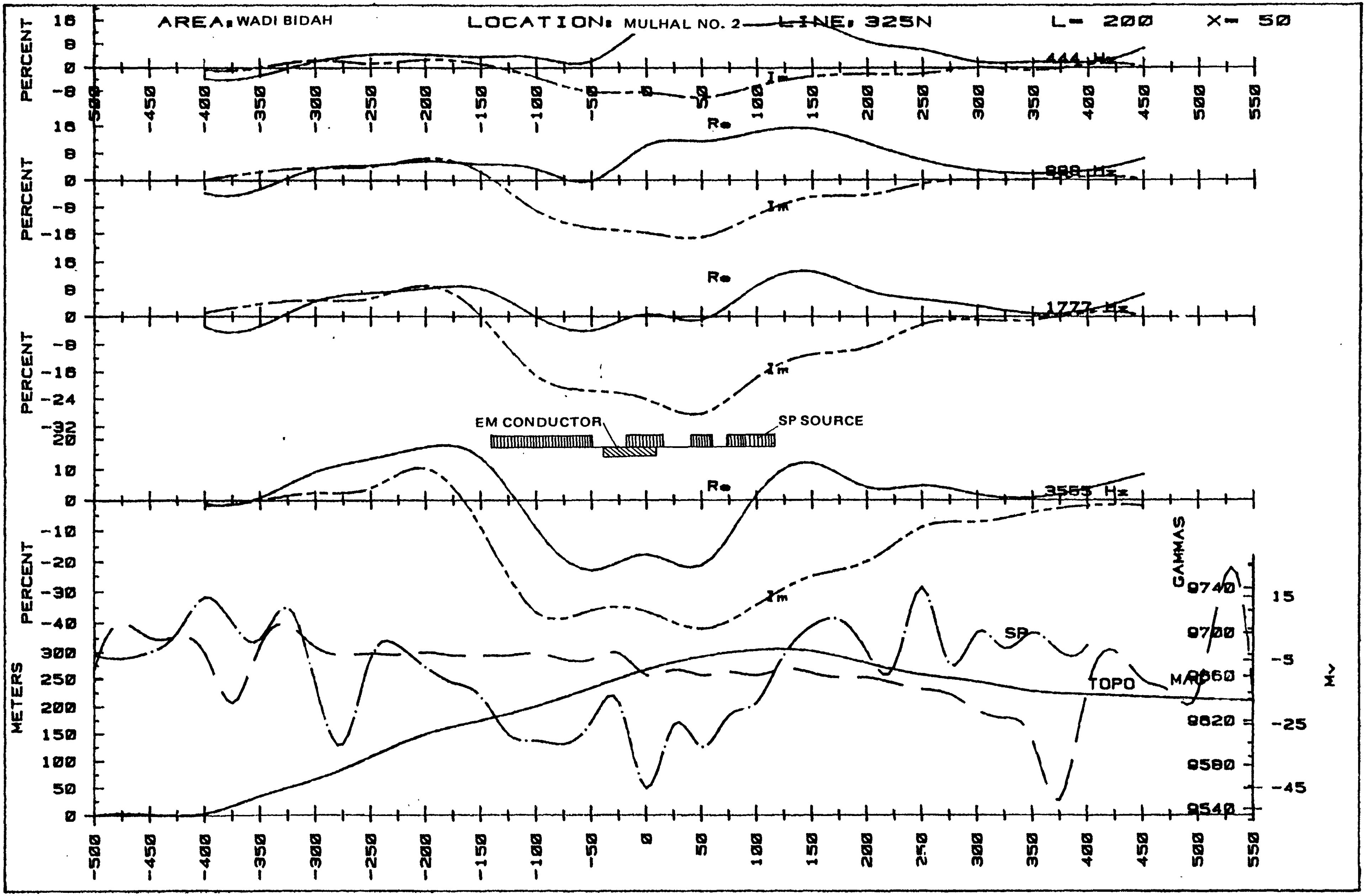


Appendix 2.--*Data profiles from Mulhal No. 2 study area*

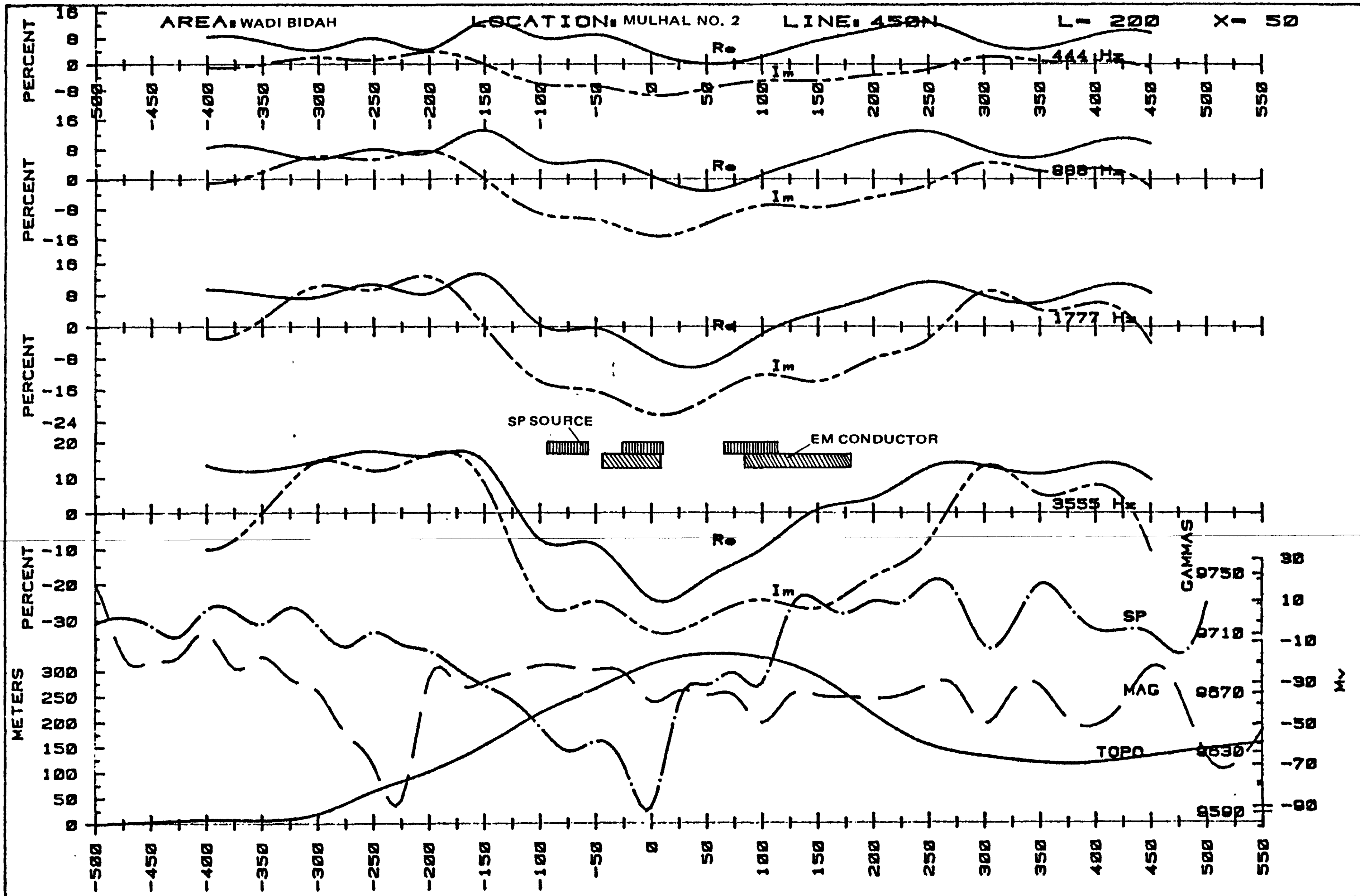
Explanation

L = 200 m.	Slingram coil separation, in meters
X = 50 m.	Slingram measurement interval, in meters
Re	Real or in-phase electromagnetic (EM) response, in percent of the primary field
Im	Imaginary or out-of-phase EM response, in percent of the primary field
444 Hz	Frequency of measured EM response
0 — 50	Slingram traverse showing station locations in meters
MAG	Total-intensity magnetic response, in gammas
SP	Self-potential (SP) response, in millivolts, measured in reference to a single fixed electrode
Topo	Altitude along geophysical traverse, in meters, measured from an arbitrary base elevation
	Interpreted EM conductor, showing approximate location and width of anomalous zone
	Interpreted SP source, showing approximate location and width of anomalous zone
	Interpreted location of local magnetic anomaly

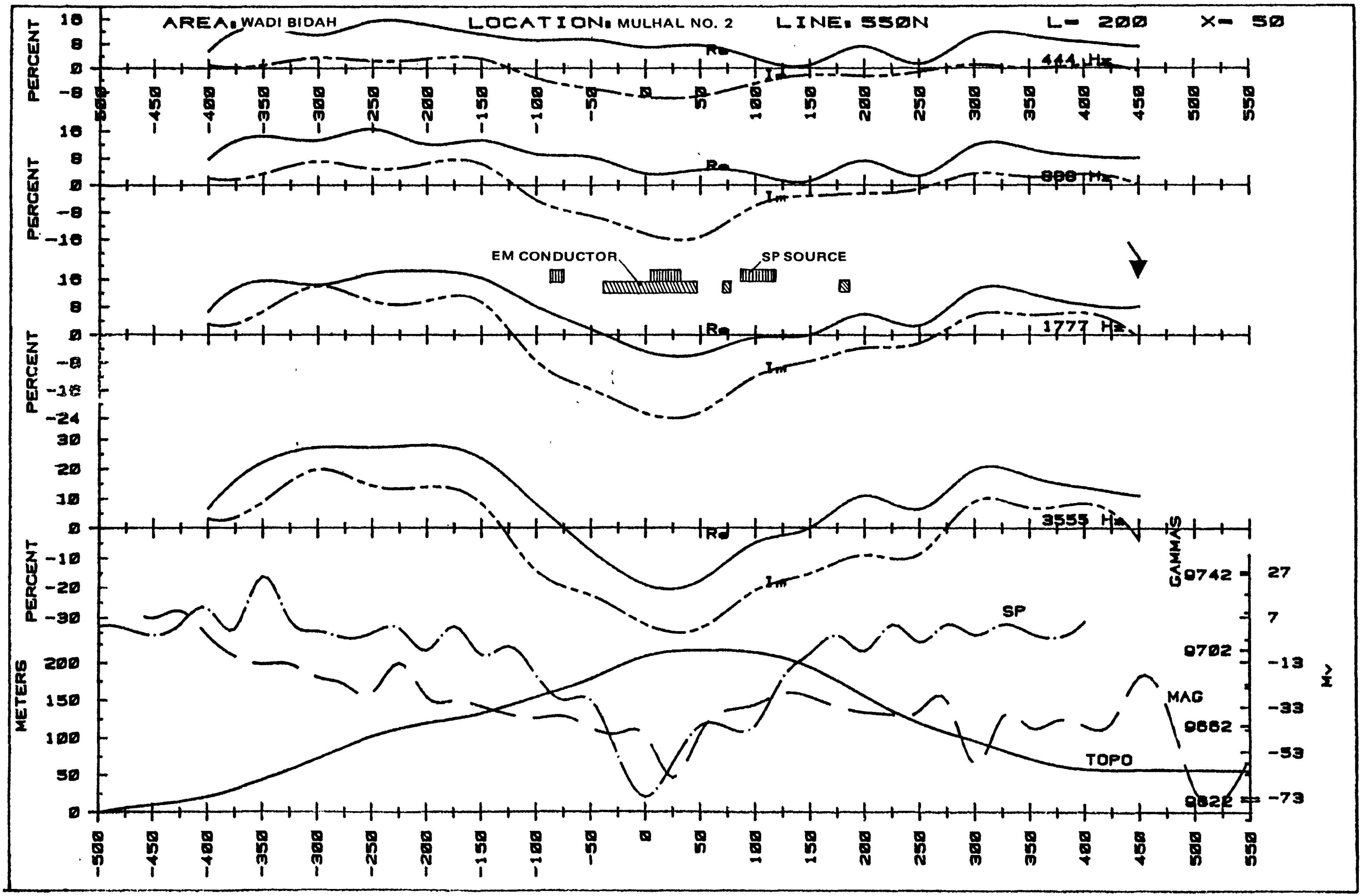
Appendix 2.--*Data profiles from Mulhal No. 2 study area*--Continued



Appendix 2.--*Data profiles from Mulhal No. 2 study area*--Continued



Appendix 2.--*Data profiles from Mulhal No. 2 study area*--Continued



Appendix 2.--*Data profiles from Mulhal No. 2 study area*--Continued