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GEOPHYSICAL EXPLORATION IN THE SOUTHERN HIJAZ, SAUDI ARABIA

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W. E. Davis and R. V. Allen

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

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Abstract

Geophysical exploratory surveys were made over 16 ancient mines and prospects found in geologic reconnaissance of the Southern Hijaz. The surveys were made with the electromagnetic dip-angle method supplemented by electromagnetic horizontal-coil and magnetometer techniques. Results of the work indicate that no commercial deposits of massive sulphides occur near the mines. Small quantities of these sulphides may be present, though they are probably too highly disseminated to be detected by electromagnetic measurements. A hidden zone of moderate conductivity that may contain massive sulphides was found in the Wadi Fig area. No economic deposits of magnetite were discovered in the exploratory magnetometer surveys.

Introduction

Exploratory geophysical data were obtained over 16 ancient mines and mineral prospects reported by local inhabitants and found in geologic reconnaissance of the Southern Hijaz (Fig. 1). Specifically the mineral occurrences investigated are:

1. Mehaid mine
2. Mulha Mine
3. As Sut mine
4. Mahawiyah mine
5. Mindaha mine
6. South Mindaha mine
7. Camden anomaly
8. Unnamed mine pit

9. Wadi Fig prospect
10. Wadi Tha mine
11. El Wakaban mine
12. El Kuthain mine
13. Esh Kamp mine
14. Unnamed mine pit
15. Unnamed mine pit
16. Tea garden prospect

The geophysical work consisted mostly of brief electromagnetic investigations which were conducted primarily to detect subsurface electrical conductive materials that may contain massive sulphides. A few magnetometer studies were made where feasible to determine the presence of magnetite deposits. Owing to the inaccessibility of most mines, field operations were conducted simultaneously with geologic mapping and accomplished by helicopter from a central camp. Field investigations were made by the authors during the period of July 20 to August 31, 1965.

The mieral deposits are in mountainous terraine more than 6000 feet above sea level between latitude 19°45'N. and 20°40'N.; longitude 41°15'E. and 42°05'E. The mines occur in northerly-trending belts marked by scattered small zones of alteration that crop out in volcanic rocks in the eastern part of the area and in chlorite-sericite schists in the western part. Locally these rocks have been intensely folded and cut by numerous steeply-dipping faults. Most of the workings are in small gossans associated with thin beds of jasper and marble. Minor amounts of malachite are exposed in the walls of many of the workings, which in general, are narrow and less than 100 meters in length. Slag dumps occur near most mines.

The small gossans and general shallow workings, as well as their scattered distribution suggest that material was mined from small exposed deposits, such as lenses and pods, which probably occurred in the oxidized zone. Very likely any supergene deposits associated with the mineral occurrences were not reached by ancient mining methods.

Instruments and field techniques

The electromagnetic data were obtained mostly with vertical-coil dip-angle equipment (Sharpe, Model SE 100) operated at a frequency of 1100 cps. The transmitter was placed over the workings and inclinations of the resulting electromagnetic field were measured at intervals of 40 feet along 3 or 4 traverses across the trend of mineralization in each locality. Where such trends were not known, exploratory measurements were made around transmitter positions over gossan and zones of highly altered rocks. Distances between traverses and between the transmitter and receiver were selected to give depths of penetration ranging from 150 to 500 feet.

A horizontal-coil electromagnetic unit (ABEM Gun) with frequencies of 1760 cps and 440 cps and coil separation of 200 feet was used in making measurements over a few mines to obtain more detailed information on subsurface conductive materials. These measurements were made 50 feet apart along traverses perpendicular to the inferred strike of the deposits. The effective depth of penetration of the measurements was between 100 and 150 feet.

A fluxgate vertical force magnetometer (Sharpe, Model MF-1) with a scale constant of 20 gammas per dial division was used in the magnetite investigations. Magnetometer measurements were made at stations 40 feet apart along traverses crossing the trend of mineralized zones. Observations were made at smaller intervals where anomalous conditions were found.

Electromagnetic investigations

Small electromagnetic variations were observed over the mineral occurrences. Dip-angles of magnitudes less than 10 degrees were common and rarely did they exceed 15°. Careful examination of the rocks indicated that most of these variations are probably associated with minor changes in conductivity of the country rock. This also is indicated in horizontal-coil data, which reveal only small in-phase variations and no significant out-of-phase anomalies. Typical electromagnetic profiles obtained over mines in the eastern and western parts of the region are shown in figures 2 & 3 for the Wadi Tha and Mindaha mines, respectively. The more pronounced indications of a good conductive source were found over the

Wadi Fig prospect. Dip-angles observed in this area are shown in figure 4.

Wadi Tha Mine: The area is underlain by altered volcanic rocks that form high ridges south of Wadi Tha (Fig. 2). These rocks are dominantly andesites with large masses of jasper and other iron-rich siliceous material. Small pods of limonite and some hematite are exposed in the gulleys. The main workings are in a small gossan near the crest of a prominent southward-trending ridge. Walls of the gossan are stained irregularly with malachite which also occurs in talus along the slopes and in creek beds.

Exploratory dip-angle measurements were made along traverses across the workings and around transmitter stations in the creeks (Fig. 2). Small changes in inclination of the electromagnetic field occur throughout the area, but no pronounced indication of subsurface conductors were observed. A very small dip-angle, whose cross-over occurs over intensely weathered rock, was observed in the southern part of traverses across the mine workings. This weak anomaly is attributed to greater conductivity of the weathered material.

Mindaha Mine: This mine was mapped in detail by C. W. Smith of the Ministry of Petroleum and Mineral Resources. The workings are in a narrow quartz-sericite gossan that lies in a series of greenschist with considerable andesite (Fig. 3). The schist is highly altered and has developed striking red and yellow colors. Foliation dips steeply and trends north-south. Small exposures of altered limestone and other sediments occur in the general area.

The exposed north-south trending ancient workings are about 500 feet long. According to reports, however, a large part of the mine is concealed by wadi sediments. The workings are scattered along the contact of an unaltered andesite porphyry dike with the schist. Gossan walls of the workings are stained with malachite.

Dip-angle and horizontal-coil electromagnetic measurements were made along eight traverses across the trend of the mine workings. The dip-angle data show minor inclinations with no pronounced indication of a subsurface conductive zone.

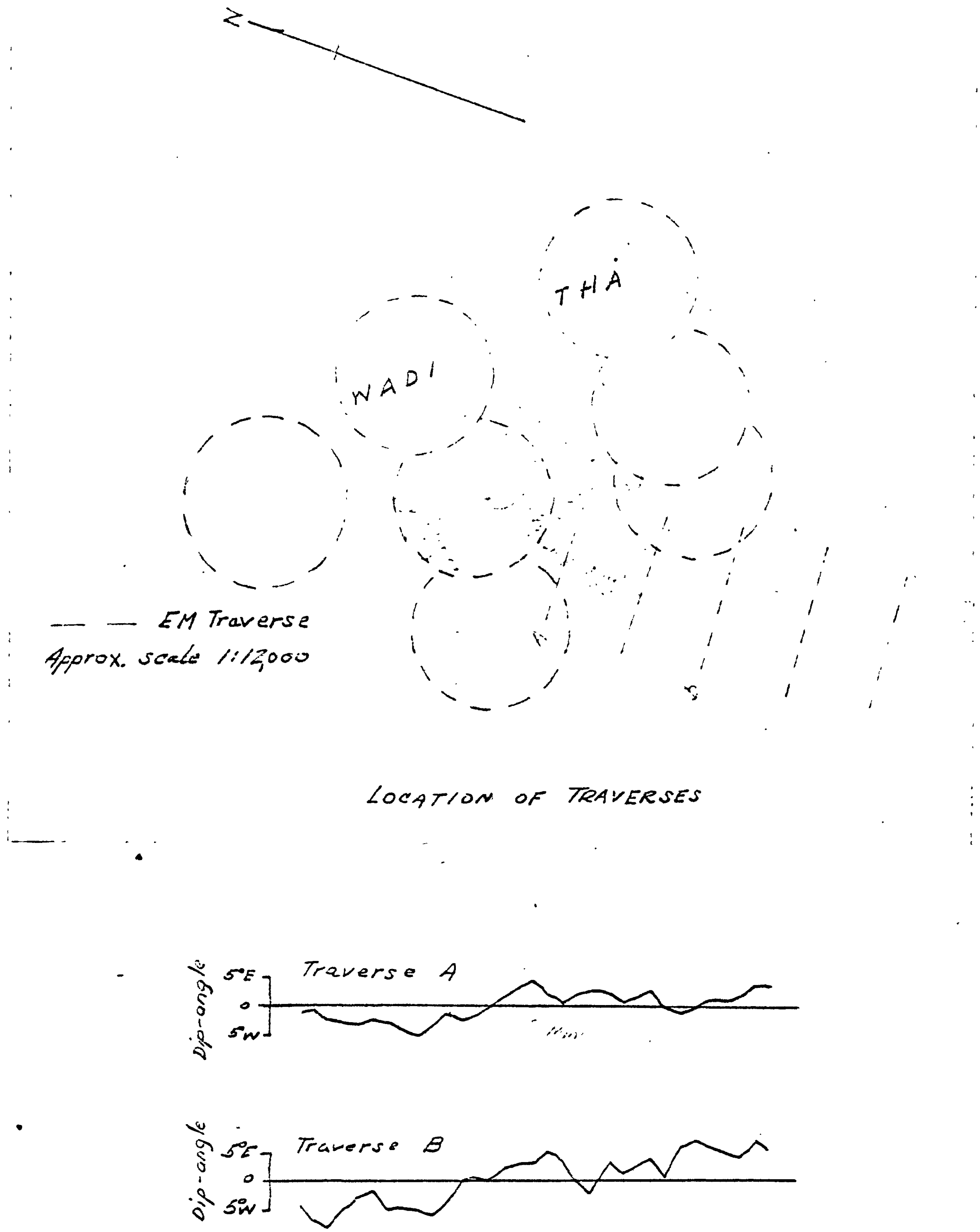


FIGURE 2. ELECTROMAGNETIC TRAVERSES AND PROFILES
WADI THA MINE AREA

The horizontal-coil measurements also show only weak electromagnetic response along the profiles. They reveal small in-phase variations and no anomalous out-of-phase field conditions. These small variations and the general lack of out-of-phase response strongly suggest that the mineralized zone is small and that the sulphide mineralization is highly disseminated.

Wadi Fig Prospect: The prospect is about one kilometer north of the Al Baha-Biljurshi road on the northwest side of the lower part of Wadi Fig. The area is underlain by chlorite schist and andesite which form low but prominent ridges near the wadi. Quartz veins and small zones of alteration are exposed along the ridges. Malachite stains and thin veins occur in parts of the schist.

Reconnaissance dip-angle measurements were made along six traverses with the transmitter placed at several locations (Fig. 4). These data reveal that a hidden conductive zone trends southward along the east side of a wadi in the central part of the area. The inferred trace of the zone is noticeably linear and lies near an andesite dike, which is in a narrow belt of weak alteration. Apparently the conductive zone continues southward out of the area mapped.

A study of these sparse data (Fig. 4) indicates that the anomalous source lies at shallow depths and dips steeply to the west. Magnitudes of the dip-angles range between 14° and 28° with the larger angles occurring along traverses B and D. The larger electromagnetic response probably represents the thicker parts of the conductive zone. The maximum depth to the top of the zone is estimated to be about 70 meters. Width of null data suggest that the source has moderate conductivity. Although the dip-angles are not large, we believe that their occurrence and apparent continuity warrants a more detailed investigation. Therefore we recommend that additional work be done in the area when geologic studies are resumed in the southern region this fall.

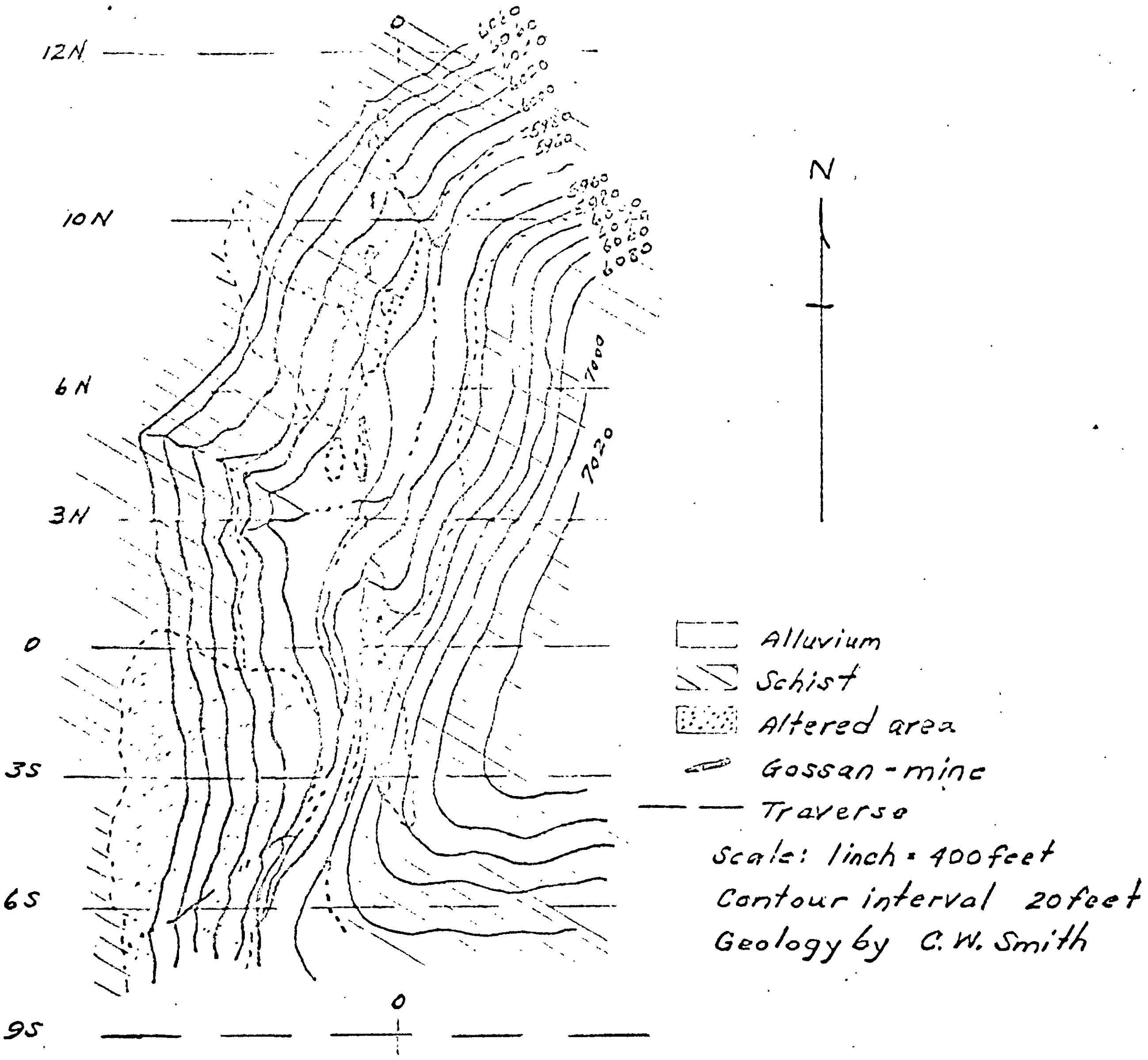
Magnetometer Investigations

Ground magnetometer measurements were made in the Camden area to define the source of a prominent total-intensity magnetic anomaly. This anomaly was observed in the aeromagnetic survey of the Al Mahawiyah region and was thought to have possible commercial significance. The ground magnetic data and results of a thorough examination of the rocks in the area reveal that the anomaly is associated with a large exposed mass of coarse-grained amphibolite which contains considerable magnetite.

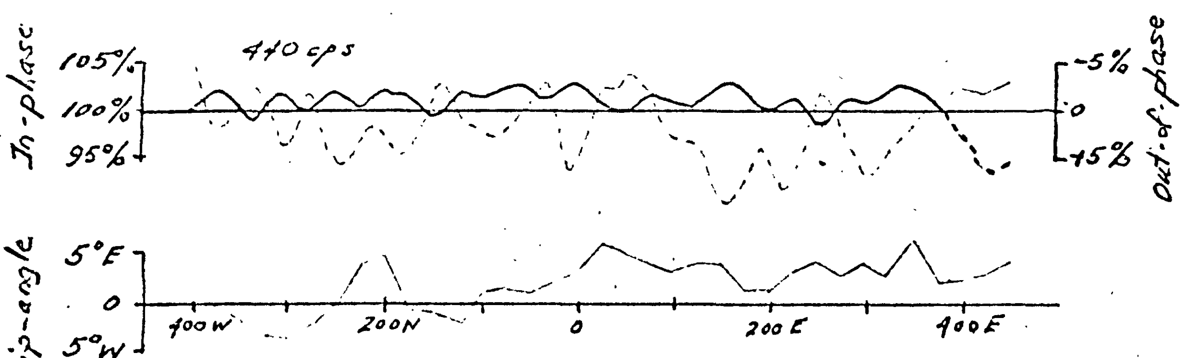
Magnetometer measurements also were made in the Wadi Tha, El Wakaban, Mindaha and Al Mahawiyah mine areas. Small magnetic anomalies of magnitudes generally less than 200 gammas and of limited areal extent were found. Examination of surface materials during the course of these investigations indicated that the anomalies are caused by minor concentrations of magnetite in the country rocks and do not seem to be related to the zones of mineralization.

Conclusion

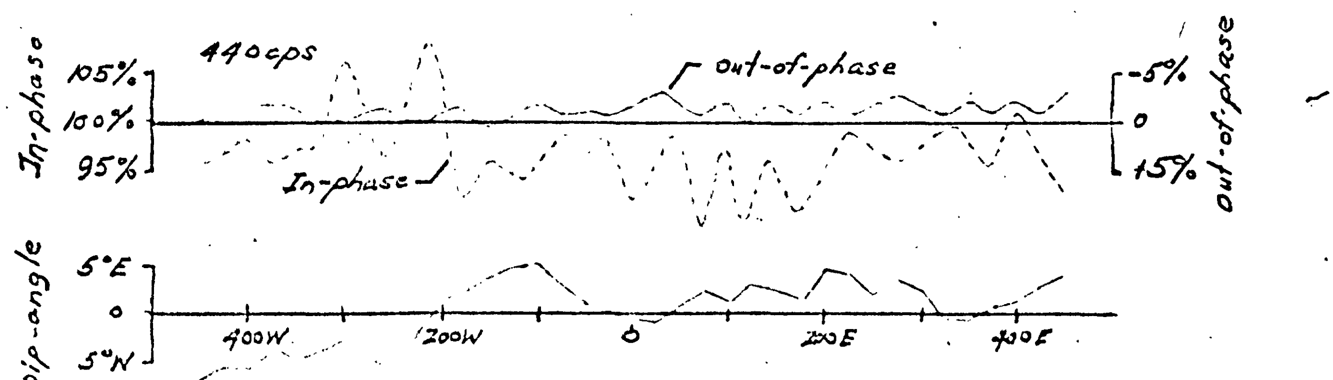
The results of this work indicate that no commercial deposits of massive sulphides occur near the ancient mines. Such sulphides, however, may be present in small quantities or may be too highly disseminated to be detected by electromagnetic measurements. Data from the Wadi Fig prospect reveal a hidden zone of moderate conductivity that may contain massive sulphides lying at relatively shallow depths. This prospect should be investigated more thoroughly when helicopter support is available. No commercial deposits of magnetite were found in the exploratory magnetometer surveys. The magnetic data do not show any anomalies that may serve as a guide in tracing the mineralized zones that were mined.



GENERALIZED GEOLOGIC MAP AND EM. TRAVERSES
MINDAHA MINE AREA

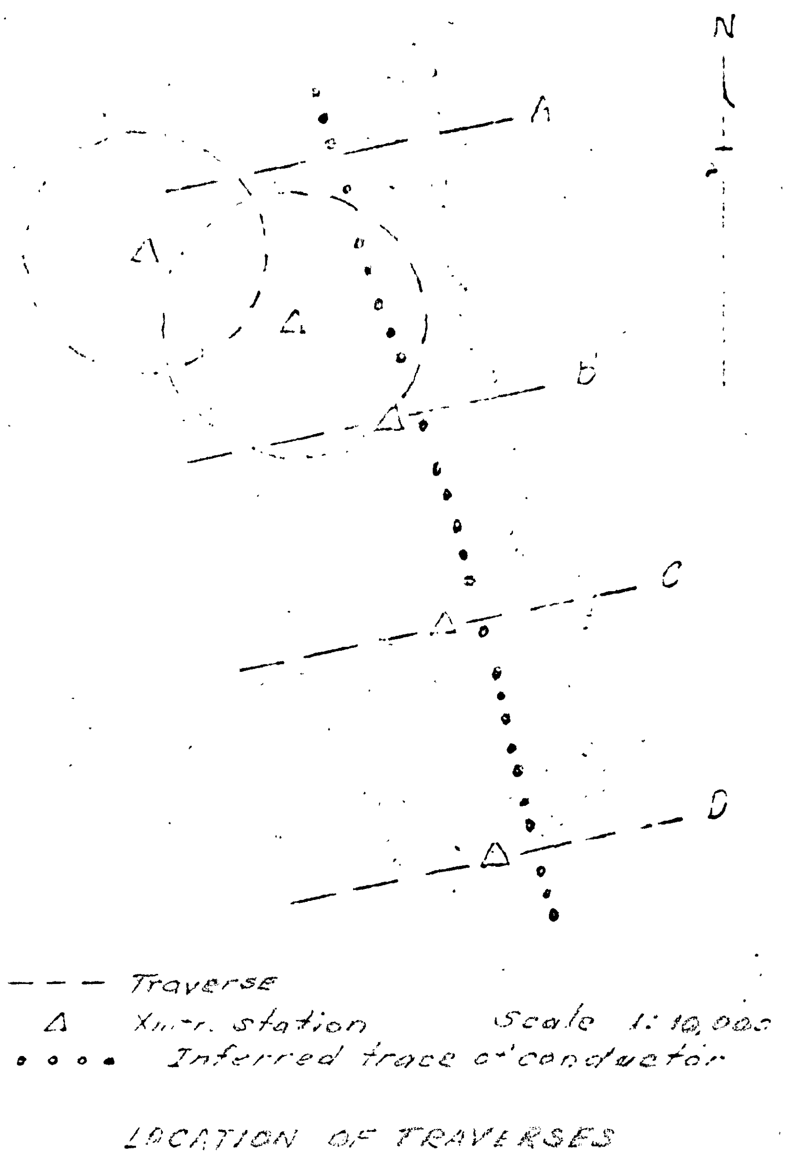


Traverse 6N



Traverse 0

FIGURE 3. ELECTROMAGNETIC TRAVERSES AND PROFILES, MINDAHA MINE AREA



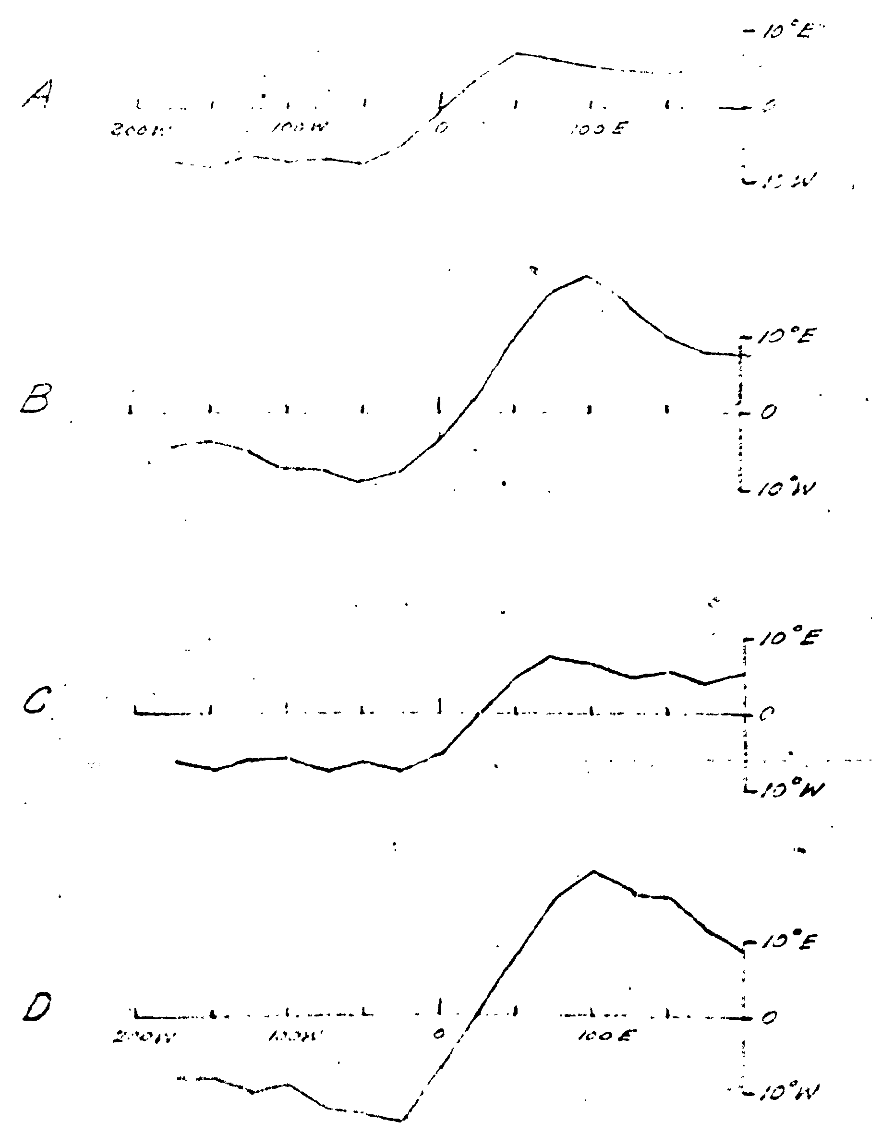


FIGURE 4. DIP-ANGLE PROFILES, WADI FIG PROSPECTS.

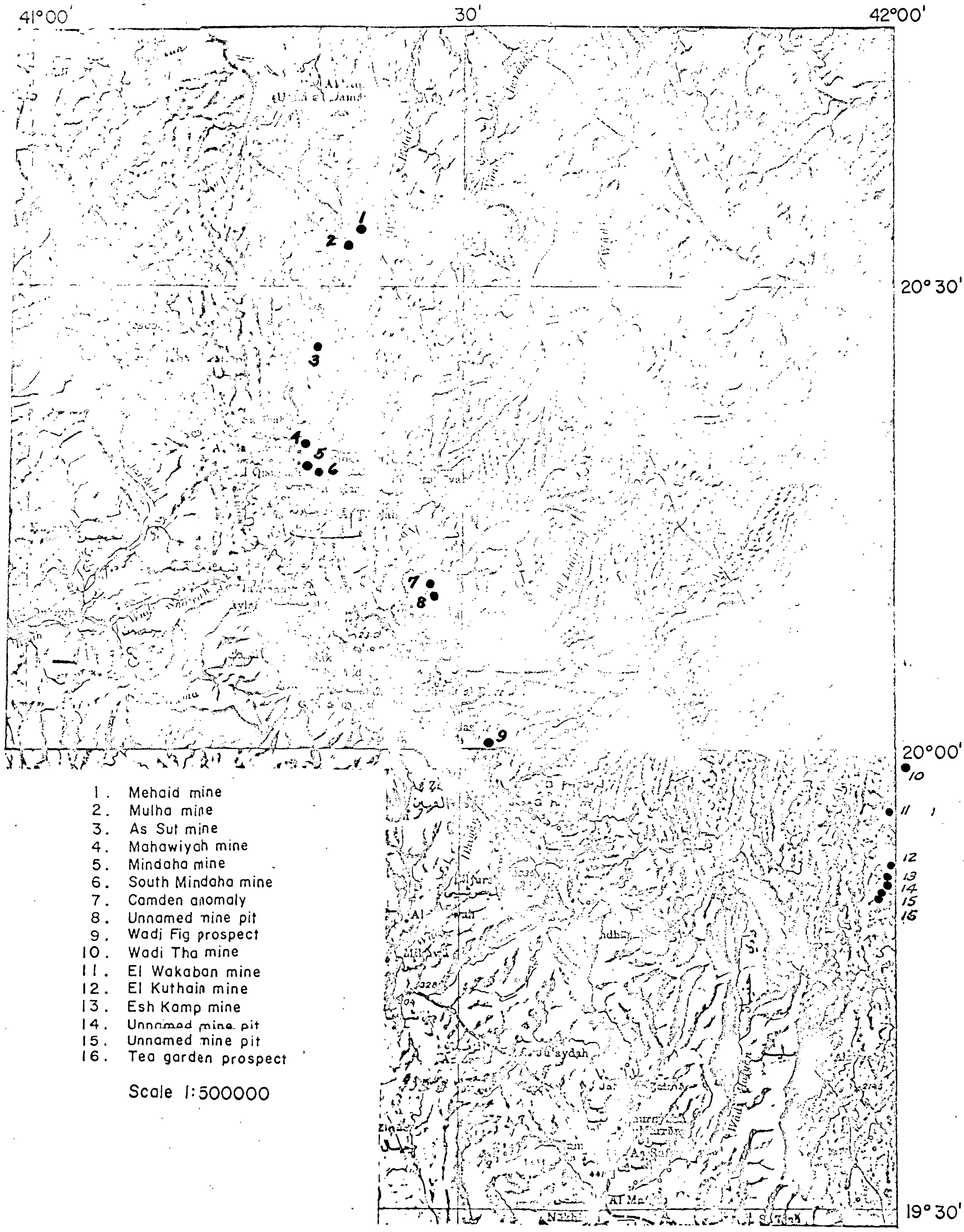


Figure 1: Location of ancient mines and prospects, Southern Hijaz