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REPORT ON EXPLORATION OF THE WADI YIBA COPPER PROSPECT, TIHAMAT ASH SHAM QUADRANGLE, KINGDOM OF SAUDI ARABIA

by

Robert L. Earhart
U. S. Geological Survey

U. S. Geological Survey
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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 Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government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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REPORT ON EXPLORATION OF THE WADI YIBA COPPER PROSPECT, TIHAMAT ASH SHAM QUADRANGLE, KINGDOM OF SAUDI ARABIA

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ABSTRACT

The first phase of an exploration program at the Wadi Yiba copper prospect consisted of geologic mapping, prospecting, sampling, geophysical surveys, and diamond drilling. Copper mineralization is in a sedimentary rock sequence comprised mostly of siliceous, calcareous, and dolomitic rocks metamorphosed to the greenschist facies. The metasedimentary rocks are overlain and underlain by metavolcanic rocks. They are folded into a tight north-plunging syncline transected by two fault systems.

Results from the exploration program indicate that a fault zone which sub-parallels the synclinal axis and cuts siliceous dolomite contains copper mineralization and small amounts of gold and silver. Copper and silver bearing pyroclastic rocks were found in the upper part of the metasedimentary rock sequence. Concentrations of copper mineralization seem to be restricted to particular rock units in the metasedimentary rock sequence. Primary sulfides have not been encountered in the drill holes to date and the results from one drill hole indicate secondary copper sulfide minerals to a vertical depth of 60 meters. Further exploration seems to be warranted and a program is proposed which includes the investigation of other mineral occurrences and geophysical anomalies in the region.

INTRODUCTION

Purpose and scope of the report

Detailed studies of the Wadi Yiba copper prospect involving geologic mapping, prospecting, sampling, helicopter borne geophysical surveys, and diamond drilling were conducted from November 1967 to April 1968. This report presents the results from these investigations and makes recommendations for further detailed exploration.

The prospect contains a large number of individual copper localities, many of them minor, over a broad area. The present investigations were not designed to closely delimit any particular mineralized zone nor to establish ore probability. There is a need to gather more preliminary data before these problems can be considered.

The objectives of the investigators during the first phase of the exploration program have been to (1) locate all mineral localities which crop out in the prospect area, (2) study the relationships of the mineral occurrences to each other, (3) discover how the mineral occurrences fit into the overall geologic framework, and (4) to obtain some idea of the type and grade of economic minerals present.

Location and accessibility

The area under detailed investigation covers about 15 square kilometers in the vicinity of lat. 19°10' N. and long. 41°49' E. (fig. 1). Wadi Yiba is a major drainage in the region and is located about 5 kilometers west of the prospect area. It empties into the Red Sea 15 kilometers south of the port of Al Qunfidhah approximately 70 kilometers to the west of the report area. A transportation route between the report area and the Red Sea port could parallel the course of Wadi Yiba. The area is connected to Jiddah to the north and Jizan to the south by unpaved roads. Landing strips suitable for bush-type aircraft are located at the copper prospect and 17 kilometers to the south.

Geography and geomorphology

The report area is in an interior drainage basin in the coastal region of southwestern Saudi Arabia. North-trending mountains with maximum elevations of about 1000 meters lie 12 kilometers west of the report area and the Red Sea escarpment is 25 kilometers to the east. The elevation at the top of the escarpment is approximately 2000 meters. Elevations within the prospect area range from about 250 to 350 meters. The area receives drainage from both the east and the west and as a result the water table is shallow and the larger wadis maintain perennial flow. The major wadis flow to the south and southwest and eventually empty into the Red Sea. The area is subject to flash floods in the winter and spring months as a result of heavy rainfalls at higher elevations.

The grazing of sheep and goats is the principal industry of the region and small areas by some of the wadis support minor agriculture.

Previous investigations

The geology of the Wadi Yiba area is shown on the Tihamat ash Sham quadrangle map (Brown and Jackson, 1958). Copper mineralization in the region was first noted by Jackson (personal communication) during a field trip in 1953. Mineral reconnaissance of the area was conducted in March 1967 (Earhart, 1969). Geophysical surveys using ground electromagnetic methods were included in the reconnaissance investigations (Davis and Akhrass, 1967).

Acknowledgements

Acknowledgement is due the Minister of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia and his staff for providing logistical support and encouragement. The author is especially indebted to Mr. Abdullah Abu-Annaja and Mr. Ishmael Husseine, geologists employed by the Ministry of Petroleum and Mineral Resources, for their contribution to the work. Mr. Abu-Annaja mapped Area 1 as part of a counterpart training program and gave strong support to the other phases of the work. Mr. Husseine demonstrated great ability in the operation of the plane table and alidade and was always available for consultation.

The author also wishes to acknowledge Mr. Eino Raisanen who supervised the diamond drilling, and Dr. George Sander and his assistants who performed the geophysic survey of the Wadi Yiba area under contract to the U. S. Geological Survey.

Mr. Ghanem Geri, a guide and professional prospector employed by the U. S. Geological Survey, made important contributions to the prospecting phase of the progra

PRESENT INVESTIGATIONS

Geologic mapping

The general geologic map (fig. 1) is taken from the original reconnaissance map (Earhart, 1969a,b) and modified as more information became available from detailed mapping. Large scale geologic maps have been made of selected parts of the area by plane table and alidade, and pace and compass methods.

The map of Area 1 (fig. 2) defines the surface expression of copper mineralization associated with siliceous dolomite and quartz-chlorite schist in that area. A second objective in mapping this area was to further the knowledge of the sedimentary rock sequence.

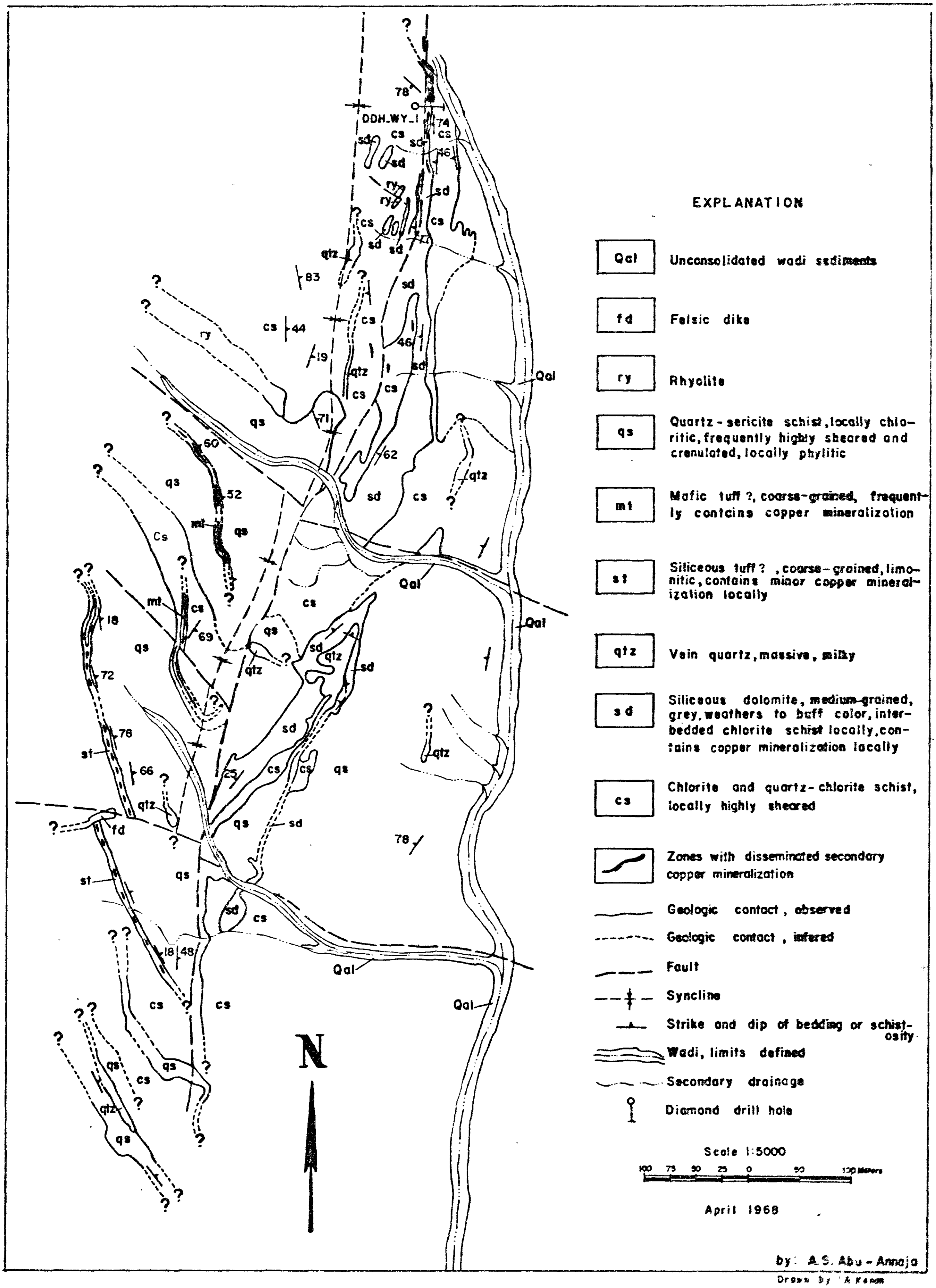


FIGURE 2.- Geologic map of Area I, Wadi Yiba copper prospect.

Outcrop maps of Areas 2 and 3 (figs. 3 and 4), made by pace and compass methods, define the surface expression of copper bearing zones, record the location of rock samples, and provide the surface data necessary for planning diamond drill hole locations and orientations.

Prospecting

The rocks of the area were prospected for indications of sulfide mineralization during reconnaissance traverses at the beginning of the program. This led to the discovery of copper mineralization in pyroclastic rocks in the upper part of the metasedimentary rock sequence. Prospecting was extended for 85 kilometers beyond the limits of the report area and included the known strike extent of the metasedimentary rock sequence. This resulted in locating other areas of copper mineralization.

Sampling

A total of 101 grab samples were collected from outcrops during mapping and prospecting. A total of 182 samples from diamond drill core were collected.

In the outcrop map areas grab samples from obviously mineralized zones were collected along intervals of approximately 20 meters where the frequency of outcrops permitted. Random grab samples were collected from outcrops which did not contain obvious copper mineralization, and an attempt was made to sample all of the rock types present.

All of the core was taken for samples from the minor amount of small diameter core recovered with a hand portable drill in some holes. The core from the other drill holes was split and one half was used for the sample and the other half was retained for future reference.

All of the samples were analyzed for copper, gold, and silver. Most of the samples were analyzed for zinc and a few were tested for lead. The samples were

ANALYSIS DATA

Cu in weight percent
Gold and silver in ounces per ton

Sample No.	Cu	Au	Ag
37477	.0063	Nil	Nil
37478	.0036	"	"
37479	.35	"	<.04
37480	.0009	"	<.04
37481	.162	"	Nil
37482	.48	"	<.04
37483	1.28	"	.066
37484	.81	"	<.04
37485	.25	"	<.04
37486	.0018	"	Nil
37487	.0475	"	"
37488	.0214	"	"
37489	.25	"	.04
37490	.79	"	.046
37491	.027	"	Nil
37492	.83	.004	.072
37493	.0176	.23	Nil
37494	.89	Nil	.08
37495	.0183	"	Nil
37496	.0003	"	<.04
37497	.0140	"	<.04
37498	.0130	"	<.04
37499	.0300	"	<.04
37500	.0012	"	<.04
37501	.0009	"	<.04
37502	.0100	"	<.04
37503	.0009	"	<.04
37504	.0023	"	<.04
37505	.0040	"	<.04
37506	.40	Nil	<.04

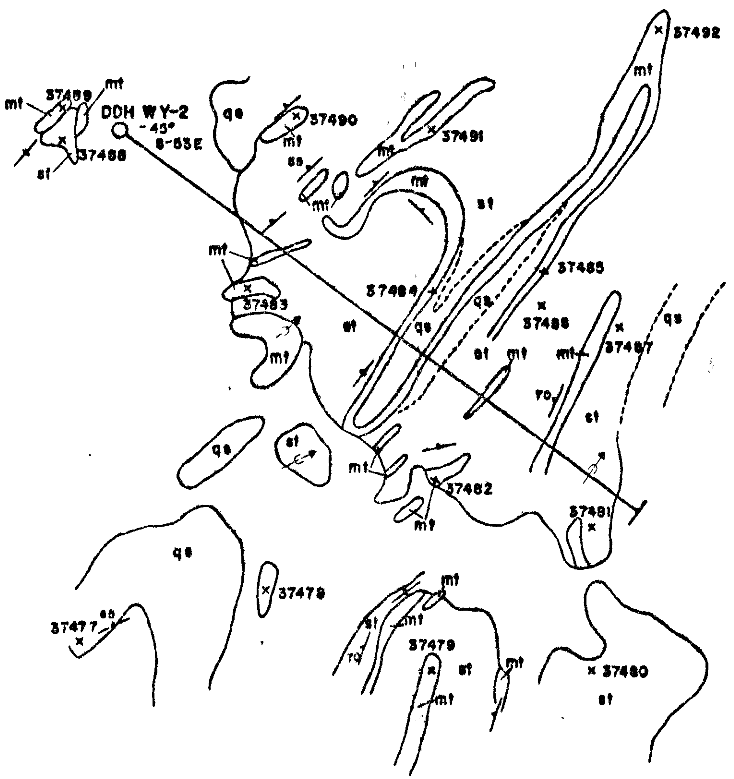
N

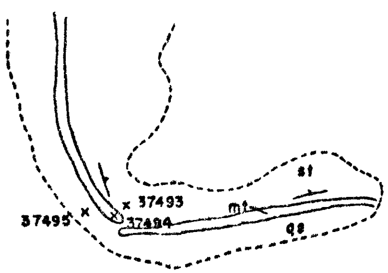
37496 37497 37498 37499 37500 37501 37502 37503 37504

Quartz sericite schist; sericite-chlorite schist; tuff and rhyolite; no apparent copper mineralization

37505
37506

Shear zone





EXPLANATION

qs — Quartz-sericite schist and sericite-chlorite schist, locally porphyroblastic

st — Siliceous-sandy tuff; fine-to coarse-grained; bedded; locally contains malachite

mt — Siliceous-mafic tuff(?), forms hard, resistant rib-like outcrops; may include some ophitic dike material; locally contains malachite and secondary copper sulfides

Limit of outcrop

Area of numerous small outcrops

Strike and dip of bedding or schistosity

Strike of vertical bedding or schistosity

Vertical projection of diamond drill hole

37500 × Sample location and number

Anticline, showing plunge

Syncline, showing plunge

Shear zone

Scale 1:2000

50 25 0 25 50 Meters

April 1968

Drawn by. I.A. Kenan

FIGURE 3.- Outcrop map of Area 2 showing sample and drill hole location

ANALYSIS DATA

Copper in weight percent
Gold and silver in ounces per ton

Sample No.	Cu	Au	Ag	Sample No.	Cu	Au	Ag
37404	.03	Nil	Nil	37449	.22	Nil	Nil
37405	.108	"	"	37450	.0011	"	"
37406	.345	"	"	37451	.93	"	∠.04
37407	.62	"	"	37452	.014	"	Nil
37408	.144	"	"	37453	.91	"	∠.04
37409	.024	"	"	37454	.38	"	∠.04
37410	.176	"	"	37455	.006	"	Nil
37411	2.28	"	"	37456	.004	"	∠.04
37412	.48	"	"	37457	Sample	lost	
37413	.132	"	"	37458	1.40	Nil	∠.04
37414	.278	"	"	37459	.015	"	Nil
37415	.78	"	"	37461	.0045	"	"
37416	.016	"	"	37462	.17	"	.046
37417	.009	"	"	37463	.04	"	Nil
37419	.91	"	"	37464	.0044	"	"
37420	.008	"	"	37465	.0011	"	"
37421	.003	"	"	37466	.0108	"	"
37422	.097	"	"	37467	.0019	"	"
37423	.29	"	"	37468	.0025	"	"
37424	1.00	"	"	37469	.0180	"	"
37425	.076	"	"	37470	.21	.079	.08
37426	.0025	"	"	37471	.0048	Nil	Nil
37427	.009	"	"	37472	.069	"	.04
37428	.053	"	"	37473	.092	"	.137
37429	.375	"	"	37522	2.00	"	.10
37430	.009	"	"	37523	.08	"	∠.04
37431	.20	"	"	37524	1.20	"	.54
37432	.06	"	"	37525	.02	"	∠.04
37440	.0015	"	∠.04	37526	.07	"	∠.04
37441	.0013	"	Nil	37527	2.50	"	.04
37442	.0026	"	"	37528	1.50	"	.57
37443	.285	"	"	37528 A	.44	"	.117
37444	.012	"	"	37529	1.00	"	.43
37445	.010	"	"	37530	2.50	Nil	.86
37446	.010	"	"				
37447	.114	"	"				
37448	.24	Nil	Nil				

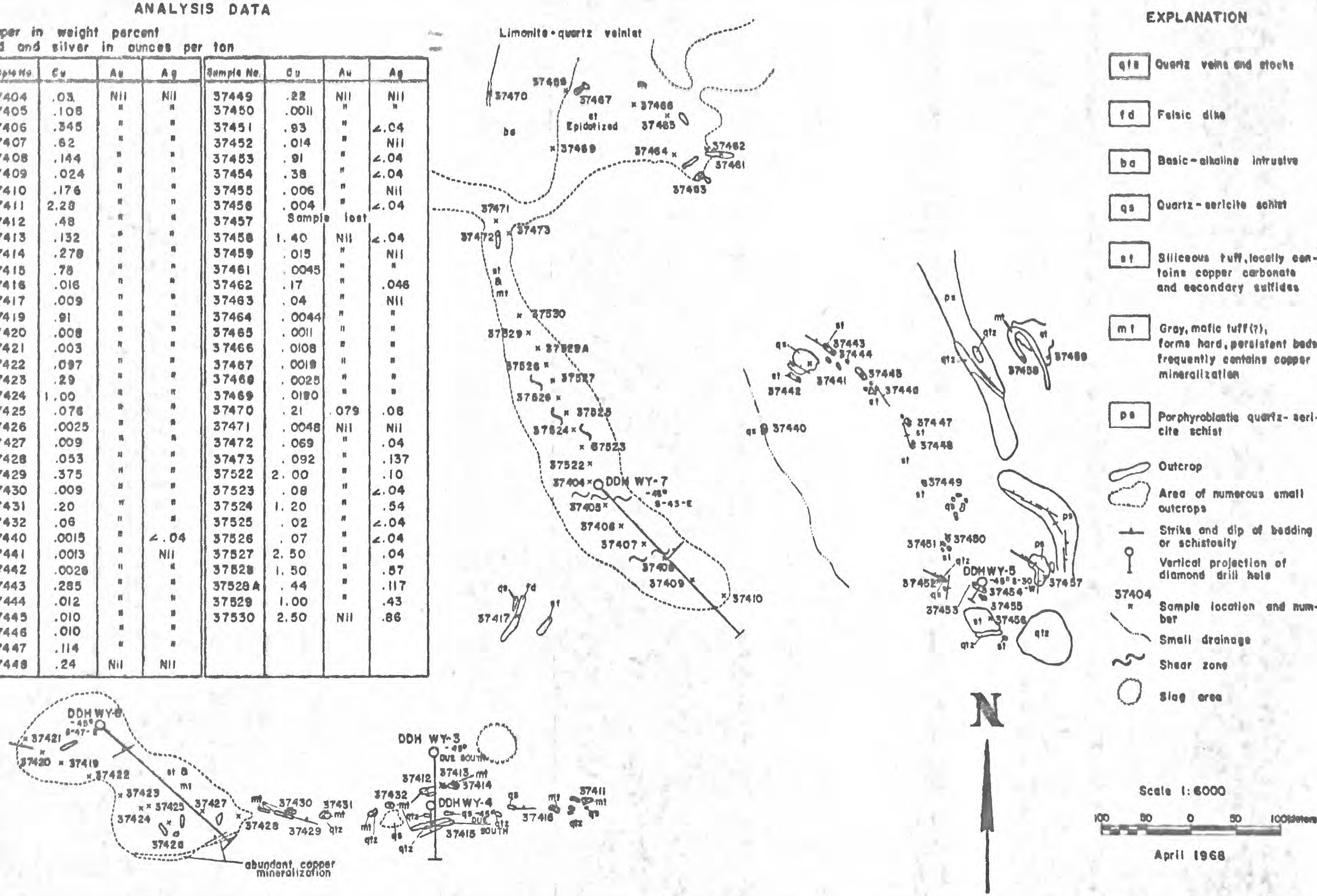


FIGURE 4.- Outcrop map of Area 3 showing sample and drill hole locations

assayed in the laboratories of the Ministry of Petroleum and Mineral Resources by atomic absorption, spectrographic, and colorametric methods. Elements from selected samples were analyzed by more than one method.

Geophysics

Results from electromagnetic (EM) surveys conducted by W. E. Davis during reconnaissance investigations at Wadi Yiba indicated that the rocks may be responsive to this geophysical method. A more extensive EM survey was therefore planned and included in the exploration program. In addition to the EM survey, a magnetometer (MAG) survey was also planned as a further aid to prospecting and to help resolve geological problems. A helicopter borne combined EM-MAG survey was conducted over the Wadi Yiba copper prospect area and along the strike of the metasedimentary rock sequence contiguous to the copper area. Approximately 2500 kilometers of line were surveyed.

Diamond drilling

The objective of the first stage of the diamond drill program was to test widely spaced mineral occurrences at shallow depth. Five holes totaling 544 meters were drilled with a Joy model 12B drill, and a rock core 30 mm in diameter was recovered. Core recovery for these five holes averaged 77.4 percent. Two holes totaling 38 meters were drilled with a small hand portable drill and approximately one third of the core was recovered. The use of this small drill was discontinued because of mechanical problems with the drill and poor core recovery. Water used for drilling purposes was taken from the wadis at a maximum distance of about 1 kilometer from the drill sites.

Drill hole locations were widely spaced over approximately 2.5 kilometers. The locations are shown on Figures 2, 3 and 4. All holes were drilled at -45° in the opposite direction to the dip of the rocks and approximately normal to strike. Inclinations were tested at depth by the acid tube method and the maximum variation from the intended angle measured 8 degrees.

GEOLOGIC SETTING

The rocks of the Wadi Yiba copper prospect area consist of highly folded metasedimentary rocks overlain and underlain by predominantly metavolcanic rocks. The rocks are transected by two systems of faults. The youngest faults strike northerly and sub-parallel to the foliation and bedding in the metasedimentary rocks. These displace an older, westerly trending set of cross-cutting faults.

The metamorphic rocks are intruded by a porphyritic and pegmatitic basic alkaline rock, peralkaline granite, numerous quartz veins and stocks, and minor rhyolite and pink feldspar dikes. These rocks comprise part of the Arabian segment of the African Precambrian shield.

Volcanic rocks which underlie the metasedimentary rock sequence are metamorphosed to the greenschist-amphibolite facies. Metamorphism has not advanced past the chlorite-sericite-epidote-actinolite sub-facies in the sedimentary and overlying volcanic rocks. Peralkaline granite does not appear to be metamorphosed and is believed to be the youngest major rock type in the area.

The metasedimentary rocks and overlying volcanic rocks are separated from older volcanic rocks by a major north trending fault in the eastern part of the map area (fig. 1). West of the fault, the rocks which predate the peralkaline granite are folded into a north plunging syncline which is the major structural feature of the area. The syncline is offset by westerly trending faults which are believed to represent the oldest faults present. Later folds superimposed on those related to the synclinal structure reflect movement on both the west and north trending fault systems. In general, the rocks are highly sheared and contain numerous secondary fold structures.

STRATIGRAPHY

Older metavolcanic rocks

Pillowed meta-andesite and pyroclastic rocks of equivalent composition, comprising part of a thick volcanic pile, are believed to represent the oldest rocks present. They are exposed in the extreme eastern part of the area under investigation. The metavolcanic rocks are separated from metasedimentary rocks to the west by a northerly striking fault.

Metasedimentary rocks

The metasedimentary rock sequence consists mostly of siliceous, micaceous, calcareous, and dolomitic rocks, and includes minor amounts of mafic tuff(?). The latter is an important rock type in that it sometimes contains copper mineralization. The stratigraphic thickness of the metasedimentary rock sequence is believed to be approximately 700 meters; the thickness is difficult to determine accurately because the rocks are deformed and repeated by folding and faulting.

The lower part of the metasedimentary rock sequence is comprised of quartzite, limey quartzite, siliceous and micaceous schist, and ferruginous sandstone. The The quartzite and limey quartzite form a high ridge along the west limb of the syncline. Siliceous and micaceous schists crop out on the east limb of the syncline, and thin-bedded ferruginous sandstone or poorly developed iron formation is exposed a short distance to the south of the map area (fig. 1) on the east limb of the syncline. The quartzite and siliceous, micaceous schist are overlain by siliceous carbonate.

Siliceous carbonate comprises the middle part of the metasedimentary rock sequence. This rock unit is referred to on maps and elsewhere in this report as siliceous dolomite. Its composition ranges from siliceous limestone to siliceous dolomite, and 'siliceous dolomite' is intended as a general term. Quartz-chlorite schist is interbedded with the siliceous dolomite and is erratically distributed. The width of the schist beds is highly variable along short strike distances.

Siliceous dolomite forms resistant ridges 30 to 100 meters high on both limbs of the syncline. It weathers to a tan or dark brown color and the more highly iron and magnesium rich parts are conspicuous in that they weather to a darker, rusty color. The stratigraphic thickness of the siliceous dolomite is believed to be less than 100 meters, but it is repeated several times by folding and faulting, and where it forms the nose of the syncline, it is drawn out and attenuated for nearly 5 kilometers to the south of the area in Figure 1. Interbedded quartz-chlorite schist and schistose rocks which overlie the siliceous dolomite commonly contain carbonates of calcium, iron, and magnesium as inclusions and it is probable that these interbedded and overlying rocks were deposited at the same time that siliceous carbonate was being precipitated.

Siliceous dolomite is overlain by foliated rocks which form the upper part of the metasedimentary rock sequence. Felsic schists are most common, although narrow bands of mafic schists are included. Both types of schist are believed to contain detrital volcanic material. Bedded siliceous tuff, minor amounts of rhyolite, and very minor and highly localized iron formation are also included in the upper part of the metasedimentary rock sequence.

The foliated rocks contain highly variable amounts of sericite, chlorite, epidote, and quartz; however, seritization, chloritization, epidotization, and silicification do not appear to transgress lithologic contacts and the present mineral assemblages are believed to reflect differences in the compositions of the original bedded rocks. At many places the foliated rocks contain distorted rhombohedral voids formed from the weathering of included carbonate minerals. Where the original carbonate mineral contained iron, the voids retain a residue of limonite. The rhombohedrons are sometimes distorted into shapes approximating cubes, and in such cases, the limonite residue is easily mistaken as a weathering product from pyrite. Actually, only a minor part of the iron oxide minerals in the schists is believed to be derived from the weathering of iron or copper sulfides.

The foliated rocks are often crenulated and incongruous drag folds are common. Boudinage structures were noted at several localities.

Narrow beds of mafic tuff(?) are interbedded in the sequence of foliated rocks. They are commonly 1 to 2 meters thick, although they appear to be wider and occur with greater frequency in the northern part of the area (fig. 4). Plagioclase, epidote, chlorite, tremolite, and secondary copper minerals appear to be the principal constituents of the mafic tuff(?) beds. Usually minor quartz is also included. The texture ranges from extremely fine grained and granular to finely crystalline.

Younger metavolcanic rocks

In the northern part of the map area (fig. 1), the trough of the syncline is occupied by metavolcanic rocks which form a progressively wider outcrop pattern toward the north in the axial portion of the syncline. The metavolcanic rocks appear to be of dacitic to andesitic composition and include equivalent pyroclastic rocks. These rocks are engulfed by peralkalic granite in the extreme northern part of the prospect area.

Intrusive rocks

A basic-alkaline intrusive rock that forms an oblong outcrop in the northwest part of the area (fig. 1) is exposed continuously for approximately 1500 meters. This rock is porphyritic, and fine- to medium-grained amphibole and pyroxene are contained in the ground mass; the phenocrysts are gray to pink potassium or soda feldspar. A parallel alignment of the pinacoidal cleavage faces of the feldspar gives the rock a lath-like pegmatitic texture. The basic-alkaline intrusive rock is apparently the principal cause of the magnetic anomaly in the northwest part of the area. The intruded rocks show increasing epidotization toward the intrusive contact.

Pink feldspar dikes form a crude radial pattern around the basic-alkaline intrusive and are believed to be related to it. They terminate abruptly a short distance from the intrusive mass against rocks included in the upper part of the metasedimentary rock sequence. Trace amounts of pyrite and malachite were noted locally in the dike rocks.

Peralkalic granite forms continuous outcrops in the extreme northwest part of prospect area. The contact formed by the granite and the intruded rocks is highly discordant. There are no obvious effects of contact metamorphism near the intrusive contact and there are no indications of sulfide mineralization in the granite nor in the rocks immediately adjacent to the granite.

Quartz veins and stocks are found throughout large parts of the area. Most of the veins parallel or sub-parallel the schistosity or bedding of the enclosing rocks, although, in some places, they are cross-cutting. The veins commonly consist of milky white, massive quartz. Minor carbonate minerals are present where the veins are included in carbonate metasedimentary rocks. Locally the veins contain minor amounts of chlorite and sulfide minerals. A high concentration of quartz veins and stocks are found along the axial portion of the syncline and for several kilometers along the west limb of the syncline.

MINERALIZATION

Indications of sulfide mineralization were observed in siliceous dolomite and in interbedded chlorite-quartz schist during the reconnaissance investigations in March 1967. Malachite and chalcocite were found as disseminations and as fracture fillings in or near the highly sheared parts of these rock units. Detailed studies have resulted in locating exposures of disseminated copper minerals in the pyroclastic rocks stratigraphically above the siliceous dolomite. Small slag heaps which contain blebs of metallic copper were located in Area 3 (fig. 4). Ore used for this ancient mining operation is believed to have come from outcrops and surface rubble of the mineralized pyroclastic rocks. Malachite and chalcocite seem to be the most abundant economic minerals present. Gold and silver may be present in economically significant amounts in the siliceous dolomite and interbedded schist, and significant silver values have been obtained from core and surface samples of copper bearing pyroclastic rocks. Analytical results of surface samples collected during the reconnaissance investigations in March 1967 indicated that some of the samples contained anomalous amounts of zinc. The analytical data from drill core samples so far indicate that zinc is not present in recoverable amounts.

Mineralization in siliceous dolomite

Copper mineralization in the siliceous dolomite and interbedded schist appears to be concentrated mainly along strike shears. Although prominent north striking shear zones are abundant throughout the area, those which contain copper mineralization are, to a large degree, restricted to a relatively narrow stratigraphic range. The distributional pattern of individual copper occurrences over several kilometers of strike length in the siliceous dolomite suggests stratigraphic control and that the original copper minerals may have been remobilized a short distance from where they were initially deposited and concentrated in dilatant zones caused by shearing.

Copper mineralization in the siliceous dolomite has been tested by only one drill hole to date. Mineralization of possible economic importance was confined to a major fault zone which sub-parallels the syncline axis; however, unfractured siliceous dolomite and schist from the bottom 8.4 meters of the hole averaged 430 ppm copper. This is believed to be 10 to 20 times the modal value of copper for siliceous dolomite of the area (Allcott, personal communication). These results further suggest possible stratigraphic control for copper mineralization.

Although stratigraphic control is suggestive, surface observations, drill hole data, and geophysical information indicate that the highest concentrations of copper and associated metals in the siliceous dolomite are probably confined to shear zones. The major fault in the center part of the map area (fig. 1), which subparalles both the synclinal axis and the strike of the siliceous dolomite, appears to be the most promising target area for copper exploration in the siliceous dolomite. The most extensive copper mineralization associated with the siliceous dolomite is located within this fault zone or in near-by related fractures. During the reconnaissance investigations, Allcott detected a soil sample anomaly across this fault zone (Earhart, 1969a), and the ground EM anomalies detected by Davis during reconnaissance investigations seem to be related to this fracture (Davis, 1967). The only EM anomalies found over the siliceous dolomite by the helicopter-borne survey are in the vicinity of the fault zone. An anomalous trend 1080 meters long was detected where the fault zone transects siliceous dolomite at the syncline nose. The anomalous area contains numerous small copper occurrences largely confined to shear zones; however, mineralization in this area has not yet been tested by drilling.

Analytical results from samples collected from mineralized parts of the siliceous dolomite during reconnaissance investigations indicated that, in places, small but perhaps important amounts of gold and silver are associated with copper mineralization. The analysis of core samples from Drill Hole 1 are a further indication that small amounts of gold and silver are present.

Mineralization in pyroclastic rocks

Copper mineralization in the pyroclastic rocks stratigraphically above the siliceous dolomite was not recognized during the reconnaissance investigations. Minor to moderate amounts of disseminated copper mineralization were later found in fairly narrow tuff(?) beds in the upper part of the metasedimentary rock sequence. These beds are believed to form the nose of the north plunging syncline in the central part of the prospect area, and are therefore absent in the southern part. The tuffaceous beds are narrow and erratically distributed along the strike in the central part of the area, but occur with increasing consistency toward the north.

Copper mineralization appears to be most abundant and most consistent in the mafic tuff(?) beds which form a nearly continuous cupriferous outcrop with an average width of about 1.5 meters for approximately 1 km between Areas 2 and 3 (figs. 3 and 4). In the vicinity of Area 3, the mafic tuff(?) beds appear to be thicker and occur with greater frequency. Mineralization consists of minor to moderate amounts of malachite and chalcocite which may be argentiferous in part. Gold or other metals of value have not been detected in the mafic tuff(?). The chalcocite disseminations are normally extremely fine so that it is very difficult to estimate megascopically the copper content of this dark colored rock.

Copper mineralization has also been observed in the thin-bedded siliceous tuff that occurs both above and below the mafic tuff(?) beds. Copper mineralization in siliceous tuff appears to be both minor and erratic. A possible exception to this is found in the eastern part of Area 3 (fig. 4). The siliceous tuff is poorly exposed in this area, but it does form a few small outcrops along a strike length of approximately 350 meters. Most of the samples collected from these outcrops were found to contain anomalous amounts of copper. The principal copper mineral is malachite, but very minor amounts of chalcocite were also observed. Disseminated copper mineralization is concentrated in beds 1 to 2 centimeters thick separated by beds of approximate equal thickness which contain little to no copper minerals.

Bedding is not everywhere discernable, but where it is discernible it appears that copper mineralization comprises a bedding feature in the rock and it is believed that the original copper mineral may have been deposited contemporaneously with the other rock constituents.

Mineralization in vein type rocks

Indications of sulfide mineralization are locally found in quartz and quartz-carbonate veins. This type of occurrence is fairly common in veins included in the siliceous dolomite and in or near the mafic tuff(?) beds. Elsewhere, mineralization of this type is rare. Copper bearing quartz-carbonate veins may contribute to ore potential in or near the siliceous dolomite where it forms the nose of the syncline in the south part of the map area (fig. 1). The veins are less than a meter wide and strike parallel to sub-parallel to the enclosing rock. Mineralization consists of limonite pseudomorphic after pyrite, malachite, and chalcocite. Rarely, a core of chalcopyrite is included in the chalcocite. Analytical data (Earhart, 1969a) indicate that the veins contain small but perhaps recoverable amounts of gold and silver. Mineralization occurs in vugs and fractures, and rarely do ore minerals comprise approximately 25 percent of the vein.

Feldspar dikes in the vicinity of the cigar shaped intrusive in the north part of the area contain minor amounts of sulfide minerals or their oxidized products. Limonite and pyrite are most common, but malachite and chalcocite were also observed. Of four selected samples collected from this rock type, one contained ore grade values of copper, two contained weakly to moderately anomalous copper values, and one contained only a normal background amount (Earhart, 1969a).

Supergene enrichment

Field studies indicate that only very small amounts of primary sulfide minerals were deposited in the metasedimentary rock sequence. Possible economic interest in the copper occurrences is inspired only by the fact that the small amounts of primary sulfide minerals have been exposed to along, continuous cycle of supergene enrichment. Diamond drill holes have so far failed to encounter primary sulfides, and the results from one drill hole indicate secondary copper sulfides at a vertical depth of 60 meters. Enrichment is known to extend well below the present water table.

A 900-meter escarpment lies about 25 kilometers east of the Wadi Yiba copper prospect area. The prospect area is located on the down side of the escarpment. The escarpment is the most prominent topographic feature in western Saudi Arabia and reflects movement on the east side of the Red Sea graben. The present position of the escarpment represents an erosional horizontal retreat of approximately 70 kilometers eastward. The prospect area has, therefore, undergone extensive erosion in relatively recent geological times. The presence of secondary sulfide minerals well below the present water table indicates that the water table has fluctuated. Progressive erosion, fluctuating water table, and arid climate are physiographic factors greatly enhancing the possibility of the formation of extensive supergene deposits in chemically inert rocks which contains primary sulfide minerals.

The presence of supergene sulfide minerals in the oxidation zone of the mineralized rocks at Wadi Yiba indicate that the rate of erosion in thelater stages of the supergene cycle has greatly exceeded the rate of oxidation. Both siliceous carbonate and inert, mineralized pyroclastic beds contain secondary sulfide minerals; however, the ratio of chalcocite to malachite is generally much higher in the chemically inert rocks.

GEOPHYSICAL RESULTS

A regional helicopter-borne EM-MAG survey was conducted over the metasedimentary rock sequence. Approximately one fourth of the survey included the Wadi Yiba copper prospect area. The method employed utilizes an electromagnetic instrument with vertical and co-axial coils which operate at a frequency of 1052 cycles per second. The coils are separated by a boom structure approximately 7 meters long which is towed about 25 meters above the ground by the helicopter. The instrument measures the in-phase and out-of-phase components of the primary field in parts per million. The effective depth of penetration is reported to be about 45 meters. A nuclear precession magnetometer is also mounted on the boom and records magnetic measurements at 1 second intervals. Instrument data is recorded on a six-trace galvanometer type recorder. Aerial photographs enlarged to 1:15,000 scale were used for survey control. This scale corresponds to the horizontal scale on the recording tape. To insure maximum control, easily identifiable points on the ground were simultaneously marked on the photo and the recording tape so that adjustments could be made for scale variations.

Other phases of the exploration program were in progress when the geophysical work was initiated. As a result, the compilation of the geophysical survey data was not available until after the end of the field work. Geophysical targets should be carefully evaluated in future phases of the exploration. Some preliminary investigation and observations relating to the geophysical results have been made and are discussed in the following paragraphs. These discussions are based on field observations, consultations with Mr. Don Hase, U. S. Geological Survey geophysicist, and on information contained in a geophysical report submitted by Dr. George Sander of Sander Geophysics Limited.

Sander compiled and presented two series of maps covering the survey area. One series contains the EM data and shows the in-phase and out-of-phase curves as well as the theoretical position of the anomalies. The other series of maps contains the magnetometer data expressed as contours measured in gammas. The author has superimposed the theoretical location of the EM anomalies, which show both in-phase and out-of-phase responses, over the magnetic data and the general geology. The geophysical part of this compilation is taken directly from Sander's work. The resulting map is presented as Figure 5 of this report.

EM anomalies are clustered in two distinct parts of the area: (1) in the vicinity of the syncline nose as formed by siliceous dolomite in the southern part of the area, and (2) southwest of the basic alkaline intrusive in the northwestern part of the prospect area.

In the south area, seven EM anomalies show both in-phase and out-of-phase responses. The anomalies on the east limb of the syncline near the nose are nearly superimposed on ground anomalies surveyed by Davis and Akhrass (1969). The anomalies occur in an area where copper mineralization is exposed in outcrop. The more recent EM data extends and defines the limits of the conductor located by Davis. The results from the Sander Survey indicate a continuous conductive zone of 1080 meters strike length. The out-of-phase responses are on the order of 100 ppm above background; in-phase responses are weak. The position of the anomalous trend corresponds well with that of the fault which sub-parallels the syncline axis and cuts slilceous dolomite. The anomalous trend is therefore believed to reflect conductive material in this fault zone and related fractures. The fact that copper mineralization has been found in

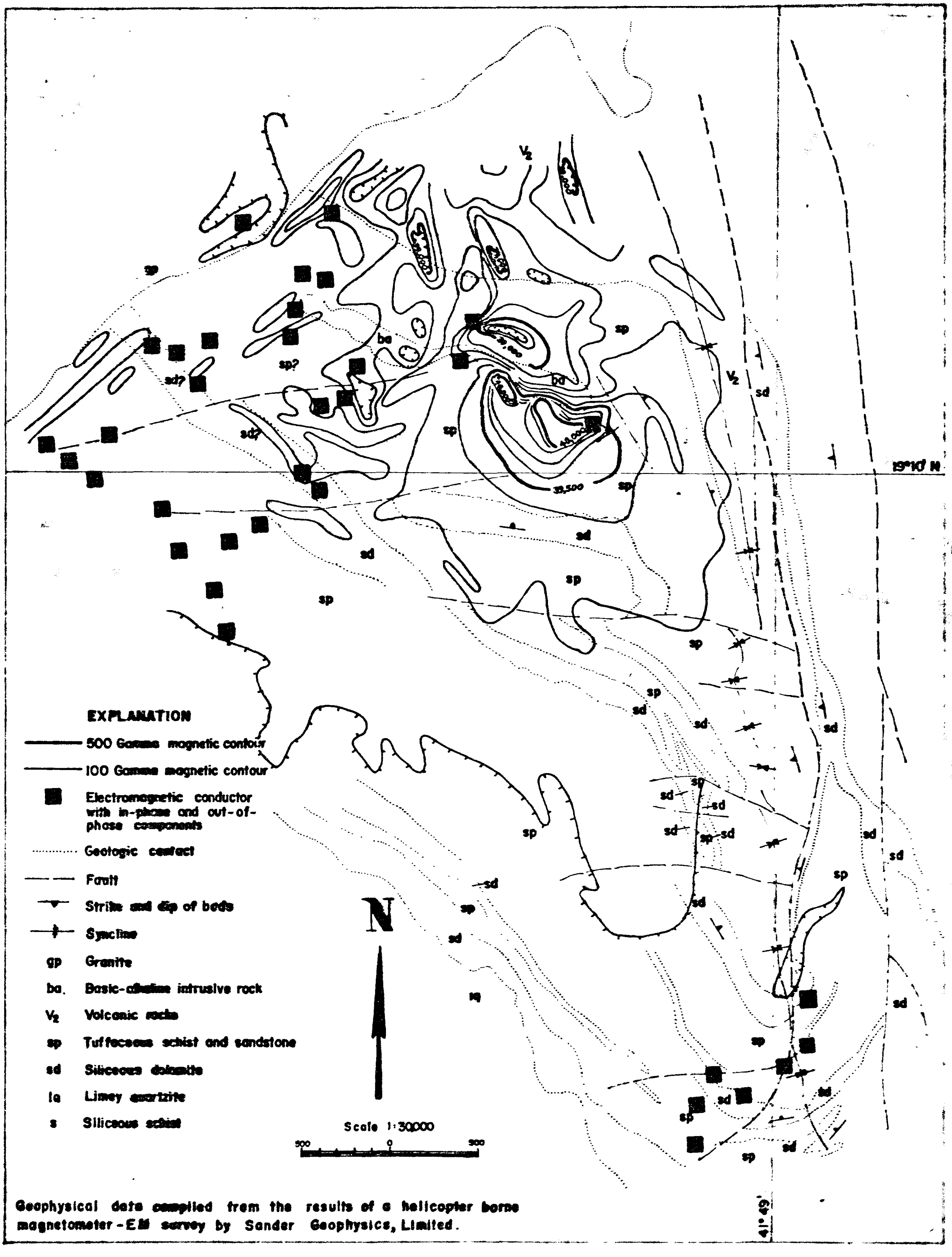


FIGURE 5.- Geophysical map of the Wadi Yiba copper prospect.

outcrop over the conductive zone gives rise to the hope that the conductive material is sulfide mineralization. The EM data for this anomalous zone was not available during the first phase of the diamond drill program, and it was deemed advisable to wait for the geophysical results before a drill hole was located in this area. As a result, this conductor has not yet been tested by diamond drilling. It is considered a prime target when drilling is resumed in the spring of 1969.

A cluster of 28 EM anomalies which show responses in both the in-phase and out-of-phase components cover an area of approximately 2 square kilometers in the northwest part of the prospect area. Most of the anomalies are located to the southwest of the basic-alkaline intrusive and south of the peralkalic granite in rocks which are believed to be part of the metasedimentary series. The rocks of this area are poorly exposed and the area has not received detailed study. The anomalies indicate weak to moderate conductivity. They form crude trends which strike almost normal to the strike of the country rock and they appear to be closely related to cross-cutting magnetic trends. The anomalous zones may represent cross-cutting dikes or fracture zones which contain conductive material.

The basic-alkaline intrusive is strongly reflected by the magnetic data, which indicates that the intrusive probably plunges to the southwest towards the cluster of EM anomalies. Cross-cutting magnetic trends which are associated with the EM anomalies appear to transect the intrusive. Magnetic conditions appear to be very 'quiet' in all other parts of the prospect area.

The geophysical survey beyond the limits of the Wadi Yiba prospect area resulted in the location of numerous EM and magnetic anomalies. It is probable that the following variable conditions are included in the causes for the EM anomalies: (1) salines and aqueous material concentrated in fracture zones, (2) salines and other conductive material in the fluvial and other recent unconsolidated sediments, (3) geological contacts between rocks of highly contrasting conductive properties, and (4) concentrations of sulfide minerals. In a few cases, magnetic anomalies are closely related to EM anomalies. Chlorite-magnetite schist and other mafic to ultramafic rock types are strongly reflected by the magnetics. Surface evaluation of the most favorably anomalous zones should be included in future explorations.

SUMMARY OF RESULTS

Detailed mapping, sampling, and diamond drilling has been confined to the three widely separate parts of the prospect area referred to as Areas 1, 2, and 3 (fig. 1).

Area 1

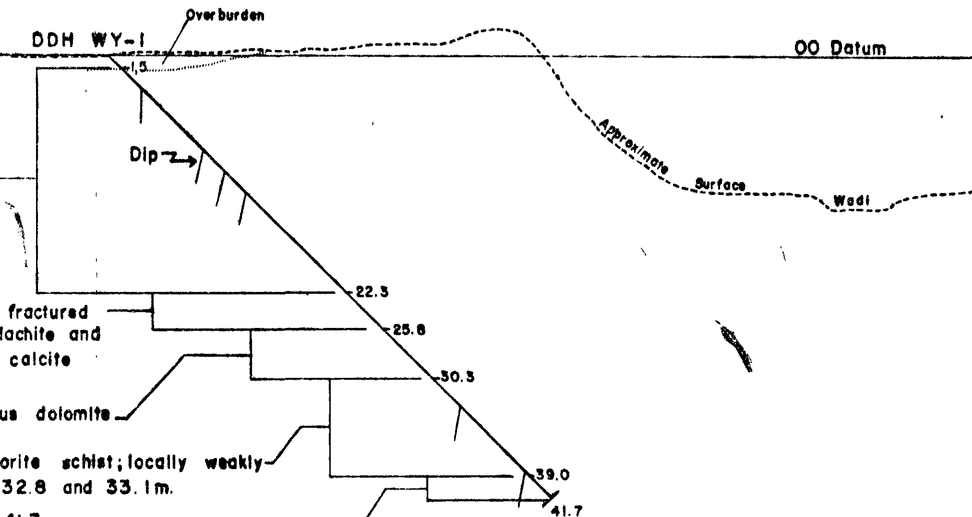
Area 1 (fig. 2) is in the central part of the prospect area, and covers approximately 5 square kilometers. Secondary copper carbonates and sulfides were observed in siliceous dolomite and interbedded quartz-chlorite schist during reconnaissance investigations of March 1967. Mineralization is along shear planes, in fracture fillings, and as disseminations in the wall rocks of highly sheared siliceous dolomite. EM surveys conducted by Davis and Akhrass (1969) during the reconnaissance investigations indicated a weak, continuous conductor for 350 meters in the extreme northern part of the map area. Plane table mapping by Abu-Annaja shows that the copper mineralization is nearly continuous in steeply dipping outcrops for about 190 meters along the conductive trend. Apparently, the mineralization is in or near the fault zone which sub-parallels the syncline axis. Surface observations and geophysical results indicate copper mineralization associated with this same fault zone immediately south of Area 1 in the vicinity of the nose of the syncline.

Geological and geophysical studies indicate that copper mineralization is not continuous between these two zones. A drill hole was located in the north zone; since the final compilation of the geophysical results from the Sander survey were not available during the field program, the south zone has not yet been tested by drilling.

Drill hole WY-1 (fig. 6) was located near the northern end of the conductive zone where copper mineralization is exposed over a width of 6 meters. A suite of 4 grab samples across the mineralized zone contain from 0.046 to 2.3 percent copper, (Earhart, 1969a). Some of these samples contain anomalous amounts of zinc, gold, and silver. The drill hole was designed to transect this mineralized zone at shallow depth. Information pertaining to this drill hole is presented on Figure 6. A 3.41 meter intersection beginning at 22.3 meters contains 6.81 percent copper. .023 ounces per ton gold, and .904 ounces per ton silver. The top of the intersection is at a vertical depth of 16 meters. Copper mineralization is in a highly oxidized, leached, and cavernous fault zone. The whole rock density of the mineralized material is low due to the porous, cavernous texture of the rock. The mineralized zone is composed of malachite and minor chalcocite which occur as vug and fracture fillings in calcium carbonate and quartz. Limonite pseudomorphic after pyrite is associated with the copper mineralization. Apparently most of the leached material was calcium carbonate and secondary copper minerals have been deposited in voids resulting from leaching. Traces of malachite were observed several meters below the fault zone in weakly fractured to unfractured siliceous dolomite. Analytical results indicate that the hole ended in material containing 430 ppm copper. The zone tested by drill hole WY-1 should be transected at greater depth, and the possible continuation of this zone to the south of drill hole WY-1 should be tested by drilling.

KINGDOM OF SAUDI ARABIA

MINISTRY OF PETROLEUM AND MINERAL RESOURCES



1.5 - 22.3
Quartz-sericite schist; highly fractured; weakly limonitic; quartz stringers and veinlets; narrow zones of siliceous dolomite at 14.3 m. and 15.5 m.; traces of malachite at 22.0 m.

22.3 - 25.8
Interbedded chlorite schist and siliceous dolomite, highly fractured and locally brecciated, highly leached and limonitic, malachite and chalcocite in breccia matrix, stringers, and cavities with calcite

25.8 - 30.3
Chlorite-quartz schist with some interbedded siliceous dolomite

30.3 - 39.0
Siliceous dolomite with minor interbedded quartz-chlorite schist; locally weakly limonitic; moderately fractured; traces of malachite at 32.8 and 33.1 m.

39.0 - 41.7
Quartz-chlorite schist; traces of limonite; weakly fractured; minor quartz stringers

SAMPLE DATA

Sample No.	Interval	Au	Ag	Cu	Pb	Zn
37600	15.7-17.9	Nil	Nil	.0074	.0020	.0057
37601	17.9-19.4	"	"	.032	.0017	.0070
37602	19.4-21.3	"	.041	.0285	.0021	.0060
37603	21.3-22.3	"	<.04	.059	.0017	.0060
37604	22.3-23.5	.028	1.77	12.1	.0060	.0046
37605	23.5-24.0	.007	.67	4.9	.0017	.0065
37606	24.0 24.5	.01	.51	3.0	.0032	.0140
37607	24.5-25.8	.028	.34	4.0	.0013	.0060
37608	25.8-26.6	.0036	<.04	.0153	.0018	.0060
37609	26.6-30.3	Nil	Nil	.005	.0016	.0055
37610	30.3-32.7	"	"	.0095	.0028	.0020
37611	32.7-33.3	"	"	.015	.0016	.0020
37612	33.3-36.5	.0036	"	.043	.0035	.0060
37613	36.5-41.7	"	"	.043	.0028	.0030

Au and Ag in ounces per Ton, Cu, Pb and Zn in weight percent

COMPILATION OF SAMPLES WITH SIGNIFICANT VALUES

INTERVAL	LENGTH	TRUE WIDTH	AVERAGE GRADES Cu	Au	Ag
22.34m-25.75m.	3.41m.	3.02m.	6.81%	.023 oz/Ton	.904 oz/Ton

DRILL HOLE DATA

Date Drilled: November 1967
Total Depth : 41.7 Meters
Percent Core Recovered : 75.5 %
Recovery in Cu zone: 72.2 %
Drill Hole Inclination: - 45° at collar
Bearing - S 89° E

Scale 1:500
April 1968

FIGURE 6.- Section, diamond drill hole WY-1, looking North

Geologic mapping in Area 1 resulted in the discovery of copper mineralization in a narrow mafic tuff(?) bed on the west limb of the syncline. Mafic tuff(?) appears to be absent on the east limb due to faulting. Trace to minor amounts of malachite and chalcocite were noted in coarse-grained, limonitic, siliceous tuff. Mineralization in the pyroclastic rocks on the west limb of the syncline is narrow and discontinuous and is not believed to be of economic interest. Minor secondary copper minerals were noted in quartz veins and small fracture zones at various localities in Area 1.

Area 2

Area 2 (fig. 3) is about 1 kilometer north of Area 1 in the central part of the map area (fig. 1). It covers about 15,000 square meters and is situated near the syncline axis. The rocks of the area consist of schistose, felsic, and mafic bedded rocks. Minor to moderate amounts of malachite and chalcocite occur as very fine disseminations and fracture fillings in the mafic bedded rocks. Thirty samples were collected from outcrops of the various rock types present. The location of these samples and the analytical data are given on the pace and compass outcrop map (fig. 3). The rocks of the area form very tight, nearly isoclinal folds which strike and plunge steeply to the northeast, while the axial planes dip steeply to the northwest. The mafic tuff(?) bed or beds which contain copper mineralization are 1 to 1.5 meters thick and are repeated several times by folding. They are drawn out and attenuated for several meters along the noses of folds. The drill cores from drill hole WY-2 (fig. 7) indicate that the folds are shallow structures and as a result, the mafic tuff(?) beds are present to a maximum of 32 meters vertical depth.

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U.S. GEOLOGICAL SURVEY

KINGDOM OF SAUDI ARABIA
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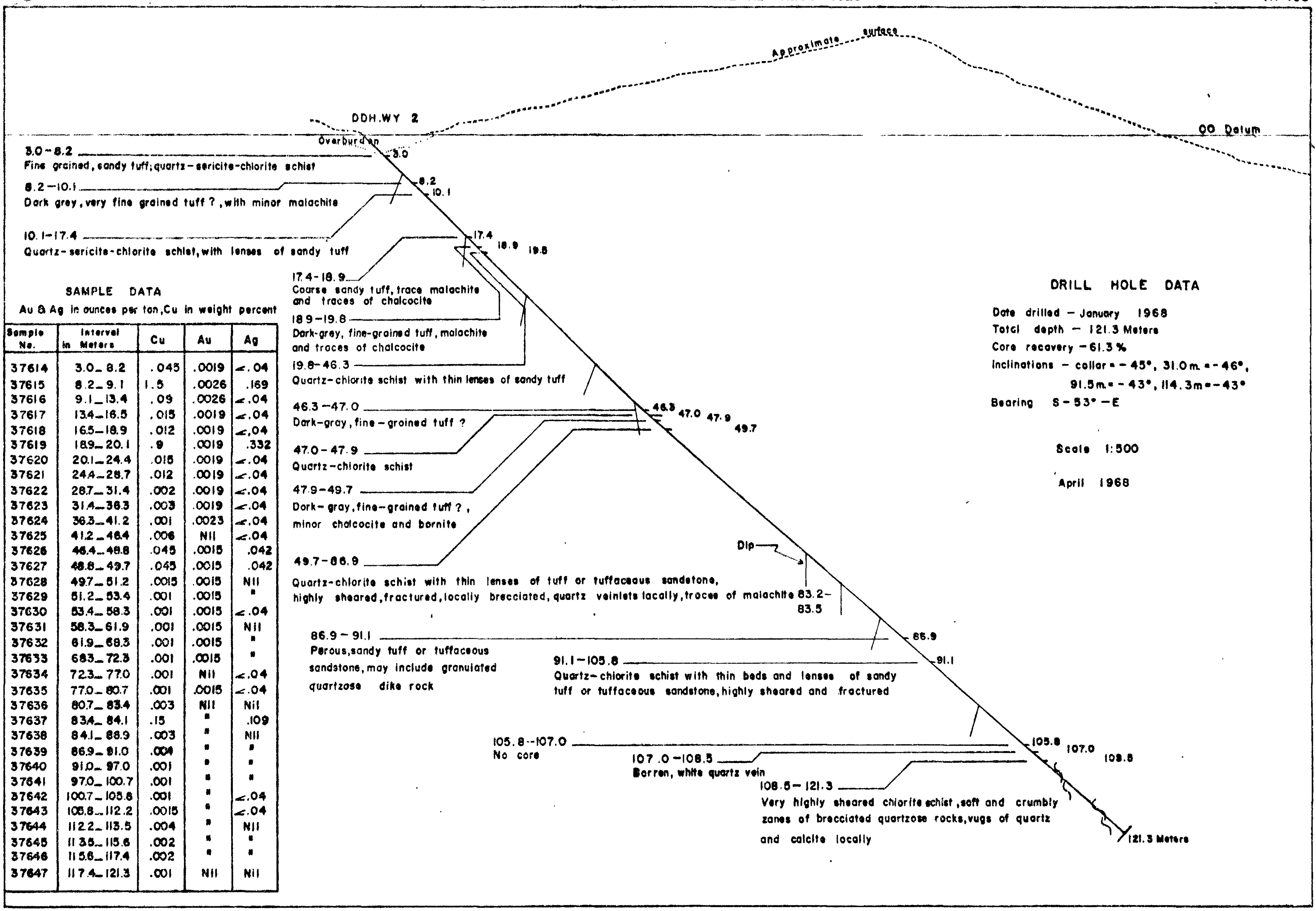


SAMPLE DATA

Au & Ag in ounces per ton, Cu in weight percent

Sample No.	Interval in Meters	Cu	Au	Ag
37614	3.0 – 8.2	.045	.0019	< .04
37615	8.2 – 9.1	1.5	.0026	.169
37616	9.1 – 13.4	.09	.0026	< .04
37617	13.4 – 16.5	.015	.0019	< .04
37618	16.5 – 18.9	.012	.0019	< .04
37619	18.9 – 20.1	.9	.0019	.332
37620	20.1 – 24.4	.015	.0019	< .04
37621	24.4 – 28.7	.012	.0019	< .04
37622	28.7 – 31.4	.002	.0019	< .04
37623	31.4 – 36.3	.003	.0019	< .04
37624	36.3 – 41.2	.001	.0023	< .04
37625	41.2 – 46.4	.006	Nil	< .04
37626	46.4 – 48.8	.045	.0015	.042
37627	48.8 – 49.7	.045	.0015	.042
37628	49.7 – 51.2	.0015	.0015	Nil
37629	51.2 – 53.4	.001	.0015	"
37630	53.4 – 58.3	.001	.0015	< .04
37631	58.3 – 61.9	.001	.0015	Nil
37632	61.9 – 68.3	.001	.0015	"
37633	68.3 – 72.3	.001	.0015	"
37634	72.3 – 77.0	.001	Nil	< .04
37635	77.0 – 80.7	.001	.0015	< .04
37636	80.7 – 83.4	.003	Nil	Nil
37637	83.4 – 84.1	.15	"	.109
37638	84.1 – 86.9	.003	"	Nil
37639	86.9 – 91.0	.004	"	"
37640	91.0 – 97.0	.001	"	"
37641	97.0 – 100.7	.001	"	"
37642	100.7 – 105.8	.001	"	< .04
37643	105.8 – 112.2	.0015	"	< .04
37644	112.2 – 113.5	.004	"	Nil
37645	113.5 – 115.6	.002	"	"
37646	115.6 – 117.4	.002	"	"
37647	117.4 – 121.3	.001	Nil	Nil

FIGURE 7.- Section, diamond drill hole WY-2, looking North 35° East

Analytical results from outcrop and drill core samples of the other rock types present show that they do not contain significant amounts of copper. One outcrop sample from siliceous, sandy tuff in the western part of the area contained 0.23 ounces per ton gold, and weakly anomalous amounts of gold were detected in the upper part of the drill core from WY-2.

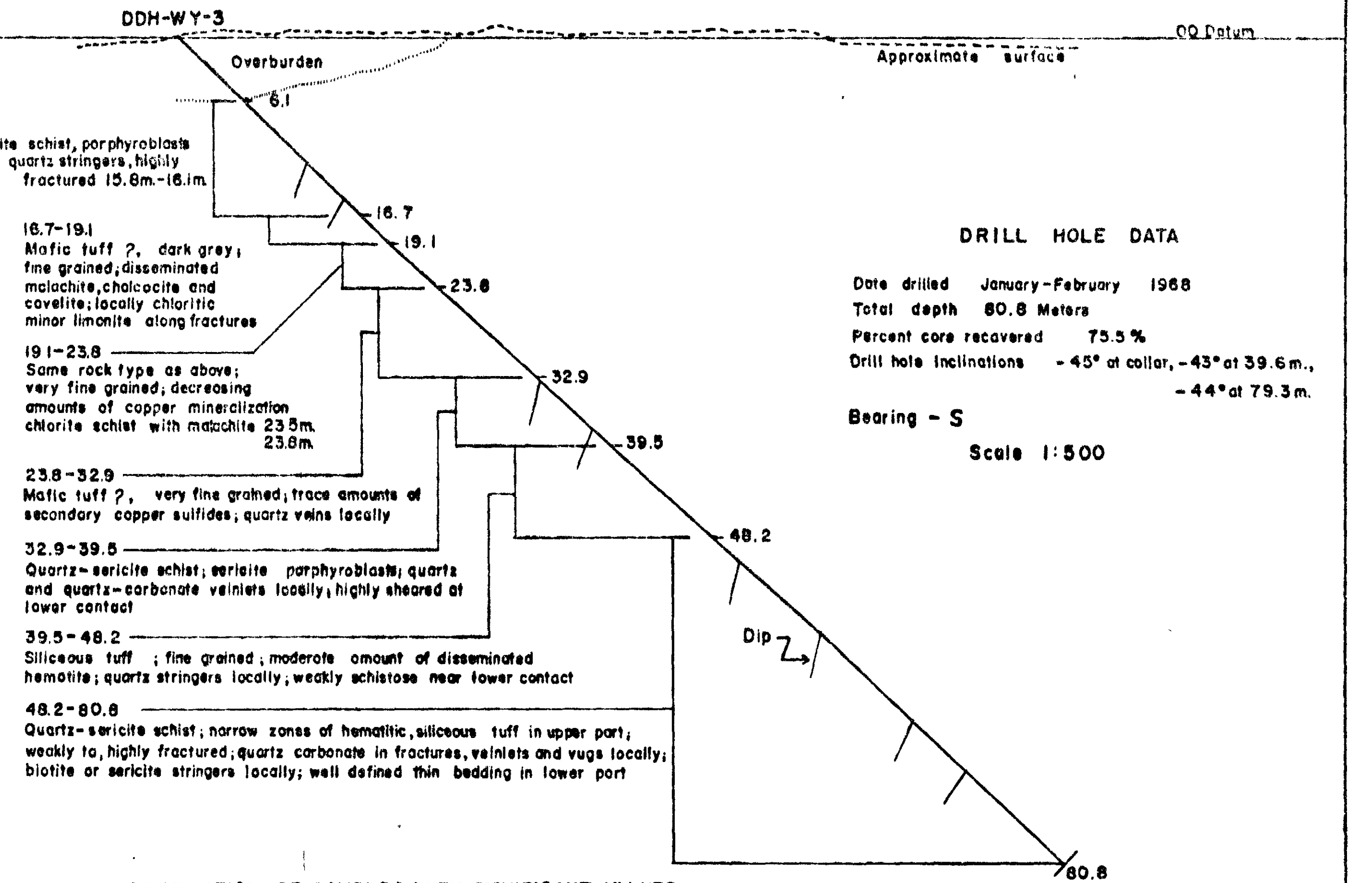
The mafic tuff(?) bed present in Area 2 forms a continuous copper bearing outcrop 1 to 2 meters wide between Areas 2 and 3. There are no surface indications of copper mineralization in the schistose rocks immediately above and below the mafic tuff(?) bed.

Area 3

Area 3 (fig. 4) is in the northern part of the map area (fig. 1), about 1 kilometer northwest of Area 2. The area covers about 270,000 square meters. Mafic and siliceous tuff, quartz-sericite schist, quartz veins, basic-alkaline intrusive rock, and felsic dikes crop out in the area. Volcanic rocks of intermediate to basic composition may be included with mafic and siliceous pyroclastic rocks. Fine-grained clastic sedimentary rocks, possibly of non-volcanic origin, were encountered in drill hole WY-7; however, the equivalents to these rocks were not recognized in outcrops. The rocks are poorly exposed over a large part of the area, and an abundance of white vein type quartz in the pebble to boulder size range is included in the alluvium. The rocks strike northwest to west and dip moderately to steeply to the northeast and north.

Seventy two grab samples were collected from outcrops of the various rock types present. Sample locations and analytical results from these samples are given on the pace and compass outcrop map (fig. 4). Significant copper values were detected in a dark-gray, fine-grained mafic tuff(?), and in siliceous, sandy tuff. Minor amounts of secondary copper minerals were found in quartz veins where they transect the aforementioned rocks. In general, quartz veins are barren of mineralization. Soft quartz-sericite schist and silty sedimentary rocks are believed to be the predominant rock types in the area. Analytical results from outcrop and drill core samples show that these rocks contain 30 ppm or less copper. Chalcocite is the most abundant copper mineral in the mafic tuff(?) beds. It occurs as very fine disseminations and as fracture fillings. Malachite is commonly associated with chalcocite in mineralized outcrops. In some cases, copper mineralization is most abundant where the mafic tuff(?) is highly fractured. In other cases, there is apparently no relationship between the intensity of copper mineralization and fracturing. Minor, but perhaps recoverable, amounts of silver are associated with the copper, but other metals of economic interest have not been detected in significant amounts.

The mafic tuff(?) beds in Area 3 were deposited along several stratigraphic horizons; however, all of them do not contain significant amounts of copper. Two copper zones are indicated by the logs and analytical results of core samples from drill holes WY-3, 6, and 7 (figs. 8, 9, and 10). The average true width of the upper copper zone as determined from the drill hole data is 3.2 meters. The width of the lower zone averages 2.2 meters. The distance between the footwall of the upper zone and the hanging wall of the lower zone is about 13 meters in drill holes WY-3 and WY-6, and 7 meters in drill hole WY-7 where wider intersections of copper mineralization were encountered. The collar of drill hole WY-6 is 375 meters west of the WY-3 collar; however, the holes were not drilled parallel because of strike variation, and the



SAMPLE DATA

Au & Ag in ounces per ton, Cu, Pb & Zn in weight percent

Sample No.	Interval	Au	Ag	Cu	Pb	Zn
37648	12.5-14.2	Nil	<.04	.002	.001	.005
37649	14.2-15.6	"	<.04	.003	.002	.005
37650	15.6-16.7	"	.05	.0115	.0004	.005
37651	16.7-17.3	"	3.25	4.26	.002	.0875
37652	17.3-17.9	"	2.1	3.00	.001	.0875
37653	17.9-18.6	"	2.2	1.15	.002	.100
37654	18.6-19.1	"	.17	.23	.002	.0025
37655	19.1-19.8	"	.046	.045	.001	.0075
37656	19.8-20.3	"	<.04	.040	.002	.0050
37657	20.3-21.7	"	Nil	.004	.001	.0025
37658	21.7-22.6	"	.046	.004	.001	.0025
37659	22.6-23.2	"	.055	.0115	.003	.0175
37660	23.2-23.5	"	<.04	.0075	.002	.0075
37661	23.5-24.2	"	<.04	.020	.001	.0075
37662	24.2-24.9	"	<.04	.0225	.001	.0075
37663	24.9-25.7	"	.083	.080	.0005	.0075
37664	25.7-26.2	"	<.04	.010	.003	.005
37665	26.2-26.9	"	.082	.045	.005	.003
37666	26.9-28.0	"	Nil	.060	.002	.005
37667	28.0-28.3	"	"	.010	.001	.0025
37668	28.3-28.7	"	"	.076	.002	.0025
37669	28.7-29.9	"	.165	.23	.003	.030
37670	29.9-31.1	"	<.04	.030	.005	.0025
37671	31.1-31.4	"	.214	2.25	.003	.05
37672	31.4-31.7	"	<.04	.015	.002	.0025
37673	31.7-32.9	"	<.04	.040	.003	.0075
37674	32.9-36.2	"	Nil	.010	.003	.005
37675	36.2-39.5	"	"	.004	.002	.005
37676	39.5-40.6	"	"	.0115	.001	.005
37677	40.6-41.9	"	<.04	.010	.001	.005
37678	41.9-42.5	"	.10	.060	.001	.0025
37679	42.5-43.3	"	Nil	.006	.001	.0025
37680	43.3-44.2	"	.041	.004	.002	.0025
37681	44.2-45.4	"	.067	.004	.003	.0025
37682	45.4-46.5	"	Nil	.010	.001	.0025
37683	46.5-48.2	"	<.04	.002	.001	.0025
37684	48.2-49.6	"	<.04	.030	.003	.0025
37685	49.6-52.8	"	Nil	.0115	.005	.005

COMPILATION OF SAMPLES WITH SIGNIFICANT VALUES

INTERVAL	LENGTH	TRUE WIDTH	AVERAGE GRADES Cu	Ag
16.7-19.8	3.1m	2.9m	1.71%	1.61 oz/ton
31.1-31.4	.3m	.3m	2.25%	.214 oz/ton

FIGURE 8.- Section, diamond drill hole WY-3, looking East

strike distance between the hanging wall intersections of the upper copper zone in the two holes is 270 meters. Continuity of copper mineralization between the two holes can be reasonably established on the basis of mineralized outcrops and surface sample data. The collar of drill hole WY-7 is 360 meters northeast of WY-3. Outcrops are lacking over much of the area between these two holes; therefore, continuity of copper mineralization is less certain. The average grades and widths of copper mineralization are given in Table 1.

Table 1. - Average grade and width of copper and silver mineralization in drill holes WY-3, 6, and 7.

UPPER MINERALIZED ZONE

Hole No.	Intercept	Length	True width	Average grade Copper	Average grade Silver
WY-3	16.7 - 19.1 m.	2.4 m.	2.3 m.	2.24 %	2.33 oz/ton
WY-6	64.6 - 67.7	3.1	2.8	0.39	0.18
WY-7	3.8 - 9.6	5.8	4.6	0.92	0.19
		TOTALS	3.2	1.08	0.69

LOWER MINERALIZED ZONE

Hole No.	Intercept	Length	True width	Average grade Copper	Average grade Silver
WY-3	31.1 - 31.4 m.	0.3 m.	0.3 m.	2.25 %	0.21 oz/ton
WY-6	81.7 - 84.6	2.9	2.6	1.58	0.58
WY-7	16.5 - 21.2	4.7	3.8	1.37	0.77
		TOTALS	2.2	1.49	0.67

Note: Compiled from data presented on figures 8, 9 and 10.

In presenting this data, the author does not necessarily imply that mineralization is continuous between the three holes. The data have no volumetric significance; they merely indicate the average widths and grades of mineralization that might be expected within the area represented by the three holes. The grades of mineralization as shown in Table 1 can, of course, be increased by decreasing the width of the zones.

A few small outcrops of sandy, siliceous tuff contain copper mineralization in the eastern part of the map area (fig. 4). This rock type is exposed intermittently over a 350 meter strike length and most of the samples collected from outcrops over the entire strike length contain anomalous amounts of copper. The width of the cupriferous tuff is not known, but it probably does not exceed 3 or 4 meters. Quartz-sericite schist above and below the tuff contains less than 20 ppm copper. Malachite, the dominant copper mineral in these rocks, occurs as disseminations between quartz grains in alternate thin beds. Chalcocite is a minor copper mineral in the surface rocks. The rocks are porous and are therefore more easily oxidized than the mafic tuff(?)

Two drill holes, WY-4 and WY-5, were drilled with a small hand portable drill, but with limited success. One of these holes was designed to test the cupriferous siliceous tuff beds, but was stopped after penetrating 24.1 meters because of mechanical difficulties. Core recovery in this hole was very poor. The other hole was drilled on the same section as WY-3, but was also unsuccessful in recovering adequate core. Data pertaining to these drill holes are given on Table 2.

Outcrop samples collected along intervals of approximately 20 meters to the north of drill hole WY-7 contain copper values which are consistently higher than samples from any other part of Area 3. The sample line nearly parallels shearing in the rocks, and the high values may reflect concentrations of copper in the shear zones. The rocks in this area have not yet been tested by drilling and are considered as a priority target when drilling is resumed.

Mafic tuff(?) is exposed in the extreme eastern part of the map area (fig. 4) and to the northeast of the map area. It is known to contain copper mineralization at these localities; however, the extent of the mineralization has not been studied.

Table 2. - Data from drill holes WY-4 and WY-5 drilled with hand portable diamond drill

HOLE NUMBER WY-4

Location - Area 3, Total depth - 14.3 meters, Core recovery - 32.6%

Interval in meters	Description	Copper assay interval and value
0 - 4.3	Overburden, no core recovered.	
4.3 - 11.9	Dark gray, fine grained tuff?; minor malachite and chalcocite locally; abundant vein quartz 4.3 - 7.6.	4.3 - 7.6 - 0.015% 7.6 - 9.4 - 0.013% 9.4 -10.9 - 0.053% 10.9 -11.9 - 0.350%
11.9 - 14.3	Quartz-sercite schist with stringers and vugs of quartz.	11.9 -14.3 - 0.030%

HOLE NUMBER WY-5

Location - Area 3, Total depth - 24.1 meters, Core recovery - 33.4%

Interval in meters	Description	Copper assay interval and value
0 - 1.8	Overburden, no core recovered.	
1.8 - 24.1	Sandstone and tuffaceous sandstone, very fine grained to gritty and porous, no apparent mineralization.	1.8 - 6.7 - 0.002% 6.7 - 9.5 - 0.018% 9.5 -12.4 - 0.002% 12.4 -14.5 - 0.004% 14.5 -17.7 - 0.040% 17.7 -24.1 - 0.104%

Future investigations should include these areas as well as the geophysically anomalous area a short distance to the west and northwest of Area 3.

OTHER MINERAL OCCURRENCES IN THE REGION

Mineralized zones were discovered beyond the limits of the Wadi Yiba prospect area during the program. Those of greatest interest are copper showings. Brief examinations have been made of some of the mineralized areas.

A small eliptical gossan, 5 kilometers southwest of the south end of the Wadi Yiba copper prospect, contains malachite in massive limonite. The approximate coordinates of the gossan are lat. 19°07' N. and long. 41°48' E. The gossan is less than 100 meters long and about 20 meters wide. Copper mineralization in the gossan is believed to be derived from the weathering and leaching of copper bearing chlorite-magnetite schist which overlays the gossan.

Copper mineralization was noted in quartz veins, black fine-grained rock, and in siliceous carbonate in samples collected by Ghanem Geri from about 10 kilometers south of the south end of the Wadi Yiba copper prospect. The coordinates of the locale are lat. 19°04' N. and long. 41°49' E. Four samples contain from 0.91 to 26.0 percent copper. The author has briefly visited the area and noted that most of the copper mineralization appears to be in quartz veins. One sample collected from pyritic, marbelized, siliceous carbonate contains 130 ppm copper.

Geri found pyritiferous marble at several localities over a broad area in the metasedimentary rock sequence. The localities extend from lat. 18°47' N. to lat. 19°16' N. between long. 41°42' E. long. 41°58' E. Five samples of this material contain 70 to 200 ppm copper. Copper mineralization associated with quartz veins also occur at several localities. None of these occurrences appear to be of possible economic importance; however, they could possibly be an indicator of important amounts of copper mineralization in near by rocks. For this reason, the distribution of these occurrences should be plotted on a plan and compared with regional geology, and geophysical data.

Malachite and chalcocite were observed in chlorite schist at Murayba, a small village near lat. 18°56' N. and long. 41°55' E. Part of the village is constructed on copper bearing outcrops. The extent of the mineralization is not known.

Richly disseminated to massive sulfides which contain copper and zinc mineralization are indicated by a gossan at Jabal Sarbon (Earhart, 1969b). The south end of the gossan is near lat. 18°52' N. and long. 41°57' E. Grab and channel samples from this locale contain highly anomalous values. Mineralization is in an amphibolite host rock. The gossan may be 2 kilometers long and 4 meters or more wide. Indications of disseminated sulfide minerals were observed in the wall rocks on either side of the gossan.

Iron formation is approximately 30 meters wide over a fairly short strike length at Jabal Hajari near lat. 18°58' N. and long. 41°47' E. At some places, the near-surface iron formation has been enriched by weathering processes, and the enriched part has been used, until recent years, as a source of iron ore for local consumption. Unweathered iron formation is estimated to contain about 25 percent Fe. The deposit is not of sufficient size or grade to be of economic interest.

In addition to the mineral showings, numerous EM and magnetometer anomalies were recorded beyond the limits of the Wadi Yiba copper prospect area. Geological evaluations of geophysically anomalous areas should be included in the next phase of the program.

The strongest EM anomalies found are 43 kilometers west of Wadi Yiba in an area earlier referred to (Earhart, 1969b) as the "Pyroclastic rocks 13 kilometers west of Suq Al Khamis." The conductive zone is in an area of alluvial cover near a pyroclastic pile. The conductors are aligned with the strike projection of the pyroclastic rocks. The geophysical data suggest a series of parallel conductors over a strike length of nearly 4 kilometers. A magnetic anomaly is closely related to the conductors. Investigation of the cause of the anomalies will probably require diamond drilling.

CONCLUSIONS AND RECOMMENDATIONS

The results from the exploration program at the Wadi Yiba copper prospect indicate the presence of copper mineralization in siliceous dolomite and in pyroclastic rocks above the siliceous dolomite. One drill hole has tested the mineralization in the siliceous dolomite. Ore grade copper mineralization with recoverable amounts of gold and silver were encountered in this hole; however, the mineralized section was highly weathered and the mineralized zone is not believed to be representative of the zones outlined by mapping, sampling, and geophysical data. Additional drilling is proposed for this area.

Analytical results from surface samples and drill cores indicate marginal values for copper and silver in the pyroclastic rocks above the siliceous dolomite in the northern part of the area. The mineralized beds are narrow and their strike extent has not been established. Drilling to date has not delimited the copper mineralization, and there is a suggestion that the mineralized zones widen in the vicinity of drill hole WY-7. Additional drilling is proposed for this area in order to test the entire width of mineralization in the vicinity of WY-7, to test the mineralized zones encountered in WY-7 at greater depth, and to test the strike extension of mineralization in the pyroclastic rocks to the northeast of WY-7. The siliceous bedded tuff in the eastern part of Area 3 should also be tested by drilling. The analysis of drill cores from this drilling would provide the basis for a more accurate estimation of the grade of mineralization in the pyroclastic rocks. A total of seven drill holes and an estimated 1100 meters of drilling are recommended.

The entire prospect area should be mapped on a scale of 1:1000. It would be expeditious to do the mapping on large scale aerial photographs. This would require low level photography of the area and this type of coverage is in the planning stage. Color photographs would be especially helpful.

Mapping and sampling should be concentrated in the northwest part of the area during the first part of the continued program. Geophysical results indicate highly anomalous conditions in this part of the area.

Mineralized zones in other parts of the belt of metasedimentary rocks should be studied in greater detail. An exploration program in the Jabal Sarbon area has been proposed (Earhart, 1969b). Geological evaluation of other mineral showings and of geophysical anomalies should be included with the work at Wadi Yiba. The results thus far indicate that sulfide enrichment may extend to a considerable depth. This provides added incentive to the search for other mineral occurrences in the region.

Logistical factors favor the continuation of copper exploration in the region, which is favorably located in respect to the Red Sea. Water is plentiful as compared to other parts of Arabia, because the region is situated favorably with respect to the escarpment and receives drainage from the frequent rainfalls in the higher country. The most important ore mineral in the region appears to be chalcocite and therefore a high copper unit concentrate could be expected as the mill product from the ores of the region. This is a factor which greatly affects the transportation costs.

Considerations which may detract from the economic potential of the Wadi Yiba copper prospect are (1) the results thus far indicate that the mineralized zones, because of their configuration, would probably not be amenable to open pit mining and (2) the copper mineralization found to date may be of insufficient grade to allow profitable extraction by underground mining methods. The region is subject to severely high summer temperatures; however, this is not considered to be a serious determent to mining or milling operations.

In conclusion, the results from investigations to date at the Wadi Yiba copper prospect and at other mineral occurrences in the region indicate that additional work is warranted in order to further evaluate the mineral potential.

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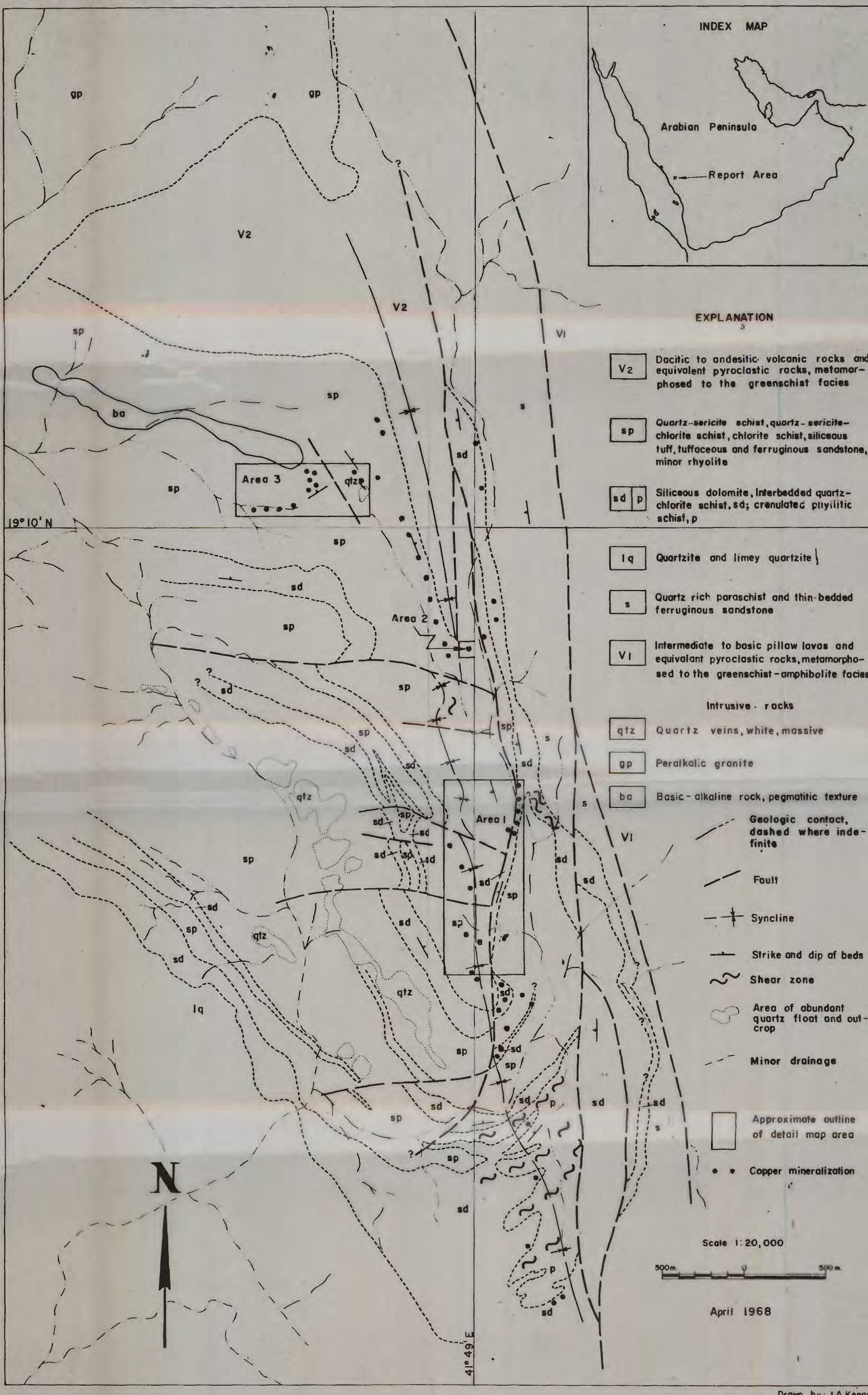

FIGURE 1.- Geologic map of the Wadi Yiba copper prospect