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THE JABAL MURRYYI COPPER PROSPECT, AL 'AQIQ QUADRANGLE SHEET 20/41D

KINGDOM OF SAUDI ARABIA

By Ronald G. Worl and Vincent J. Flanigan

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ABSTRACT

The Rafa Formation of the Ablah Group, outcropping in the general area of Wadi Bahrr in the southwest part of the Al 'Aqiq quadrangle, contains several malachite- and chrysocolla-rich zones. All occurrences noted are syngenetic with enclosing metasediments, mainly siliceous wacke that lie in a gradational transition zone between basal conglomerate and arkosic wacke. The largest occurrence, the Jabal Murryyi prospect, is in a highly sheared and broken synform. The exposure of mineralized rock, 250 m in length and about 4 m in width, averages 1.5 percent copper and 22 grams/ton silver; and is not considered large enough or rich enough to warrant development at the present time. The presence of a syngenetic copper deposit in rocks of the Rafa Formation; however, makes that formation a prime target for further exploration.

INTRODUCTION

The Jabal Murryyi copper prospect is one of several malachite- and chrysocolla-bearing outcrops scattered through an area 1000 m in length and 300 m in width (fig. 1). Although the prospect as presently outlined is not large enough to warrant further exploration it is of geologic significance. This copper prospect is markedly different from the massive sulfide deposits of the Wadi Bidah and Ablah districts and thus constitutes an additional target type to consider in prospecting for base metals in the southern part of the Precambrian Shield.

The Jabal Murryyi prospect (fig. 2) is at the top of a small jabal near Wadi Bahrr, at lat 20°07'N., and long 41°34'E., in the southwest part of the Al 'Aqiq 1:100,000-scale quadrangle (Greenwood, 1975). Although located in rugged terrain the prospect is easily accessible from the

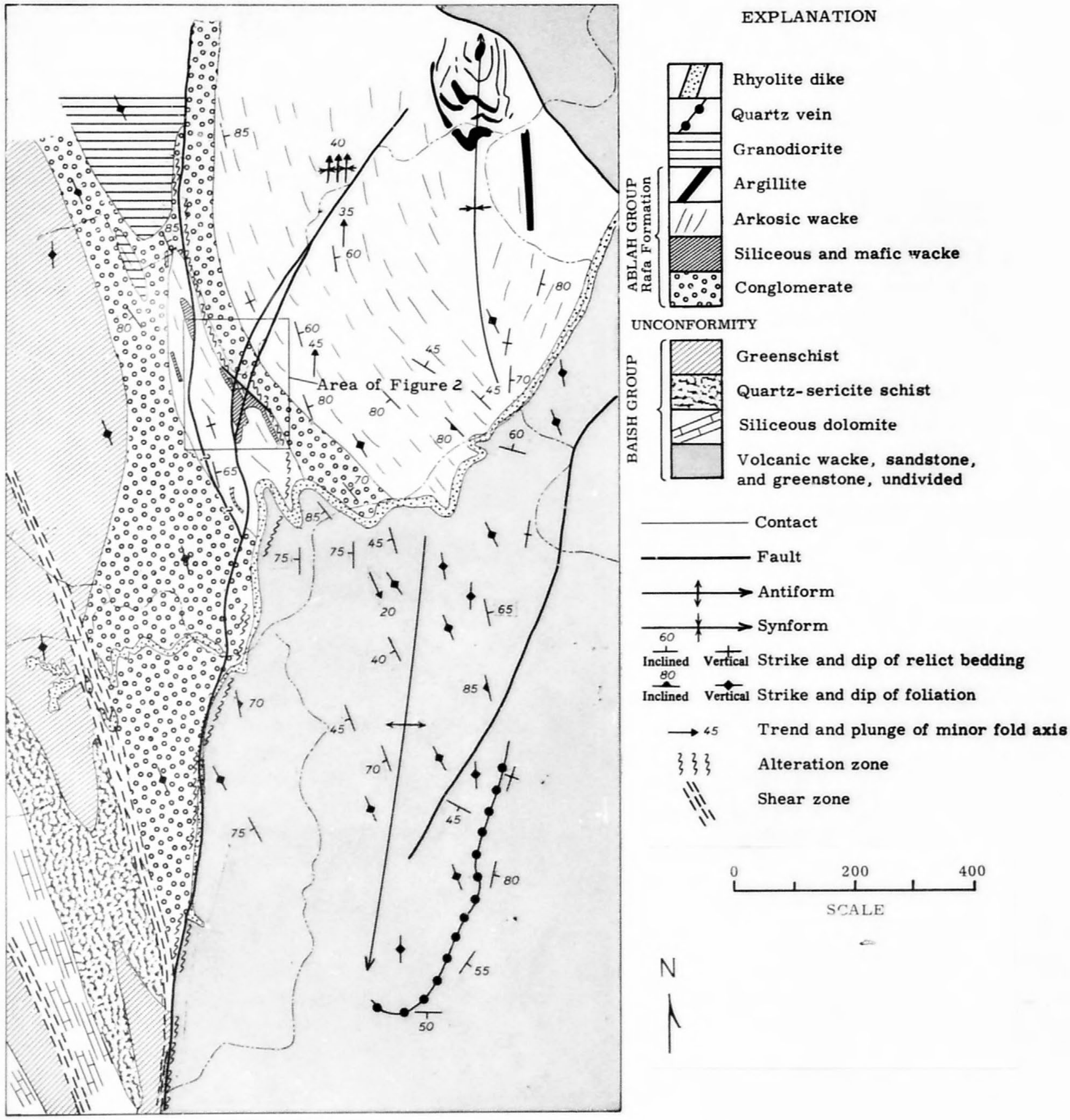

Figure 1. - Reconnaissance geology of the Jabal Murryyi area.

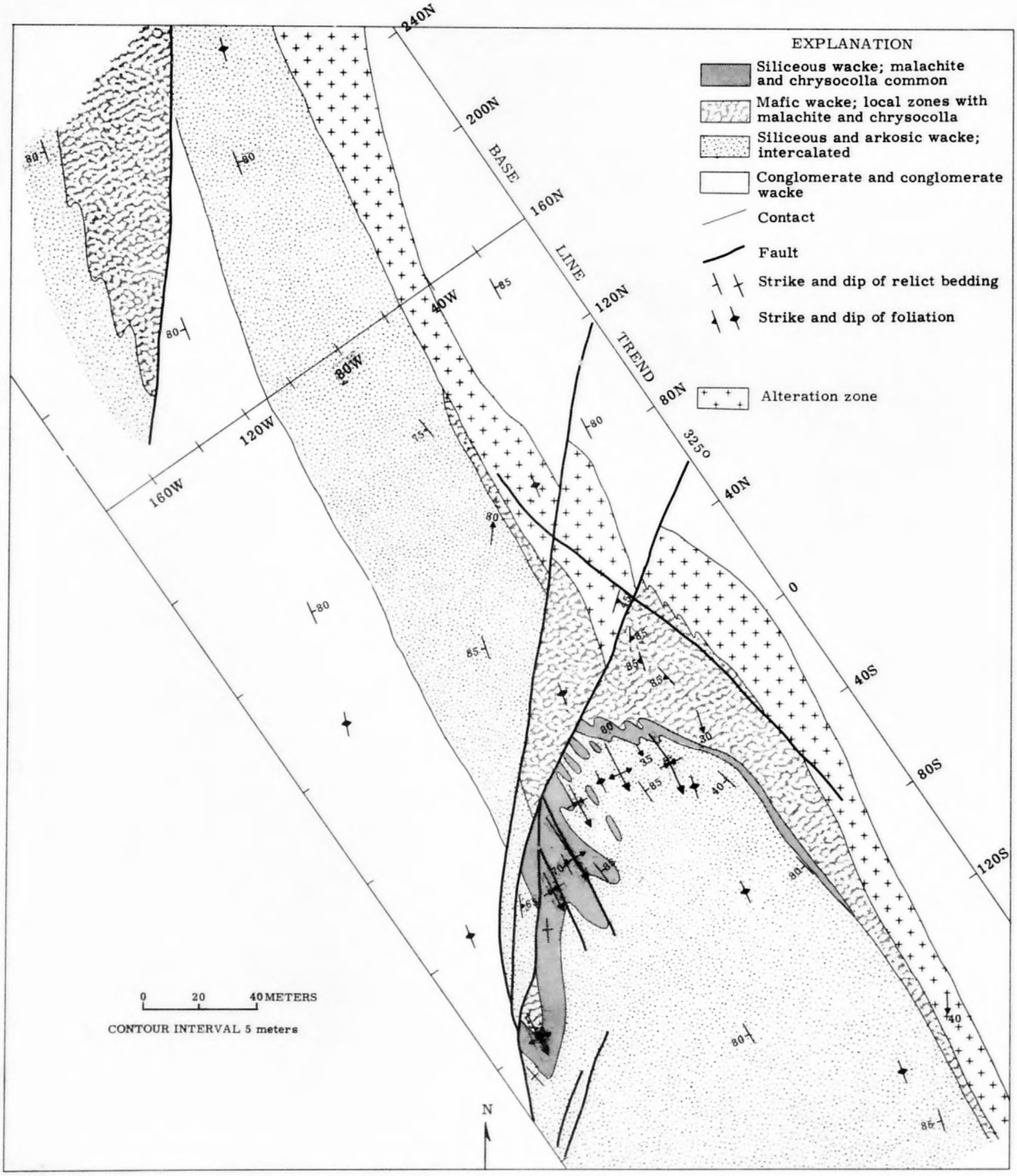

Figure 2. - Geology of the Jabal Murryyi prospect.

Al Bahah to Al 'Aqiq road, from a point where the road crosses the northernmost fork of Wadi Bahrr. The prospect is named after Murryyi bin Bunayan Almutayri of the U. S. Geological Survey staff, who found the prospect in September of 1973, while searching the region for ancient mines. One small pit, 2 by 4 by 2 m deep, presumably dug by the ancients in quest of copper, is along a fault through the richest part of the prospect.

The Aqiq quadrangle has been mapped and the lithology and structure studied by Greenwood (1975). Other previous investigations of the region include short reports on the Gennaida prospect (Shanti, 1958) and the Ain Khathamah prospect (Schaffner, 1958). Although location descriptions and latitude and longitude given for the Gennaida and Ain Khathmah prospects place them many kilometers from the Jabal Murryyi prospect area, they both in fact seem to be descriptions of the Jabal Murryyi prospect. Goldsmith (1971) gives different coordinates for Gennaida and Ain Khathamah, also several kilometers from the Jabal Murryyi prospect. A helicopter and ground search at the locations given by Shanti (1958), Schaffner (1958), and Goldsmith (1971) failed to reveal any ancient mines or altered and mineralized zones, although country rocks were metasediments of the Rafa Formation.

As part of a regional investigation of mineralized areas in the southeastern part of the Jabal Ibrahim quadrangle and the southwestern part of the Aqiq quadrangle, the prospect was evaluated as a target for further exploration work. Fieldwork during the first week of November 1973, consisted of mapping the area at a scale of 1:10,000, using aerial photography as a base; mapping the immediate prospect area at a scale of 1:1000, using a Brunton and tape base map; and sampling the mineralized zones. Ground geophysical investigations consisted of electromagnetic and self-potential surveys conducted during the latter part of November 1973. All work was performed in accordance with a work agreement between the U. S. Geological Survey and the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia. The results of the geological reconnaissance, geochemical sampling and the geophysical investigations are reported here.

This study was not of a scope to outline in detail the physical, chemical, and genetic aspects of the metals and enclosing Rafa Formation host rocks. The purpose of this report is to present salient aspects of the mineralized occurrence, as based upon limited reconnaissance investigations, and to record the occurrence of syngenetic copper in sedimentary rocks of the Ablah Group.

GEOLOGIC SETTING

The southwestern Aqiq quadrangle is underlain by two distinct sequences of regionally metamorphosed greenschist. The older sequence consists of the Baish and Bahah Groups and the younger of the Rafa Formation of the Ablah Group. The Baish Group, mainly medium to dark greenish gray metabasalt, and the Bahah Group, mainly dark-gray fine-grained arkosic graywacke and ashy and marly black chert, is unconformably overlain by medium- to coarse-grained clastic rocks of the Rafa Formation (Greenwood, 1975). Several plutonic bodies of coarse- to medium-grained granodiorite and dikes and sills of pink K-feldspar rhyolite intrude both sequences. The regional structure is dominated by strong north to northwest-trending shear zones and parallel schistosity that obscure most primary features. All lithologies are affected. The Rafa is assigned an age of 800 m.y. to 960 m.y. by Greenwood (1975) based upon radiometric dates of overlain and intruding batholiths.

The Baish Group exposed at the Jabal Murryyi prospect consists of greenstone and greenschist, derived from volcanic basalt, volcanic wacke, and mafic sandstone. Small exposures of quartz-sericite schist and siliceous dolomite in the southwestern part of the mapped area (fig. 1) are included in the Baish, although this assignment is uncertain. The dark- to medium-green greenstone and greenschist range from slightly cleaved massive to extremely schistose and crenulated rocks, and contain amygdules composed of quartz, albite, epidote, and carbonate. Pods, lenses, and boudins of epidote with quartz, chlorite, and albite are common. Groundmass is composed of varying amounts of actinolite, albite, epidote, chlorite, and carbonate. The volcanic wacke is generally schistose and displays no obvious primary textures. Plagioclase, epidote, and chloirte are the main constituents with lesser amounts of quartz and fragments of mafic volcanic rock and black chert. Pale-green to tan massive sandstone is largely epidote, feldspar, chlorite, and quartz, with scattered larger fragments of quartz, chert, and feldspar. This rock is cleaved, slightly schistose, and retains a faint primary bedding. Several generations of foliation, schistosity, cleavage, and folding in the Baish Group mask most original primary features. Lithologic layering can be traced with difficulty in the greenstone, greenschist, and volcanic wacke while relict bedding is present locally in more massive sandstone units.

A well-exposed section of the Rafa Formation, Ablah Group, extends from west to east across the northern part of the area (fig. 1). The contact between Rafa Formation and Baish Group is unconformable; the younger overlying Rafa conglomerate fills channels in the Baish. Lithologic layering and epidote-rich boudins in the Baish are truncated at the unconformity. The presence of cleaved and schistose fragments of Baish greenschist and epidote-rich clasts in the Rafa conglomerate just above the contact indicates that the Baish was a metamorphic schistose rock prior to deposition of the Rafa. The section of exposed Rafa Formation grades from coarse conglomerate at the lower contact through wacke and arkosic wacke into argillite in the northeast corner of the map area. All lithologies have been metamorphosed to the greenschist regional metamorphic facies and strongly sheared locally. Typical mineral assemblages are quartz-albite-epidote, quartz-muscovite-chlorite, and quartz-feldspar-epidote-chlorite with locally abundant hematite, leucoxene, and calcite.

The conglomerate is unsorted but contains local minor medium-grained beds with relict bedding. Cobbles as much as 50 cm in diameter can be found, but most are in the range of 5 to 20 cm and are subangular to rounded. The coarsest conglomerate is 20 to 30 m above the Baish-Rafa contact. Cobbles are of diorite, quartz diorite, quartz monzonite, red chert, basalt to latite volcanics, vein quartz, greenschist, and gray tuff. Texture of the rock is generally schistose with the schistosity flowing around slightly to strongly elongated cobbles. The matrix of the conglomerate consists of quartz, feldspar, epidote, and chlorite with locally abundant carbonate and hematite.

In contrast to the underlying Baish, the Rafa is affected by only one main s-surface, a northwest-trending nearly vertical plane of schistosity, shearing, and cleavage that transects original bedding and lithologic layering at small to large angles. The conglomerate tends to be schistose while the medium- and fine-grained rocks are cleaved. Relict bedding with grading and local cross-bedding is common in the finer-grained units. Minor folded bedding and crenulationed schistosity are common.

A narrow zone of alteration consisting of veinlets and pods of calcite, quartz-calcite, and quartz-K-feldspar in partially silicified and sericitized wacke and conglomerate extends southward from the granodiorite the length of the map area. Near the Jabal Murryyi prospect (fig. 2) the alteration is confined to one conglomeratic wacke unit, but to the south it cross-cuts all lithologies. Quartz and K-feldspar pegmatites as much as 1 m wide are common in the altered zone and in the vicinity of Jabal Murryyi. These pegmatities contain scattered remnant fragments of malachite-bearing country rock. The alteration probably was associated with the intrusion of the granodiorite and centered along a preexisting zone of fracturing.

Medium- to coarse-grained granodiorite composed of hornblende, biotite, quartz, plagioclase and interstitial K-feldspar intrudes the Rafa Formation in the northern part of the map area. This is the southern tip of an exposure of granodiorite 7 km long and as much as 2 km wide. The granodiorite crosscuts lithologies and the finer-grained wacke and the matrix of the conglomerate is a hornfels for a distince of 50 to 150 m from the intrusive contact. The actual contact is disrupted by strong north- to northwest-trending shearing. Quartz-K-feldspar pegmatites associated with the zone of alteration extend into the intrusive.

Structure in the vicinity of the Jabal Murryyi prospect is dominated by the strong north- to N.25°W.-trending nearly vertical S-surface expressed by schistosity, foliation, axial plane cleavage, and shearing planes. Folding in both the Rafa Formation and the Baish Group is evident, although it is partly masked by the north- to northwest-trending surfaces. The youngest structural units are north- to northeast-trending faults with small offsets that cut all lithologies and also cut the major north- to northwest-trending shearing. The Rafa Formation as exposed is a syncline with numerous nearly isoclinal subsidiary folds in its western flank. Folding as outlined by bedding in the wacke is both isoclinal shear and open flexures, around north-plunging axes that have been broadly warped by later tectonic deformation. Folding within the Baish Group is not readily obvious, although isolated limbs and noses of very tight isoclinal folds can be seen. The volcanic wacke and sandstone of the Baish define a broad south-plunging antiform that postdates the tight isoclinal folding.

Major structural and lithologic differences exist on opposite sides of a rhyolite dike that extends from the southwest quadrant to the northeast quadrant of the map (fig. 1). Lithologies cannot be traced across the dike. Structural attitudes also commonly are greatly disparate across the dike. It is assumed the dike was emplaced along a preexisting fault, probably of shallow dip, prior to regional shearing along the north-trending S-surface.

MINERALIZATION

All known copper occurrences in the area are within metamorphosed clastic sedimentary rocks of the Rafa Formation. Although this report covers only the Jabal Murryyi occurrence (fig. 2) there are many small occurrences of malachite throughout the exposed rocks of the Rafa Formation in the southwestern Aqiq quadrangle, and Goldsmith (1971, p. 32) lists three occurrences of malachite and chrysocolla in metasedimentary rocks in the southwestern part of the Aqiq quadrangle.

The mineralized outcrops contain disseminated malachite and chrysocolla and finely-dispersed chalcocite within beds of siliceous and mafic wacke that lie in the gradational transition zone between conglomerate and arkosic wacke (fig. 1). The siliceous wacke beds are discontinuous massive lenses and boudins that are generally less than 2 m thick but continue sporadically for relatively long distances along strike. The lenticular shape of the outcrops of siliceous wacke is due in part to shearing and attenuation associated with metamorphism and deformation but may be a primary feature that has been accentuated by later metamorphism and deformation. Faint relict bedding is common in the siliceous wacke. Quartz and plagioclase, both with sculptured edges, are the major constituents of the siliceous wacke. Lithic fragments of tuff, greenschist, volcanic clasts ranging from basalt to latite, chert, diorite, and quartz monzonite are abundant locally, as are chlorite and epidote. All are set in a fine-grained matrix of quartz and feldspar(?). Rounded grains of rutile occur sporadically; leucoxene, as an alteration product of rutile and sphene, is ubiquitous within distinct 1 mm-thick layers. Fine- to coarse-grained hematite is locally abundant. Malachite and chrysocolla occur in three forms: 1) irregular interstitial grains within quartz-monzonite fragments; 2) ragged grains within the layering of the wacke and often associated with aggregates of quartz and feldspar; and 3) cross-cutting veinlets along fractures and cleavage. Neither grains nor casts of chalcopyrite or pyrite were noted. Chalcocite occurs as scattered irregular dark grains and as part of the fine-grained dusty material that occurs in much of the rock.

The amount of pyroclastic material present in the siliceous wacke is unclear. Some of the siliceous groundmass resembles ash and a few of the larger fragments in the groundmass of the rock may be stretched lapilli. A very similar copper-bearing rock within clastic metasedimentary rocks of the Ablah Group in the Wadi Yiba district has been termed a mafic tuff(?) by Earhart (1969). The rock at Wadi Yiba has been subjected to higher grade metamorphism and is generally strongly sheared thus making an accurate determination of the original rock type difficult.

The chlorite-rich mafic wacke at the Jabal Murryyi prospect is strongly foliated, retains no relict textures, and is difficult to distinguish from sheared arkosic wacke. This poorly exposed unit may be as much a product of shearing, metamorphism and hydrothermal alteration as of primary deposition. Mineralogically the mafic wacke is similar to the siliceous wacke except for the dominance of chlorite. Malachite and chrysocolla are as seams and lenses along foliation planes. Pyroclastic material, mainly banded mafic volcanics and glassy fragments, is relatively common, but still constitutes a minor portion of the rock.

The mineralized rocks at the prospect do not form gossans. The weathered surface of mineralized rock is a camel-tan varnish that masks the dispersed malachite and chrysocolla. No hypogene minerals with the exception of finely disseminated chalcocite have been noted nor have casts of pyrite or other sulfides been noted. Iron oxides within and around some of the malachite and chrysocolla grains suggest a source from the weathering of chalcopyrite.

The largest lense of mineralized rock is a sheared, folded, and broken sheet of siliceous wacke about 250 m in length and an average width of roughly 4 m (fig. 2). The resistant siliceous wacke here forms minor topographic highs and stands 30 cm to 3 m above the surrounding arkosic wacke.

The mineralized zone was sampled by taking chip samples along specified traverse lines. Each sample was composed of approximately 3 Kg of 3-6 cm-sized chips taken along the length of the sample interval (fig. 3). The samples were analyzed at the Ministry of Petroleum and Mineral Resources-USGS laboratory in Jiddah. Gold, silver, copper, lead, zinc, cadmium, cobalt, manganese, and nickel were determined by atomic absorption methods; tungsten, molybdenum, and arsenic by colorimetric methods; and iron, magnesium, calcium, titanium, barium, beryllium, chromium, lanthanium, antimony, scandium, vanadium, yttrium, and zirconium by semiquantitative spectrographic methods. Values for copper and silver are reported on figure 3, and values for manganese, iron, magnesium, calcium, titanium, and vanadium are summarized in table 1. The other metals occur in concentrations at or below detection limits and are not shown.

Analyses of samples indicate an average value of 1.5 percent copper and 22 g/t of silver for the sample interval of mineralized rock. The figures are thought to be

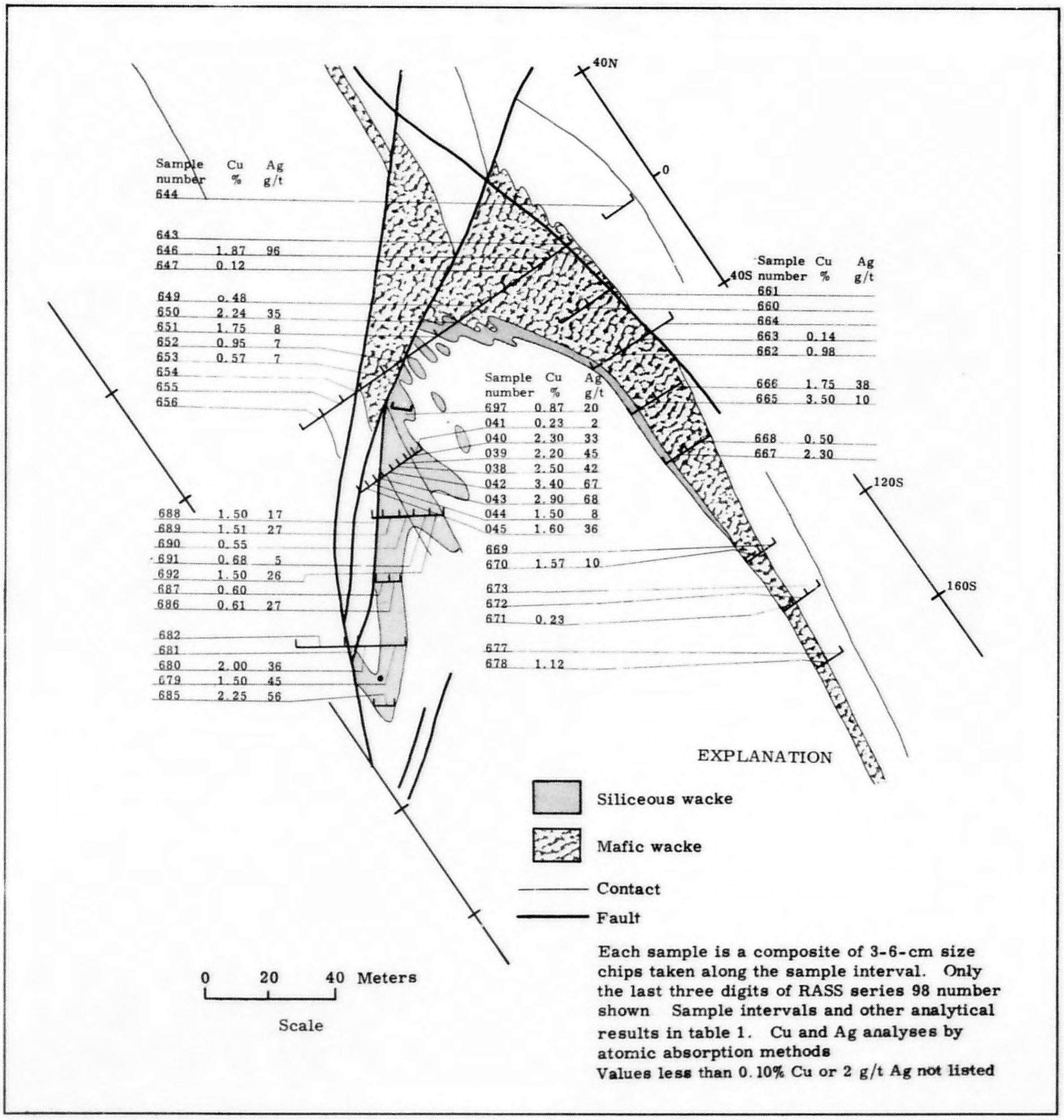

Figure 3. - Sample location map, Jabal Murryyi prospect.

Table 1.--Analytical results of samples from the Jabal Murryyi prospect. Mn determinations by atomic absorption and Fe, Mg, Ca, Ti, and V by semi-quantitative spectrography. Sample locations on figure 3.

Sample number	Mn ppm	V ppm	Fe %	Mg %	Ca %	Ti %	Sample Interval meters
98038	540	150	2.0	1.0	1.0	.5	3
98039	555	150	2.0	1.0	2.5	.5	3
98040	200	30	.5	.1	.1	.2	3
98041	275	50	1.0	.3	.3	.2	3
98042	215	50	.7	.2	.1	.2	3
98043	410	70	2.0	1.0	.1	.3	3
98044	665	70	2.0	1.0	.1	.3	3
98045	400	50	1.5	.5	.3	.3	3
98643	330	30	1.0	.2	1.0	.1	7
98644	640	100	3.0	1.0	1.5	.2	14
98646	1000	300	3.0	1.0	.5	.2	6
98647	680	150	2.0	.5	.7	.3	10
98649	790	150	2.0	.5	.5	.2	10
98650	980	500	3.0	1.0	.1	.2	6
98651	980	200	5.0	1.0	.2	.2	10
98652	320	100	1.5	.2	.3	.2	10
98653	440	150	3.0	.5	.2	.2	10
98654	820	200	7.0	1.0	.5	.3	10
98655	420	100	5.0	.5	.5	1.0	10
98656	470	100	3.0	1.0	.5	.5	10
98660	910	100	3.0	1.0	1.5	.7	10
98661	520	50	1.5	1.0	.7	.7	10
98662	680	150	1.5	.5	.5	.7	10
98663	680	100	2.0	1.0	.3	.5	10
98664	298	30	1.0	.3	.5	.2	10
98665	880	150	2.0	1.5	.05	.3	8
98666	1000	150	3.0	1.5	2.0	.5	10
98667	1050	150	2.0	1.0	.5	.5	8
98668	810	150	2.0	1.0	.3	.5	10
98669	520	50	2.0	1.5	.5	.3	6
98670	1000	200	1.0	.5	5.0	.5	4
98671	1100	200	3.0	1.5	2.0	.5	6
98672	720	70	1.0	.5	2.0	.2	5
98673	460	50	1.0	.5	2.0	.3	10
98677	1000	500	5.0	3.0	.5	.3	8

Table 1.--Analytical results of samples from the Jabal Murryyi prospect. Mn determinations by atomic absorption and Fe, Mg, Ca, Ti, and V by semi-quantitative spectrography. Sample locations on figure 3 (cont'd.)

Sample number	Mn ppm	V ppm	Fe %	Mg %	Ca %	Ti %	Sample Interval meters
98678	740	70	1.5	.7	3.2	.2	4
98679	410	70	1.5	1.0	.1	.2	7
98680	340	200	1.5	.5	.3	.5	7
98681	480	200	3.0	.7	.5	.5	5
98682	350	70	1.5	.5	1.5	.2	15
98685	330	50	.5	.5	1.5	.2	6
98686	430	100	1.0	.5	.3	.2	4
98687	530	150	2.0	.7	.5	.3	4
98688	300	70	.5	.2	.7	.3	3
98689	110	30	.5	.2	1.0	.15	5
98690	320	100	3.0	.2	.1	.2	5
98691	340	100	1.5	.3	.1	.15	5
98692	420	100	1.5	.5	.1	.2	5
98697	280	100	1.5	.5	.05	.3	9

reasonable estimates of the metal values of the outcrop. There seems to be no enrichment of copper at the surface zone nor is there evidence of copper depletion during metamorphism or weathering. Thus the values given are reasonably close to protore values.

GEOPHYSICAL SURVEYS

Geophysical surveys at the Jabal Murryyi prospect covered an area of about 480 x 280 m (fig. 4 and 5). The main mineralized outcrop is in the center of the area between profiles 40S and 40N and about 100-120 m west of the base line. Turam electromagnetic (EM) amplitude ratios (fig. 4) are near a normal 1:1 indicating that the induced electrical field was distorted very little by subsurface conductors. A slight high (1.0 to 1.1) was detected parallel to the geologic strike and 60 m west of the base line along profiles 40N to 280N. This coincides with a zone of alteration and pegmatites. The EM response may be reflecting conduction resulting from increased micaceous minerals in the altered zone.

Another area of slightly higher EM values was dectected along the western end of profiles 160N and 280N. A highly weathered zone of schist along a fault was observed at the surface in this area, and the EM anomaly is tentatively interpreted to be associated to this clay zone. The 1.1 ratio contour in this area however indicates that the entire area is slightly anomalous, and the survey should have been extended further west and north to outline the exact areal extent of this anomaly.

Self-potential values are very low over most of the surveyed area (fig. 5). Background variations of the self-potential values were determined by repeated observations of two profiles on successive days. The magnitude of the variation was found to be about $\pm$ 10 millivolts (mv). There are only two areas where the self-potential determinations exceed the background variation; these are along profiles 80N and 200N to 280N. The maximum negative value (-40 mv) is less than what is generally considered as being indicative of subsurface mineralization. The anomaly along the western end of profiles 200N-280N coincides generally with the EM anomaly, and suggests that this area might be looked at in more detail, but the low values of both anomalies indicate that the area has a low probability for a subsurface mineralized deposit. Geophysical investigations did not define any large anomalies. In retrospect the geophysical methods used are probably not too meaningful, if the entire deposit is composed of disseminated chalcocite

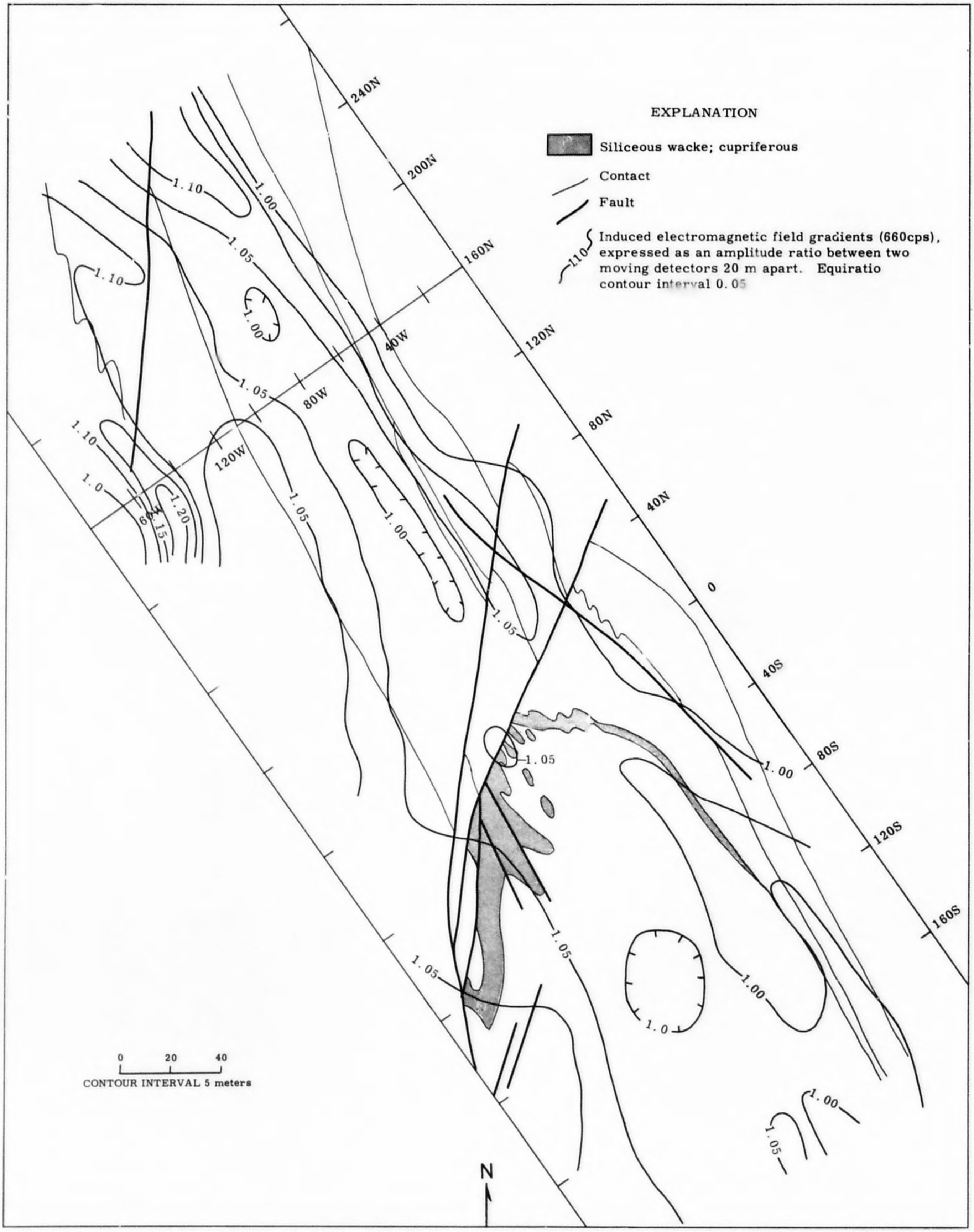

Figure 4. - Turam electromagnetic amplitude ratio map, Jabal Murryyi prospect.

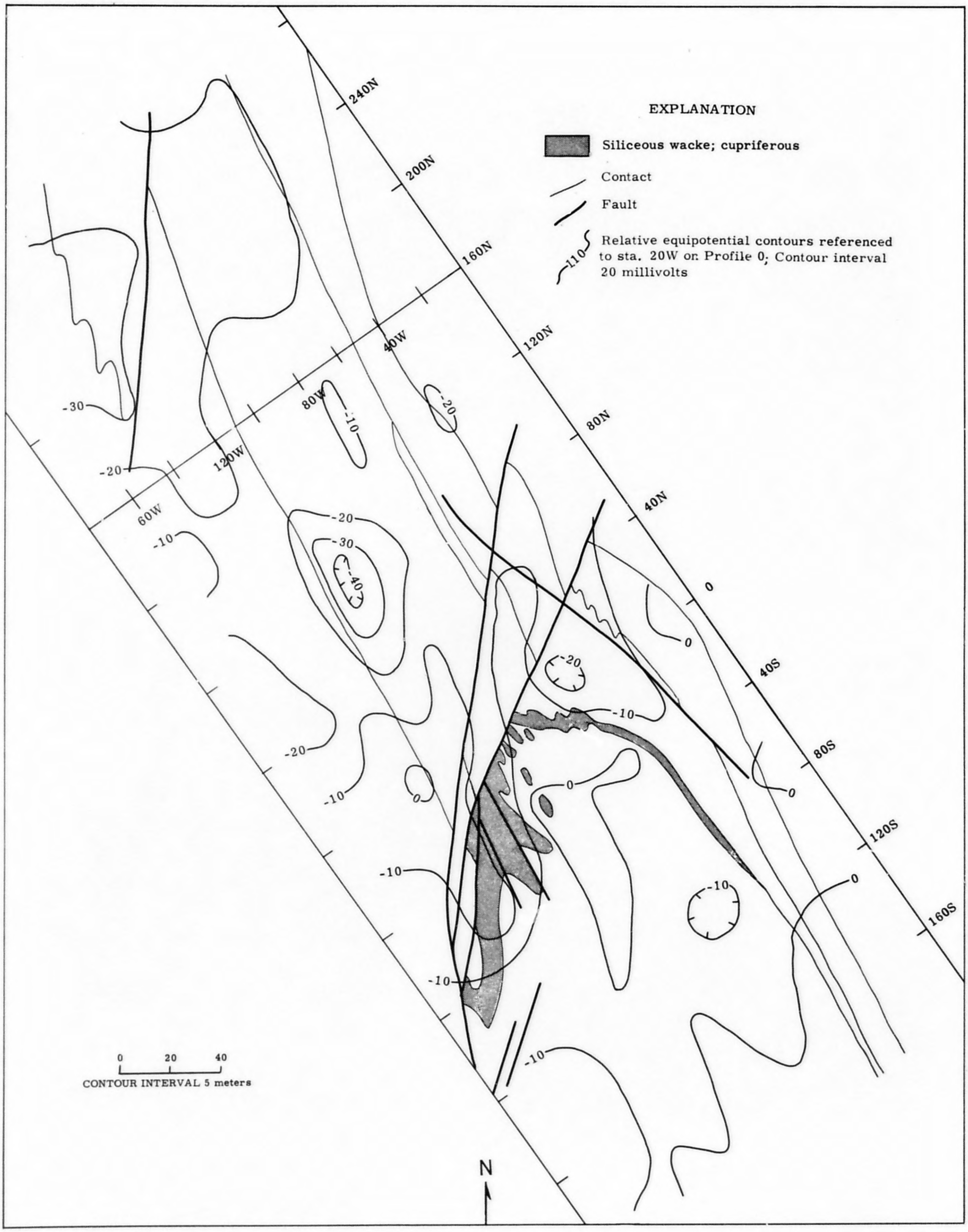

Figure 5. - Self-potential map; Jabal Murryyii prospect

and chalcopyrite instead of disseminated sulfides over and around beds of massive sulfides.

CONCLUSIONS

The syngenetic copper occurrences in sedimentary rocks at the Jabal Murryyi prospect are in sharp contrast to the massive pyrite, pyrrhotite, chalcopyrite, sphalerite deposits in the Wadi Bidah district, 30 km to the northwest. Deposits at Wadi Bidah are in the predominantly volcanic Baish Group, whereas the Jabal Murryyi prospect and nearby occurrences are in the younger overlying predominantly sedimentary Rafa Formation of the Ablah Group.

The Rafa Formation, as exposed in the prospect area, constitutes a transgressive shallow water marine sedimentary sequence of immature to submature quartz-feldspar clastics that were locally dolomitic or argillaceous. Source for the Ablah rocks was a rapidly eroding terrain of older low-grade metamorphic rocks (Baish), basalt to latite volcanic rocks, chert, tuff, quartz veins, and diorite to quartz monzonite plutonic rocks. Pyroclastic material was added from local andesitic volcanism. The abundance and the tabular shape of some of the plagioclase suggests slight reworking of crystal tuffs deposited directly into the basin or ejecta washed into the basin from a close source.

The anomalous copper and silver concentrations are near the top of a basal conglomerate sequence in finer-grained sediment, deposited during a period of relative quiescence or more likely deposited in local restricted basins or lagoons. The dark gray to black color of fresh rock suggests deposition under foul bottom conditions. Although it is not clear, the texture and distribution of the secondary malachite and chrysocolla and the dusty chalcocite suggests a detrital source for the copper, and presumably the silver also. The dusty chalcocite and some of the malachite and chrysocolla are within and confined to relict bedding. Also much of the malachite and chrysocolla are within or around detrital lithic fragments. Therefore it is thought that copper and silver were transported to the site and deposited as part of the enclosing sediment, as or within detrital fragments but possibly also from colloidal suspensions or directly from solution. The presence of chalcocite as the primary hypogene mineral and lack of pyrite is probably a factor of lithofacies control at the time of deposition.

Characteristics of this copper deposit can be summarized as follows:

1. Copper and silver are syngenetic with the enclosing sediments.

2. The enclosing sediments are part of a transgressive sequence laid down about 850 to 960 m.y. ago.

3. The host sediments are immature fine-grained quartz-feldspar clastics deposited near the top of the basal conglomerate sequence.

4. There is no evidence for igneous activity, either volcanic or plutonic, associated with the mineralization.

5. Mineralization is not controlled by any major structures.

6. There are no obvious biogenic features associated with the mineralization.

7. Primary sulfide minerals were chalcocite and possibly chalcopyrite. Pyrite is not present.

8. Metamorphism has had no appreciable effect upon metal distribution or concentration.

9. There is no evidence for hydrothermal activity associated with the mineralization.

Although the known metalliferous exposures in the Ablah Group are small they are of a type condusive to large tonnages of relatively high-grade ore. Similar occurrences elsewhere in the world constitute major deposits or major potential resources. Cupriferous deposits in the Katanga System of the African copper belt (Stanton, 1972, p. 511), the Adelaidean System of Australia (Rowland, 1973, p. 80) and Belt Super Group of the Western United States and Canada (Harrison and Domenico, 1973, p. 113) are similar in age, genesis, host rock lithology and lithofacies, wulfide mineralogy, and texture to the occurrences in the Ablah Group.

Mineral exploration of the entire Ablah Group, concen trating upon the sequence exposed at the Jabal Murryyi prospect and the sequence exposed in Wadi Yiba (Earhart, 1969), is warranted. The Ablah Group has wide exposure in the southern Arabian Shield (Greenwood, 1975). The nature of the occurrences demands detailed surface mapping, extensive sampling, selected geochemical studies, and litho-facies studies as part of the exploration program.

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