UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Technical Letter
Saudi Arabian Mineral
Exploration - 12
Prepared June 29, 1965
Issued August 20, 1965

Dr. Fadil K. Kabbani
Deputy Minister for Mineral Resources
Directorate General for Mineral Resources
Ministry of Petroleum and Mineral Resources
Jiddah, Saudi Arabia

Dear Dr. Kabbani:

Transmitted herewith are 10 copies of:

TECHNICAL LETTER NUMBER 12
GEOPHYSICAL EXPLORATION IN THE
JABAL SAMRAN AREA, SAUDI ARABIA

by

Willard E. Davis* and Rex V. Allen*

Sincerely,

Glen F. Brown

Glen F. Brown, Chief
Saudi Arabian Mineral Exploration Project

* U. S. Geological Survey, Jiddah, Saudi Arabia

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by

Willard E. Davis* and Rex V. Allen*

Abstract

Enclosed herewith is a preliminary report on the results of a geophysical investigation in the Jabal Samran area. As supplemental to the geologic mapping, this work was conducted mostly in the wadis where the country rock is concealed by alluvium.

Four subsurface conductive zones were detected and traced by reconnaissance and detailed electromagnetic measurements. The inferred trace of these zones correspond to the general trends of mineralized vein systems found in the geologic mapping.

Many of the dip-angle anomalies associated with the conductive zones are comparable to those that occur over massive sulphide deposits in Canada. Such correlation, however, does not consititute a reliable creterion for evaluating the economic significance of the anomalies. It is known that the electromagnetic response of similar conductors varies, geographically although they occur at similar depth in much the same geologic environment. The response depends largely upon the amount and kind of moisture contained in the rocks which may be controlled in large part by climate. Because of arid conditions in the shield of Saudi Arabia, we may expect that the electromagnetic response of conductors will be different than in Canada. Therefore, we have recommended

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that four of the strongest anomalies be test drilled, not only to determine their economic significance, but also to obtain information that will serve as a guide in the interpretation of EM data elsewhere in the shield area.

Introduction

A geophysical investigation was conducted in the Jabal Samran area as part of a geologic mapping and exploratory program undertaken by the Division of Mineral Resources of the Ministry of Petroleum and Mineral Resources. Reconnaissance and detailed electromagnetic measurements were made over alluvium filled wadis bordering the mountain (Fig. 1) to locate buried zones of altered rocks and to detect electrical conductors that may represent concealed deposits of massive sulphides.

Field work was done during the period of March 2, 1965 to May 25, 1965 by the authors, who were assisted briefly by Dr. Salah I. Tashin, Mr. Rashad H. Zeidan and Mr. Mohammed R. Hanif, Mr. Peter G. Curtis mapped the trends of inferred hidden conductors and Mr. Gene W. Harbert and Mr. Thomas E. Taylor established horizontal and vertical control for a base map of the area.

The area lies near lat. 22°18'N. and long 39°32'E. in the mountain front approximately 45 kilometers east of Tuwwal, which is about 87 kilometers north of Jiddah. The mountains rise to peaks more than 650 meters above the wadi floors, which in the west part of the area are about 210 meters above sea level and are separated by low ridges. Jabal Samran reaches an elevation of approximately 785 meters and its flanks are deeply incised by erosion. Creek beds in the wadis are dry, though a few small springs occur near the mountain. A well in the main wadi entrance to the area indicates that the water table lies a depth of about 8 to 10 meters.

The country rock consists of metasediments that have been highly altered and intruded by granite and cut by andesite dike swarms. Sericite and chlorite schist with conglomerate and marble crop out along the mountain slopes. All of the rocks have been intensely folded and faulted. Several ancient mine workings occur along the flanks of the mountain and near the crests of adjacent ridges. The mineralization appears in quartz veins and in zones of alteration near andesite dikes.

Electromagnetic Response of Natural Conductors

Electromagnetic systems detect all forms of anomalous electrical conductivity in the subsurface. Therefore, all anomalies are not caused necessarily by metallic deposits. A list of natural conductors in order of expected electromagnetic response is as follows:

1. Graphite
2. Graphitic shear zones
3. Massive sulphides
4. Specular hematite, massive
5. Continuous clay beds traversed 400 meters from transmitter
6. Disseminated sulphides (10% mineralization or more) except "sphalerite" which is a relatively poor conductor
7. Serpentinized ultra basic rocks
8. Saline water
9. Continuous clay beds traversed 120 meters from transmitter
10. Anthraxalite
11. Pyrolusite
12. Magnetite or other strongly magnetic materials give moderate reverse conductivity effects.

Electromagnetic horizontal-coil and vertical-coil methods are commonly used in searching for massive sulphide deposits. Data obtained by the horizontal-coil method must be corrected for differences in elevation between coils, therefore, this method is generally used in areas of low relief. The vertical-coil technique is not subject to elevation effects, and is more suitable for use in mountainous terrain.

Application of the horizontal-coil method is based on the fact that when an electrical conductor is subjected to a primary alternating field, a secondary current is induced in the conductor. This current develops a secondary alternating field which together with the primary field produces a resultant field of different amplitude and phase from the applied primary field. These differences, which are measured by the electromagnetic unit indicate the presence of a conductor.

In applying the vertical-coil electromagnetic method, the relative strength of anomalous eddy currents induced in a conductive medium compared to the signals received directly from the transmitter is determined by the amount of tilt in degrees that the combined electrical signal has from the horizontal. The magnitude of these eddy currents and hence, the amount of tilt are indicative of the amount of anomalous conductivity associated with the conductor. Typical tilt or dip-angle curves obtained over a concealed massive sulphide deposit lying below a depth of 12 meters are shown in figure 2.

Instruments and Field Techniques

A horizontal-coil electromagnetic unit (ABEM Gun) with operating frequencies of 1760 and 440 cps and a coil separation of 200 feet was used in making most of the reconnaissance measurements. Observations were made at intervals of 25 meters along traverses crossing the general trend of the zones of alteration. The effective depth of penetration of the measurements was between 100 and 150 feet. Owing to considerable local variation in conductivity of the country rock the unit could not be calibrated accurately. Therefore, this equipment was not used in detailed phases of the investigation.

Vertical-coil electromagnetic dip-angle equipment with a 500 watt generator and operating frequency of 1100 cps (Sharpe, Model SE 100) was used in the detailed studies. Trends of conductive zones inferred from the reconnaissance data were established by means of the vertical-coil equipment. Dip-angle data were then obtained at stations 12.5 meters apart along traverses spaced 50 and 100 meters, generally crossing the trends of conductive zones at right angles. These measurements were made with the transmitting coil over the conductive zone and the receiving coil along traverses 100 to 300 meters from the transmitting source. This arrangement gave an effective depth of penetration about equal to half the distance between the transmitting and receiving coils. The traverse lines were laid out by means of compass and tape and stations were indicated by rock monuments.

Reconnaissance Survey

Reconnaissance electromagnetic measurements were made along traverses 1 and 20 near the edges of the "airstrip wadi", along traverse 2 in the "camp wadi," along traverses 14, 15, 16 and 60 in wadis near the base of the mountain, and along traverses 17, 18, and 19 in the northeastern part of the area. (Fig.1). These data revealed prominent anomalies in localities labeled A, B, C, D, and E on the accompanying map. The data obtained along traverses 14, 15, and 16, which cross the trend of a small mine in a low ridge near the mountain, do not indicate the presence of a conductor. Reconnaissance dip-angle measurements with the transmitter over the mine workings also did not reflect a hidden continuation of the ore deposit.

Detailed Surveys

Locality A

West of the main camp site, dip-angle measurements were made along 10 traverses perpendicular to a base line trending S.12°W. across the "airstrip wadi" (Fig.3). The data reveal that a hidden conductive zone extends southwesterly from a central hill to a belt of alteration that is exposed in hills on the southwestern side of the wadi. The inferred trace of the zone lies in the western part of the altered belt and appears to be offset at several places along its course, which suggests that the conductive medium probably has been displaced by faulting or folding.

An analysis of the dip-angle curves (Fig.3) and width of the null points indicates that the anomalous source has good to moderate conductivity, and lies at fairly shallow depths. Magnitudes of the dip-angles range between 28° and 48°, and corresponding to the variation in conductivity, these angles are greater in the northern part than in the southern part of the zone. Most of the curves are asymmetrical, which suggests that much of the conductive source dips steeply to the west. The parts having maximum dip are inferred to underlie traverses 21, 22, and 28. The asymmetry in curves along traverses 25 and 26 may be caused partly by the presence of another conductor west of the base line on traverse 25 and by elevation effects along traverse 26, which crossed the central hill. The general small decrease in angles beyond the maxima and minima points of the curves may be caused by comparatively moderate conductivity in the host rock or overburden. Distances between the points indicate that the conductor lies at greater depths in the northern part of the wadi than in the southern part. North of traverse 28, the maximum depth to the top of the conductive source ranges between 70 and 80 meters. Southward the maximum depth is between 50 and 65 meters.

Locality B

The electromagnetic anomaly found in this locality was investigated by dip-angle measurements made along the eastern part of traverses in Locality A and along a group of traverses continuing northward across the "camp wadi" (Fig.4). These measurements indicate that a concealed conductive zone passes along the east side of the central hill and continues across the "airstrip and camp wadis." The axis of the zone has about the same general trend as that of the conductive zone in Locality A and is similarly displaced in several places.

A study of the data indicates that the conductive source varies in conductivity and lies below depths ranging from 37 to 75 meters. The most conductive parts of the zone are inferred to lie near the central hill and near traverses 30 and 32 in the southern part of the "airstrip wadi." Auxiliary conductors occur west of the main zone. These are prominently expressed in the curves along traverses 21, 25, 32 and 44. Most of the main conductor dips steeply to the west though the dip seems to decrease in magnitude away from the central hill. Asymmetry in the curves of traverses 36, 52, and 54 suggest that the zone dips eastward in those parts of the wadis. The conductive source lies in the western part of a belt of altered rocks that crop out along the east side of the hill and in the adjoining wadi floor. General high dip-angles along the east part of traverses in this part of the area suggest the presence of a broad zone of fairly conductive host rock.

Locality C

A detailed investigation was made of an anomaly found by horizontal-coil measurements near the bend in the "airstrip wadi" (Fig.5). Results of the work indicate that a zone of moderate to weak conductivity trends eastward from the southern end of the conductor in Locality B to a point near the hills on the north side of the wadi. The irregular character of the dip-angle curves suggests that the zone consists of more than one conductor. These are best expressed in curves of traverses 68 to 72. The conductive sources are inferred to be widely separated and in this part of the area they probably constitute the more conductive part of the zone. An effort was made to map these sources individually but the attempt was not successful, because of disturbance in the induced magnetic field caused by the near proximity of the conductor in Locality B.

The magnitudes of dip-angles associated with the conductive source marked by cross-over points in the curves range from 20 to 35 degrees. Maximum depths to the top of the anomaly source in the more conductive part of the zone are estimated to be between 25 and 56 meters. The width of null data indicate that the source beneath traverses 69 to 71 is moderately conductive; elsewhere the source is inferred to be less conductive.

Locality D

Electromagnetic dip-angle data were obtained along 14 traverses in the eastern part of the "airstrip wadi" (Fig.6). These data reveal a hidden conductive zone trending southwestward from hills near the east end of the wadi to the mouth of a canyon south of the main bend in the wadi. The inferred trace of the zone is irregular and appears to lie in the northern part of a belt of altered rocks exposed in hills near the east end and along the southside of the wadi. Except in the western part of its course, the trace cuts across the drainage pattern of the wadi.

A study of the data indicates that the top of the conductive source lies at shallow depths and that good conductivity occurs in the eastern and western parts of the source. The magnitudes of the dip-angles range from 22° to 52°. Estimated maximum depths to the top of the source in the eastern part of the wadi are between 31 and 62 meters. In the western part, these depths range from 19 to 32 meters. The width of null data suggest that the host rock or the overburden in the north-central part of the zone is fairly conductive, which may be caused by water. In the western part, the conductor axis coincides with drainage of the canyon. However, we believe that the dip-angles are much too large to be caused by water in the subsurface. Throughout the zone the anomaly source is inferred to dip steeply northward with greater dip occurring in the central part of the zone.

Locality E

A brief dip-angle survey was made over a conductive zone detected by reconnaissance measurements near a mine in the northwestern part of the area (Fig.7). Results of the survey revealed prominent dip-angles that are inferred to mark the trace of a concealed conductor in a narrow wadi or canyon near the main adit of the mine. The conductor lies in a major fault zone which passes through the canyon and cuts across the eastern flank of the mountain. The zone trends NW - SE almost at a right angle to the general strike of mineralized veins in the mine and other ancient workings near the crest of a ridge to the southwest.

An analysis of the data (Fig.7) indicates that the top of the anomalous source lies at shallow depths and that the source is highly conductive. Magnitudes of the dip-angles range from 43° to more than 83°. Those over the northwest part of the conductive zone are uncommonly large and are greater than the range of the inclinometer. Maximum depths to the top of the conductor are estimated to be between 20 and 38 meters with the shallowest depths occurring in the southeast part of the surveyed area. The width of null data suggests that the conductivity of the zone is similar to that of massive sulphides and other highly conductive minerals. We infer from the asymmetry in the curves that the conductive zone dips steeply the west with the dip decreasing southward. The rapid decrease in angles beyond the maximum and minimum points of the dip-angle curves indicates that the conductive source probably is confined to the fault zone and that it does not consist of barren moist brecciated material that may be expected to extend to great depths. The conductor was not traced completely, however, auxiliary measurements indicate that the source continues for a considerable distance beyond the limits of the survey.

Test Drilling

Several of the dip-angle anomalies observed in this work are inferred to be the electromagnetic expression of good conductive zones in the subsurface. These anomalies are comparable to those that occur over massive sulphide deposits in Canada. Therefore, we recommend that the anomalous zones be test-drilled. The drilling should be done at the following locations:

Locality A -

Position: On traverse 21; 60 meters west of base line; inclined 45°, bearing S 78°E.

Comment: The top of the conductor is inferred to lie beneath the traverse about 25 meters east of the base line at an estimated maximum depth of 70 meters. The maximum slant depth or length of hole should be about 115 meters. Hole will have to be started in alluvium.

Locality B -

Position: On traverse 25; 165 meters east of base line; inclined 45°, bearing S 78°E.

Comment: Top of conductive zone lies about 75 meters to the east at a maximum depth of 44 meters. Slant depth or length of hole should be about 100 meters. Drilling will begin in rock outcrop.

Locality D -

Position: On traverse 5.25; 150 meters northwest of baseline; inclined 45°, bearing S 35E.

Comment: At this location, drilling will begin in solid rock. Top of the conductor probably lies about 65 meters to the southeast at an estimated maximum depth of 39 meters. Slant depth or length of hole should be about 90 meters.

Locality - E

Position: On traverse J; 70 meters east of base line; inclined 45°, bearing S 82°W.

Comment: Top of conductor is inferred to lie about 50 meters to the west at a maximum depth of 38 meters. Slant depth or length of hole should be approximately 75 meters. Drill site is on exposed country rock.