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EVALUATION OF THE UMM AL KHABATH COPPER PROSPECT JABAL IBRAHIM QUADRANGLE,

SHEET 20/41C
KINGDOM OF SAUDI ARABIA

By Ronald G. Worl

With a section on
GEOPHYSICAL INVESTIGATIONS

by Vincent J. Flanigan and Habib M. Merghelani

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ABSTRACT

The Umm Al Khabath copper prospect (lat 20°10'N.; long 41°23'E.) was tested by 815 m of diamond drilling in three holes. Meager metallization of copper, zinc, gold, and silver is related to a distinct phase of quartz-pyrite veinlet stockworks and associated silicification, sericitization, and pyritization. Alteration and metallization are within a major north-trending shear zone, 10-50 m wide. Lithologies cut by the shear zone are pyroclastic agglomerate and tuff with intercalated ferruginous chert, wacke, and basalt flows, all belonging to the Precambrian Baish Group. The outcrop of the shear zone for a length of 1400 m contains scattered gossan, local zones of abundant malachite and chrysocolla veinlets, patches of malachite-rich calcrete cap, and several shallow ancient workings. Composite chip samples taken from the surface across the sheared and altered zone contain anomalous concentrations of copper and zinc in amounts greater than can be expected from the weathering of the slightly metallized rock of the sheared and altered zone.

INTRODUCTION

Location and description

The Umm Al Khabath prospect is at lat 20°10'N. and long 41°23'E. (sheet 20/41C), 25 km north of the Emirate of Al Bahah and 1 km east of the macadam highway leading south from At Ta'if, 185 km northwest (fig. 1). The prospect is at the head of a small tributary near the top of the steep west rim of Wadi Bidah, a major north-draining wadi. Terrain in the vicinity is rugged with a total vertical relief of approximately 600 m in a distance of 2 km from the top of the west rim to the bottom of Wadi Bidah. Total relief within the prospect area is 130 m; the highest point is approximately 2200 m above sea level.

Umm Al Khabath is just east of the densely populated and cultivated region of Bilad Zahkan located along the escarpment 8 km to the west. The village of Al Gawaur is 2 km west and the village of Bani Sar 6 km south. The prospect area is not terraced or cultivated, but serves as

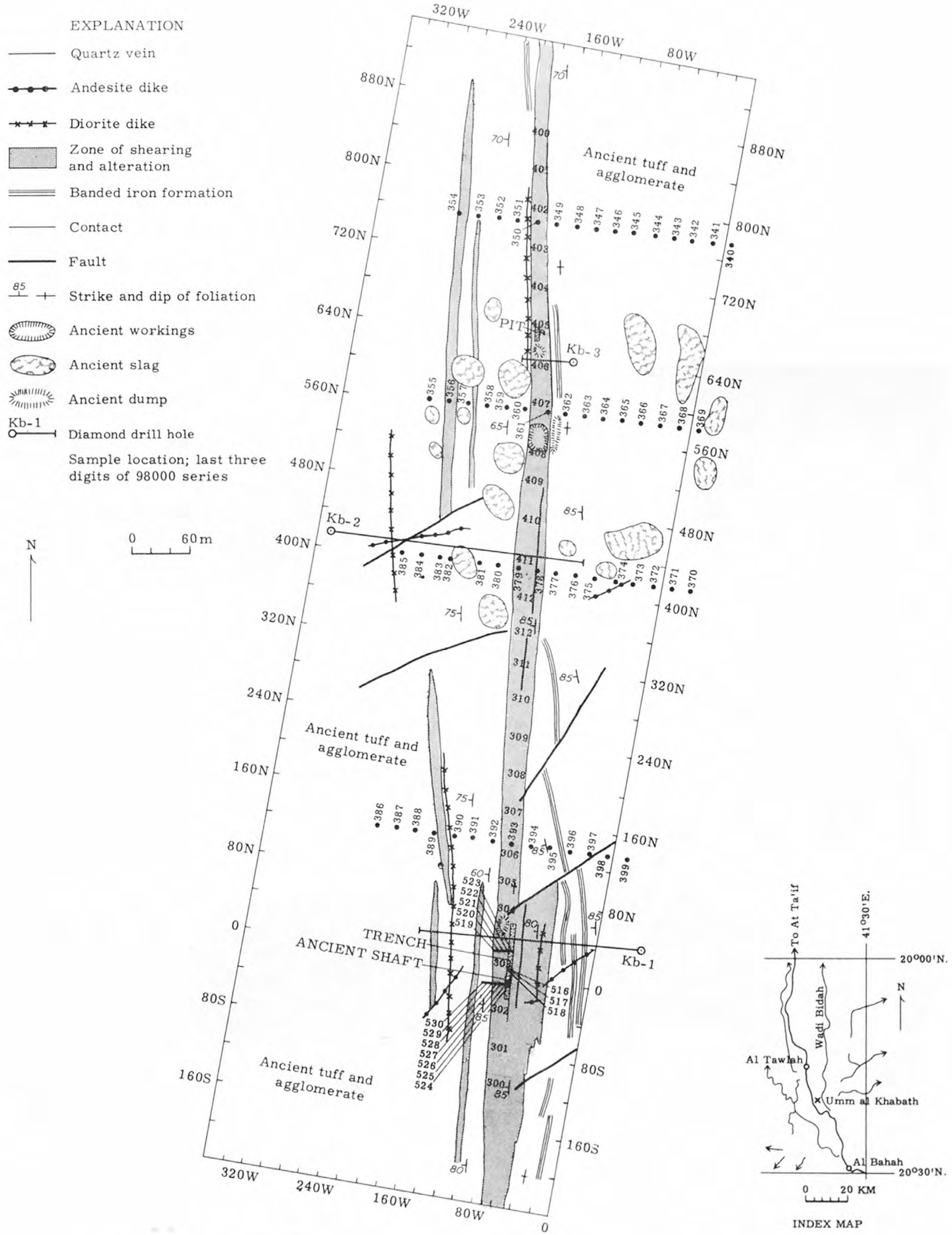

Figure 1. - Geologic map of the Umm al Khabath prospect showing sample locations.

grazing ground for herds of goats and sheep ranging out of nearby villages.

The prospect consists of several malachite-stained gossans and ancient workings scattered along an altered shear zone for a distance of 1400 m. Umm Al Khabath(mother of slag), the local name, comes from the great abundance of large slag dumps left from the ancient smelting operations in the central part of the area (fig. 1). Much of the slag is copper-stained and some contains small beads of native copper. An extensive ancient village site is in and around the slag dumps. Fragments of copper-glazed pottery and partly devitrified green bottle glass can be found among the ruins. Mining and smelting activity was probably greatest in the eighth and ninth centuries during rule of the Abbasid Caliphate. This was a period of extensive mining activity in many parts of the Arabian Shield.

The slag dumps and ancient workings were reported by Murryyi bin Bunayan Almutayri of the U. S. Geological Survey Saudi Arabian Project staff in September of 1973, following a reconnaissance of the general area for ancient mines. Goldsmith (1971) mentions the prospect (number 31 in his table 2, p. 31), but gives no information other than to mention the copper-stained slag. No other mention of the prospect was found in the literature. The prospect is in the Jabal Ibrahīm quadrangle which has been mapped at a scale of 1:100,000 by Greenwood (1975). A summary of all known prospects in the quadrangle is included in Greenwood's report.

Acknowledgements

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The guidance and discussions concerning this study by T. H. Kiilsgaard, R. J. Roberts, D. L. Schmidt, and W. R. Greenwood, of the U. S. Geological Survey and W. K. Liddicoat of the Directorate General of Mineral Resources, all of whom visited the area, are gratefully acknowledged. Topographic surveys were conducted under the field direction of K. S. McLean, while F. G. Lavery handled the aerial photographic mission and prepared the 1:2,000 topographic base map. Prospectors, guides, surveyors, and samplers Murryyi bin Bunayan Almutayri, Meghim Selmi Al Murtaryyri, and Murdi Mabsouk Almtari made important contributions. Acknowledgement is extended to the field services section of the USGS Saudi Arabian Project for providing excellent logistical support.

All samples were analyzed in the Directorate General of Mineral Resources-USGS laboratory, Jiddah.

Purpose of study

Umm Al Khabath is one of several ancient mines and prospects examined during a reconnaissance study of parts of the Al 'Aqiq (20/41D) and Jabal Ibrahīm (20/41C) quadrangles during the fall of 1973. Four of the prospects, including Umm Al Khabath, were selected for further economic evaluation. The prospect was selected as the best of several similar potential areas. If Umm Al Khabath were to prove to be of potential economic value numerous other sheared and altered zones throughout the Jabal Ibrahīm and Al 'Aqiq quadrangles also might warrant extensive prospecting. The geology of the prospect area was first mapped at a scale of 1:10,000, using enlarged aerial photography as a base. Geochemical and geophysical surveys were conducted using a 1:1,000-scale Brunton and tape base map. Sheared and altered rocks also were mapped on this base. Later all information was transferred to a 1:2,000-scale topographic map prepared from low-altitude aerial photography. Following the geologic, geochemical, and geophysical investigations the prospect was tested by three diamond drill holes. This paper presents the geological, geochemical, and geophysical evaluations of the prospect and outlines the results of the diamond drilling program.

Diamond drilling program

The Arabian Drilling Company drilled a total of 815 m of diamond drilling in three holes at the Umm Al Khabath prospect during the period March 1 to June 1, 1974 (table 1).

Table 1. Diamond drill hole data, Umm Al Khabath prospect

Hole No.	Depth	Azimuth	Inclination	Map coordinates
Kb-1	249.95	275°	35°	48N./46E.
Kb-2	299.45	95°	40°	408N./34SW.
Kb-3	265.80	275°	70°	630N./128W.

The purpose was to test the major sheared and altered zone for sulfide potential, either massive lodes or disseminations. The drill hole locations were based upon a combination of geologic, geochemical, and geophysical information. Drill holes Kb-1 and Kb-2 were designed to test a geophysical anomaly that coincides with ancient workings and surface geochemical anomalies within the main sheared and altered zone. The holes were laid out to explore rock adjacent to the main sheared and altered zone and to intersect the sections at nearly right angles to the structure. Drill hole Kb-3 was designed to test a down-dip length of the main sheared and altered zone below an ancient working and a surface geochemical anomaly. Complete logs of each drill hole including complete drilling and geologic information are on file with the Directorate General of Mineral Resources, Jiddah. Analyses of split drill core samples are listed in Appendix A, drilling data and locations are in table 1, summary geologic logs in table 2, and zones of metallization on fig. 2.

GEOLOGY

Regional setting

Umm Al Khabath is near the west edge of the Bidah mineral belt, a north-trending zone of tectonism, plutonism, and base metallization (Greenwood, Roberts, and Bagdady, 1974). This belt which extends approximately 100 km east, 70 km north, and 120 km south, is defined by strong north-trending shear and fault zones, intrusive bodies of diorite and quartz diorite, ancient copper and gold mines, and the outcrop pattern of the Precambrian layered rocks. Massive sulfide deposits composed of pyrite, chalcopyrite, and sphalerite occur 25 to 50 km north in the Wadi Bidah district (Earhart and Mawad, 1970; Greenwood and others, 1974). The largest Wadi Bidah deposit defined to date by diamond drilling is a steeply dipping lenticular tabular body at least 200 m long and as much as 19 m thick. This conformable body (the Rabathan deposit) forms the nose and east limb of a steeply north-plunging fold and contains at least 1.5 million metric tons averaging 2.14 percent copper. Massive sulfide deposits in the Wadi Bidah district are mainly in carbonate-quartz-sericite schist in close proximity to graphitic schist of the Precambrian Baish Group. One deposit, the Gehab mine, is in part within the quartz porphyry.

The eastern part of the Jabal Ibrahīm quadrangle is underlain mainly by rocks of the Precambrian Baish Group and plutonic bodies of diorite and quartz diorite with minor exposures of rocks of the Precambrian Bahah Group and sills and dikes of quartz porphyry (Greenwood, 1975). The Baish and Bahah Groups comprise a metabasalt-graywacke-chert assemblage that is the oldest of three major assemblages recognized in the southern Arabian Shield (Greenwood and others, 1976). Baish Group rocks in this area are composed predominantly of basalt pyroclastic rocks with volcanic and sedimentary breccias. Much of the rock is blocky breccia suggestive of near vent facies, or alternatively submarine slide deposits (Greenwood, 1975). The younger Bahah Group, exposed mainly to the west and south of Umm Al Khabath, is characterized by graywacke, arkosic graywacke, chert, and marble with local beds of graphitic chert and marble. Both groups are metamorphosed to the greenschist regional metamorphic facies and locally to the amphibolite regional metamorphic facies. The major shear and fault zones, foliation,

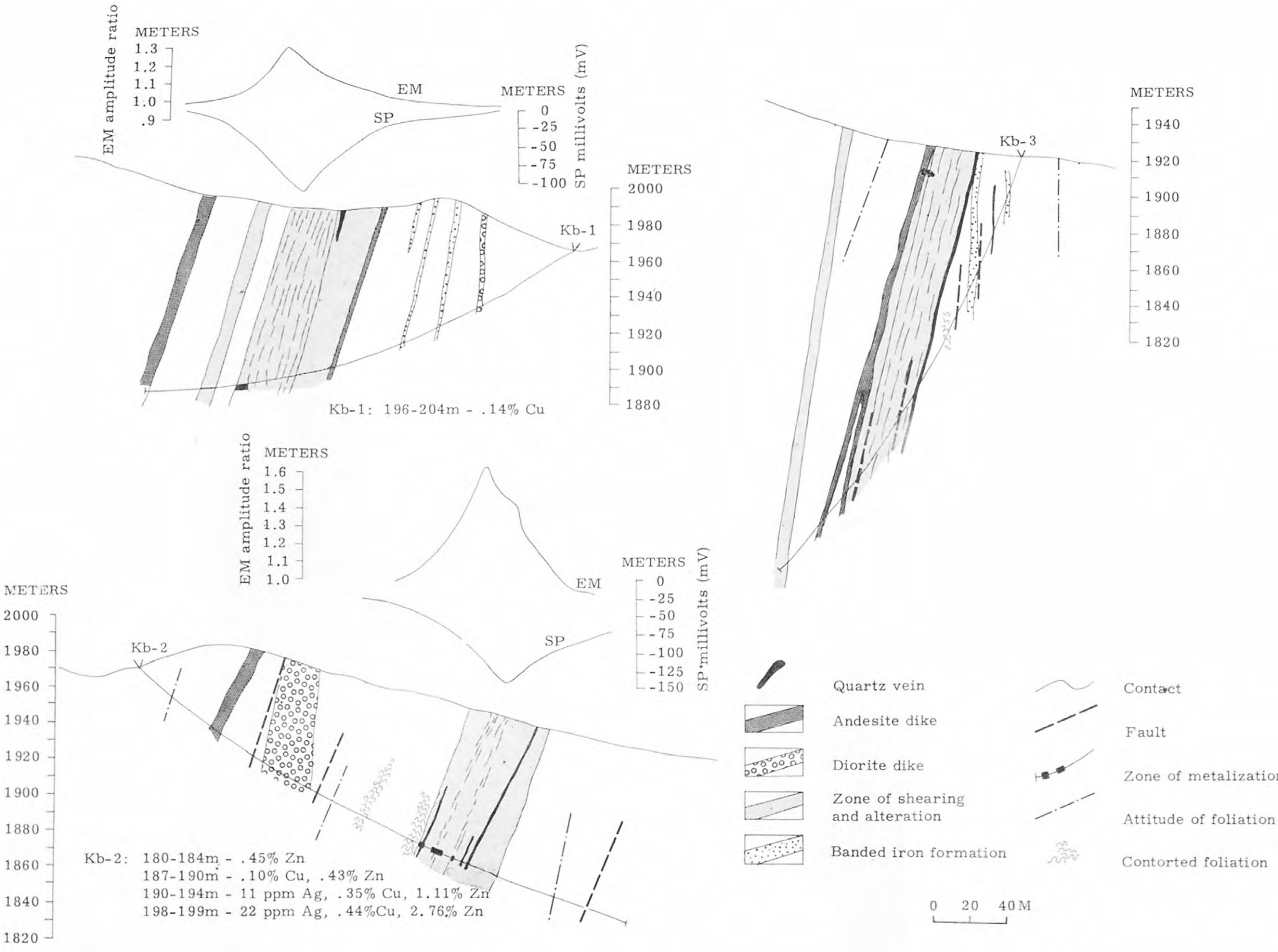

Figure 2. - Vertical sections through diamond drill holes Kb-1, Kb-2, and Kb-3 showing relationship of geophysical data to geology for Kb-1 and Kb-2

Table 2. Summary geologic logs of diamond drill holes Kb-1, 2, and 3, Umm Al Kabath prospect

Summary log Kb-1

From	To	Description
0	47.60	Weathered tuff
47.60	60.25	Andesitic tuff. Four intergradational types interbedded throughout drill hole. 1. massive fine grained 2. pyroclastic 3. banded carbonate-rich 4. clastic
60.25	61.82	Diorite dike
61.82	73.45	Andesitic tuff
73.45	84.07	Siliceous tuff, large diffuse siliceous pyroclasts in subordinate chloritic groundmass
84.07	85.45	Ferruginous chert
85.45	92.43	Siliceous tuff, overprint of chlorite along shear planes
92.43	105.00	Andesitic tuff
105.00	107.40	Ferruginous chert
107.40	143.82	Quartz-sericite schist, nil to abundant carbonate
143.82	146.33	Andesite dike
146.33	200.00	Chlorite schist, dense gray groundmass of fine-grained quartz, sericite and pyrite, abundant talc, zone of strongly sheared rock extends from 165 to 200
200.00	210.00	Siliceous tuff
210.00	217.00	Quartz-sericite schist, crenulated
217.00	248.07	Andesitic tuff
a 248.07	249.95	Andesite dike

Table 2. Summary geologic logs of diamond drill holes Kb-1, 2, and 3 (continued)

Summary log Kb-2

From	To	Description
0	10.15	Weathered tuff
10.15	23.45	Andesitic tuff. Four intergradational types interbedded throughout drill hole. 1. massive fine grained 2. pyroclastic 3. banded carbonate-rich 4. clastic
23.45	37.90	Andesite, amygdaloidal, intercalated with andesitic tuff
37.90	38.55	Shear zone
38.55	50.40	Andesitic tuff
50.40	56.47	Andesite dike
56.47	75.03	Andesitic tuff, mostly pyroclastic
75.03	86.85	Siliceous tuff
86.85	87.80	Fault zone
87.80	101.60	Andesitic tuff
101.60	111.79	Diorite dike
111.79	179.86	Andesitic tuff, carbonate-rich locally
179.86	192.60	Quartz-sericite schist, crenulated, diss. pyrite, zone of slightly to strongly sheared rock.
192.60	194.25	Massive pyrite in siliceous groundmass
194.25	198.85	Quartz sericite schist
198.85	208.56	Andesitic tuff
208.56	220.47	Quartz-sericite schist, zone of slightly to strongly sheared rock
220.47	299.45	Intercalated massive andesitic tuff and sheared and crenulated quartz-sericite schist

Table 2. Summary geologic logs of diamond drill holes Kb-1, 2, and 3 (continued)

Summary log Kb-3

From	To	Description
0	17.17	Massive andesitic tuff
17.17	58.30	Siliceous tuff, diffuse gray siliceous pyroclasts in chloritic groundmass. Local zones ferruginous chert
58.30	61.00	Fault zone
61.00	84.20	Siliceous tuff
84.20	130.20	Andesitic schist, massive, pyroclastic, and banded carbonate-rich types interbedded
130.20	149.85	Quartz-sericite schist, zone of intensely sheared rock
149.85	154.90	Several post-shearing fault zones
154.90	164.08	Siliceous tuff
164.08	175.65	Quartz-sericite schist, zone of intensely sheared rock
175.65	181.45	Siliceous tuff
181.45	196.50	Quartz-sericite schist, zone of strongly sheared rock
196.50	265.85	Mainly quartz-sericite schist interbedded with less sheared and altered andesitic tuff and siliceous tuff
203.30	205.40	Andesite dike
223.40	227.00	Andesite dike

and schistosity in the eastern part of the Jabal Ibrahīm quadrangle are dominantly north-trending and nearly vertical. Layering and foliation within the units is generally parallel to the regional trends although tight shear folding of competent beds is common.

Lithologies and structure

Rocks of the Umm Al Khabath prospect are mainly pyroclastic volcanic rocks, tuff to agglomerate, with intercalated basaltic flows, wacke and ferruginous chert formation. All rock types have been metamorphosed to the greenschist facies and are composed of varying amounts of plagioclase (albite-oligoclase?), chlorite, epidote, quartz, and calcite with locally abundant amphibole, probably actinolite, pyrite, hematite, and magnetite. The metamorphic effects combined with ubiquitous shearing tend to mask the original rock types; however, enough relict textures remain to make reasonably accurate determinations of the original lithologies. Pyroclastic fragments range in size from ash to bombs and blocks as much as 10 cm in diameter. Many of the pyroclasts seem to be rounded, and detrital quartz is a minor constituent in the tuff and agglomerate. Clasts of plagioclase crystals and aggregates of plagioclase, commonly with pyroxene or epidote and chlorite are in most rock types with the exception of the basaltic flow rocks. The larger pyroclasts are dark gray, locally vesicular, siliceous in places with abundant carbonate or pyrite. Clots of chlorite and epidote probably represent mafic pyroclasts but have been sheared, stretched, and recrystallized beyond recognition. Groundmass of the pyroclastic rocks is composed of varying amounts of untwinned plagioclase (albite-oligoclase?), quartz, chlorite, and epidote. Calcite is a common but variable constituent as 1 to 10 mm long lenses, layers, and interstitial grains in all rock types except the ferruginous chert.

Ferruginous chert composed of quartz and magnetite or hematite with locally abundant pyroclasts and minor chlorite is well- to poorly-bedded and occurs as lenses within the tuff and agglomerate. The tuff is finely laminated, crenulated, locally sorted and contains small amounts of detrital quartz. Minor lenses of wacke composed of quartz, feldspar, and lithic fragments occur within the tuff and agglomerate. Crosscutting the volcanic-sedimentary assemblage are small dikes of diorite that trend northeast and cut the north-trending foliation of the country rock, but are sheared out along the north-trending shear zones. Lenses of massive andesite, probably dikes or sills, are conformable to the foliation and shearing.

The main structure at the prospect is a north-trending zone of shearing 10 to 50 m in width (fig. 1) that extends several kilometers north and south of the map area. Several episodes of shearing can be recognized in the zone. The effects of shearing are evident in all lithologies and range from slight rotation of feldspar clasts and development of chlorite along a preferred orientation to the development of massive mylonite. All gradations between slightly foliated greenstone to mylonite composed of quartz and sericite can be found, and remnants of less sheared and altered greenschist with relict tuff and agglomerate textures are common within the shear zone. All lithologies are foliated, generally, but not strictly parallel to layering, and in some sections of drill core two slightly divergent foliations can be detected. Shear folding on a minor scale is common and probably exists on large scales but is indistinguishable in the area. At Wadi Mandahah, 20 km north, the same sequence of rocks is strongly shear folded at all scales.

Mineralization and alteration

The main shear zone (fig. 1) contains numerous ancient workings which explore limonitic (hydrous iron oxides that have not been specifically identified) gossans and locally abundant malachite and chrysocolla stringer zones. The gossans are not strong but are large and indicative of mainly fine-grained disseminated sulfides and stringers of sulfides with scattered small lenses of massive sulfides. Malachite and chrysocolla stringers 1 to 10 mm in width occur along shear planes and cross fractures and are also common in less sheared rock along the edge of the sheared and altered zone. Malachite is locally very abundant as stringers and masses in a calcrete cap that covers parts of the shear zone.

Ancient workings consist of one trench about 60 m long, 1-2 m wide, and 2-3 m deep: several smaller pits and trenches: and a pit 20 by 30 m and unknown but shallow depth. A shaft about 1.5 m square leading to shallow underground workings was exposed by caving of a rain water filled sample trench. The shaft, of unknown depth, is within a 60 m long ancient trench now filled with alluvion and silt.

Several thousand tons of ancient slag are found scattered along parts of the shear zone. The amount of slag present seems greater than could have been produced from ancient workings, suggesting that either large amounts of ore were hauled in from elsewhere, or that there are extensive working in the near vicinity that have not been discovered. However, another likely source is the malachite-rich calcrete cap that covers parts of the sheared and altered zone. The ancients may have stripped large areas of formerly extensively malachite-rich calcrete cap and malachite-bearing gossans and hand cobbed the material to a depth of several meters. Remnants of malachite-rich calcrete caps and the nature of the rock found in spoil piles supports this idea. Collectively these sources would provide a large tonnage of ore easily obtained with crude tools, and this may have been the source of the copper ore, and thus the slag.

Drilling penetrated wide zones of altered and slightly mineralized rocks in the shear zone. The major shear and altered zone is largely silicified, pyritized, and sericitized. The rocks have possibly been subjected to hydrothermal propylitization, but shearing and greenschist facies metamorphism mask the effects. Hydrothermal alteration in the shear zone is centered around veinlets of gray quartz and sulfides and spreads laterally from the veinlets as a flooding of gray quartz, very fine-grained pyrite, and sericite. Some parts of the shear zone are entirely altered with minor remnants of greenschist while in other parts the alteration occurs as irregular patches in sheared and mylonitized green schist. This alteration obliterates or greatly subdues the mylonitic texture. The altered zones are cut by veinlets of carbonate, veins of milky white quartz, which in turn are cut by talc-rich shears. Two generations of quartz veins have been noted. The older is in northeast-trending structural features outside the main sheared and altered zone and as boudins and lenses within the shear zone. The younger milky white veins are both inside and outside the main sheared and altered zone. The older generation may be the source of the local gold and silver anomalies.

Pyrite, a common but minor constituent of the sheared, but unaltered greenschists, is most abundant within the altered rock where, along with lesser amounts of chalcopyrite and sphalerite, it forms fine disseminations, stringers, veinlets, and 1 to 10 mm layers conformable to the shear foliation. The sulfides are locally very abundant, but do not form massive bodies more than 5 cm thick. The only massive sulfide body found was intersected in drill hole Kb-2 at 192.60 to 194.25 m, where approximately 80 percent of the core was stratabound sulfide layers. Chalcopyrite and sphalerite generally occur in veinlets and stringers in the altered rock; however, their abundance is low and distribution sporadic. This is reflected in the generally low and quite variable copper and zinc values obtained by analyses of split drill core (Appendix I).

GEOCHEMISTRY

Surface sampling plan

Four groups of surface geochemical samples were taken to test the sheared and altered zone for metal content; a) rock chip samples across 10 m intervals within the main sheared and altered zone, b) selected gossan samples from the main sheared and altered zone, c) chip samples from the bottom of ancient workings cleared of debris, and d) rock chip samples taken at regular intervals along traverses across the major structural trend. Sample locations are on figure 1 and analytical results are given in Appendix A. Each sample was a rock chip sample composed of approximately 3 kg of 3-6 cm sized chips taken from outcrops along the length of the sample zone. Analyses were performed at the Directorate General of Mineral Resources-USGS laboratory, Jiddah. Other elements besides those listed, were checked, but occur in nil or minor amounts and include Mo, W, B, Be, Bi, Cd, La, Nb, Sb, Sc, Sn, Sr, and W.

Twenty-six composite rock chip samples were taken along 10 m lengths across the main sheared and altered zone at intervals of 40 m (fig. 1). The samples contained nil to anomalous concentrations of Au, Ag, Cu, and Zn. The mean and range in values are given in table 3. Copper occurs as secondary malachite and chrysocolla stringers; zinc in part as finely disseminated smithsonite and probably in part adsorbed on limonite. The nature of occurrence of the other elements is unknown.

Twenty-six selected gossan samples that correspond to the above composite chip samples were taken, one from each composite sample interval. Each sample consisted of several chips of the strongest gossan present within the sample interval. Because the samples were selected high-grade material their metal contents are not characteristic of the main sheared and altered zone. The purpose was to check for the suite of elements present and to obtain a rough estimate of the metal content of sulfide stringers, the probable source of the seams of gossan. Results of analyses are given in Appendix A, and the mean and range in values are given in table 3. The metals present are the same as detected in the 10 m interval chip samples but are present in greater abundance. No other metals were detected.

Three trenches were hand dug across the largest and most obvious ancient working (fig. 1) and surrounding sheared and altered rock. The depths of the trenches were 30-50 cm over sheared and altered rock and 1 to 2.5 m over the ancient workings. The sample material collected, although weathered, was from below the obvious surface carbonate and oxide enriched zone. Results of analyses of the fifteen samples are given in Appendix A and the mean and range in values in table 3. The same suite of metals are present, but in lesser concentrations than in the surface samples. Malachite and chrysocolla are not obvious in this rock, nor are sulfides.

Table 3. Mean and range in analytical values of surface and split core samples Umm Al Khabath prospect.

Sample group		IA - Composite chip samples, sheared and altered zone	IB - Selected gossan samples	IC&D - Composite chip samples from trenches	IE&F - Composite chip traverse samples	I-E&F - Composite chip traverse samples minus samples taken in sheared and altered zone	IIA - Split core samples from Hole 3	IIB - Split core samples from Hole 2	IIC - Split core samples from Hole 3	IIA, B, C, & D - All split core
Number of samples		26	26	15 & 15	58 & 38	52 & 34	68	32	28	128 & 13
Au	mean	.51	1.98	.28	.07[1*]	.02[1*]	.10[1*]	.09[1*]	.22[1*]	.15[1*]
ppm	range	.05-6.40	.04-17.60	.04-.88	(-)-2.00	(-)-0.41	(-)-0.26	(-)-1.06	(-)-1.88	(-)-1.88
Ag	mean	5.83	83.40	7.92	1.49[1*]	1.15[1*]	.96[1*]	3.2[1*]	2.63[1*]	1.87[1*]
ppm	range	.40-38.2	.7-396.0	.6-43.2	(-)-11.6	(-)-5.3	(-)-3.3	.7-22.0	(-)-52.0	(-)-52.0
Cu	mean	.43	5.92	.07	.08[1*]	.02[1*]	.03[1*]	.06[1*]	(-)[1*]	.02[1*]
ppm	range	.01-1.88	.04-26.25	.01-.18	(-)-1.85	(-)-.18	(-)-.23	(-)-.63	(-)-.04	(-)-.63
Zn	mean	.25	1.48	.10	.09[1*]	.06[1*]	.07[1*]	.31[1*]	.03[1*]	.12[1*]
%	range	.01-1.73	(-)-6.00	.01-.22	(-)-.41	(-)-.20	(-)-.45	(-)-2.76	(-).44	(-)-6.00
Mn	mean	568	478	689	1,902	1,930				1,573
ppm	range	80-1,870	20-1,100	200-1,300	200-5,600	200-5,600				50-5,000
Fe	mean			2.67	7.12					3.35
%	range			1.0-5.0	3.91-17.3					1.5-7.0
Mg	mean			.51						2.62
%	range			.3-.7						.5-5.0
Na_2O	mean				3.57	3.72				
%	range				.04-5.67	.04-5.67				
K_2O	mean				1.34	1.29				
%	range				.24-2.41	.24-2.70				
SiO_2	mean				61.1	60.4				
%	range				42.98-76.48	2.98-71.02				
Ba	mean			G5000						1,600
ppm	range			censored						70-5,000
V	mean			137						141
ppm	range			50-200						30-300
Y	mean			40						26
ppm	range			20-100						10-50
Zr	mean			53						48
ppm	range			20-70						10-70

*Data censored—a number of concentrations below detection limits

Sixty composite chip samples were taken along four traverses across the trend of the main sheared and altered zone. The samples were taken at 20 m intervals from random starting points. Each sample was composed of chips taken from an area approximately 10 m in diameter. Results indicate no other metal concentrations other than in the main sheared and altered zone. Analytical results are given in Appendix A, and the mean and range in values in table 3.

Core sampling plan

Altered and mineralized core was split with one half being retained, and one half submitted for analyses. Sample intervals ranged from 1-2 m of core length. The mean and range in values are given in table 3 and all analytical results are listed in Appendix A. As the samples were selective in that only altered and mineralized rock was included the analytical results are an adequate estimate of the metal content of the sheared and altered zone at depth. Metallized zones encountered in the diamond drilling were very few, and of low grade. They are listed below:

Drill Hole	Depth	Metal content
Kb-1	196-240 m	.14% Cu
Kb-2	180-184 m	.45% Zn
	187-190 m	.10% Cu, .43% Zn
	190-194 m	.35% Cu, 1.11% Zn
	198-199 m	.44% Cu, 2.76% Zn

Discussion

Distribution of anomalous concentrations of the metals copper, zinc, gold, and silver is centered upon the main sheared and altered zone. Overall primary concentration within the zone is slight, but higher metal values, corresponding to massive silicification with disseminated to massive pyritization, occur scattered throughout. Secondary concentration of copper, zinc, gold, and silver at the surface of the main and altered zone is significant. This concentration is at or just under the surface as evidenced by the low metal values of samples obtained from shallow trenches dug across the zone (table 3). Much of the copper and presumably also the zinc in the surface zone occurs as pods and lenses within the calcrete cap that covers part of the zone.

The high values of copper, and zinc in the carbonate-rich surface rocks are misleading and represent false or dispersed hydromorphic anomalies. Metals migrating along the shear zone would be trapped, by deposition, in the alkaline environment forming the calcrete cap. Source of the materials for the calcrete cap is the locally abundant carbonates in the surrounding tuffs, especially where cut by the shear zone. In this arid to semi-arid environment a strong upward percolation of the Ca^{++} and HCO_3-charged water combined with evaporation and transpiration at the surface would form the calcrete cap above or near the source carbonate. Source of the metals is not so clear. The anomalous values could represent a progressive concentration of the metals weathered in place; and retained relatively immobile by the alkaline environment. More likely the values represent an enrichment of metals from other parts of the sheared and altered zone that were deposited and trapped upon encountering the alkaline environment. Oxidation of the siliceous sulfide bodies would release the metals in an acid environment in which zine especially, but also copper, are highly mobile. These elements would then be relatively mobile until they either reached the surface, probably alkaline everywhere in this climate, or encountered a zone of alkaline waters around weathering carbonates. The copper and zinc may have migrated a few meters, many meters, or perhaps many hundreds of meters. Although these anomalies do not reflect metallization directly at depth they do point to a source somewhere within the hydromorphic system.

Detailed surface and subsurface geochemical studies of several prospects in the Wadi Bidah district by Allcott (written commun.) have pointed out the need to use elements other than copper and zinc for geochemical exploration in this area. The geologic setting of the Wadi Bidah district is similar to that at Umm Al Khabath. Massive sulfide bodies are along sericitized, silicified, and pyritized altered shear zones and are commonly associated with larger zones of disseminated and stringy sulfides. Some of the occurrences at Wadi Bidah have massive limonite gossans but the weak, malachite-bearing calcrete covered gossan over the largest deposit, Rabathan, is not unlike the leached and gossan zone at Umm Al Khabath. Allcott (written commun.) suggests that anomalous concentrations of Au, Ag, Ba, and an Fe/Mg ratio greater than 5 are significant indications of metallization and may more exactly define targets than copper and zinc. At Umm Al Khabath, samples taken from trenches across the main sheared and altered zone contain anomalous concentrations of Au, Ag, and Ba and the Fe/Mg ratio on half the samples is 5 or greater. Most of the samples from the zone contain slightly anomalous concentrations of gold and silver. However, analyses of Ba, Fe, and Mg were determined on too few of these samples to be meaningful.

GEOPHYSICAL INVESTIGATIONS

by

Vincent J. Flanigan and Habib M. Merghelani

Introduction

Geophysical surveys were carried out at the Umm Al Khabath copper prospect to provide geophysical data that might assist in understanding the structure, geology, and mineral potential of the area.

The geophysical surveys covered an area of approximately 1.4 x .25 km along the main sheared and altered zone (fig. 1). This zone presumably associated with regional faulting ranges from 10-50 m in width and can be traced for several kilometers through the area. Metavolcanic rocks of the Baish Formation have been largely altered to quartz-sericite schist in the altered zone. Non-metallic conductors such as graphitic schist, are not present in the prospect area.

Discussion of results

The results of the geophysical surveys are shown on figures 3 and 4. Five distinct lens-shaped anomalies were outlined by the self-potential (SP) method. These anomalies, located along the zone of shearing and alteration, range in size from 10-13 m wide and 100-240 m long. The maximum amplitude of the SP anomalies is -150 millivolts (mV), as referenced to base station 80S.

The self-potential method (fig. 3) measures spontaneous or natural voltages developed in the earth. The source of the self-potential determinations is not dependent upon any definite rock physical property but is due to chemical activity associated with the oxidation process (Parasnis, 1966). Sato and Mooney (1960) suggest that certain common conditions have been observed to exist where the source of self-potential values have been studied. Among these are factors that affect the oxidation process and the transfer of electrons in the ore body and surrounding country rocks. When ideal conditions are attained in nature, the self-potential will be large, reaching values on the order of 500 mV. A deterioration in one or more of these factors affecting the SP phenomena will result in lower amplitude measurements. Just how much each factor affects the overall process is not clearly understood, but this probably explains why some ore bodies can be outlined reasonably well by the SP method, whereas known extensions of the same ore body, apparently not electrically connected, reflect none or very small self-potential measurements.

The electromagnetic (EM) method (fig. 4) also outlined the altered zone where locally, values of up to 1:1.6 amplitude ratio where attained. The maximum EM values generally coincide

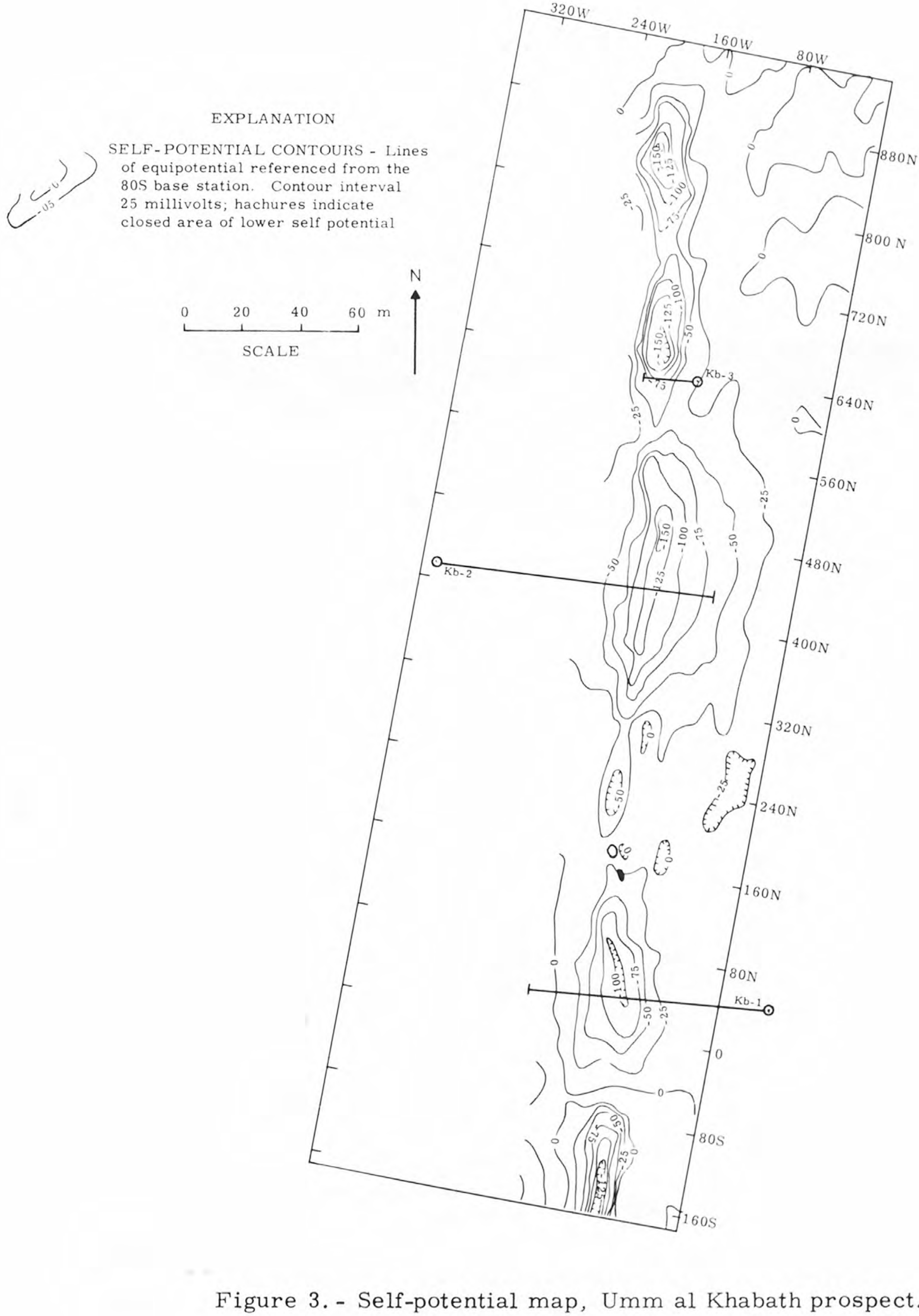

Figure 3. - Self-potential map, Umm al Khabath prospect.

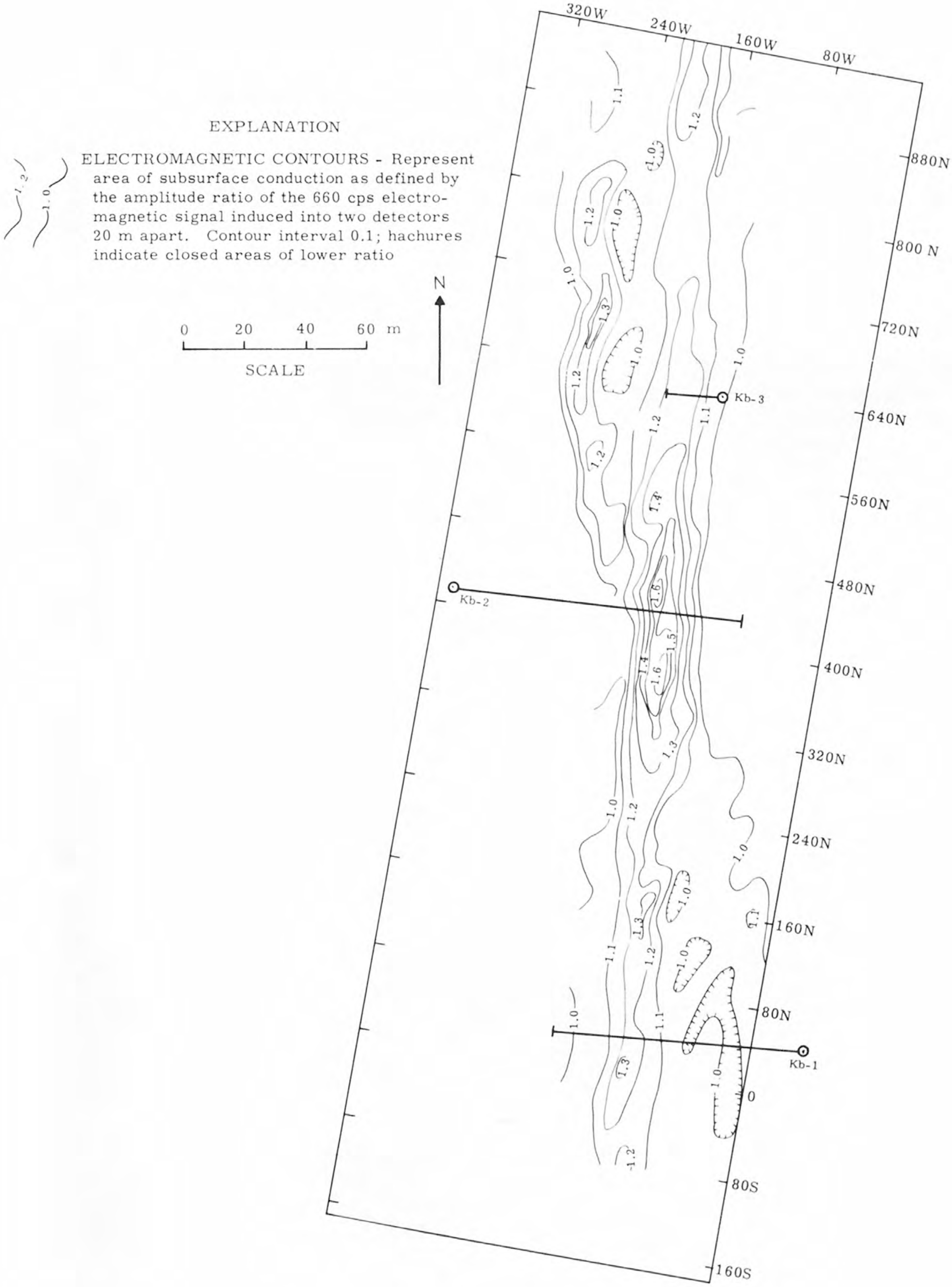

Figure 4. - Turam electromagnetic ratio map, Umm al Khabath prospect.

with the maximum SP values, except that the EM maxima are offset to the west in reference to SP maxima suggesting that the EM method may be more susceptible to the dip of the conductor than is the SP method. Phase angle differences (not shown on fig. 4) coupled with the amplitude ratio values indicate that the body centered about station 400N and 160W is a moderate to good electrical conductor.

The diamond drill holes penetrated the sources of the highest geophysical anomalies. The relationship of the geophysical data to the drill core log of the hole KB-1 is shown on figure 2. Generally the drill intersected tuff and agglomerate mineralized by disseminated pyrite. Along the zone of alteration the tuff and the agglomerate are altered to quartz sericite schist. The highest geophysical data values seem to be associated with this quartz sericite schist and may be related more specifically to the degree of alteration associated with more intensely sheared sections of the zone.

Drill hole KB-2 (fig. 2) generally shows the same relationship, that is, the highest geophysical data values are associated with the zone of shearing and alteration in which the tuffs and agglomerates are silicified, sericitized, and pyritized in varying degrees. Pyrite is abundant locally in the altered zone.

The relationship of the drill core log of hole KB-3 to the relative self potential, and to the apparent resistivity of the rocks intersected by the drill is shown in figure 5. The self potential as well as the apparent resistivity values are relative to an arbitrary datum and cannot be related to the results of the surface SP survey. However, it is apparent that within the sheared and altered zone several zones of higher self-potential exist. Anomalous zones also are reflected at 10 m intervals at 165 m and 232 m where lower apparent resistivity measurements were recorded. These anomalies may be associated with the degree of alteration, but this cannot be correlated directly.

Conclusions

The self-potential and electromagnetic anomalies of Umm Al Khabath are directly associated with the zone of shearing and alteration. Within the zone of alteration there are non-coincident zones of higher self potential and lower resistivity. The degrees of metallization and alteration, as well as the factors affecting the oxidation-reduction SP phenomena, probably account for the cause of the geophysical anomalies. The main source of the SP anomaly is probably the dark gray siliceous pyritic alteration product.

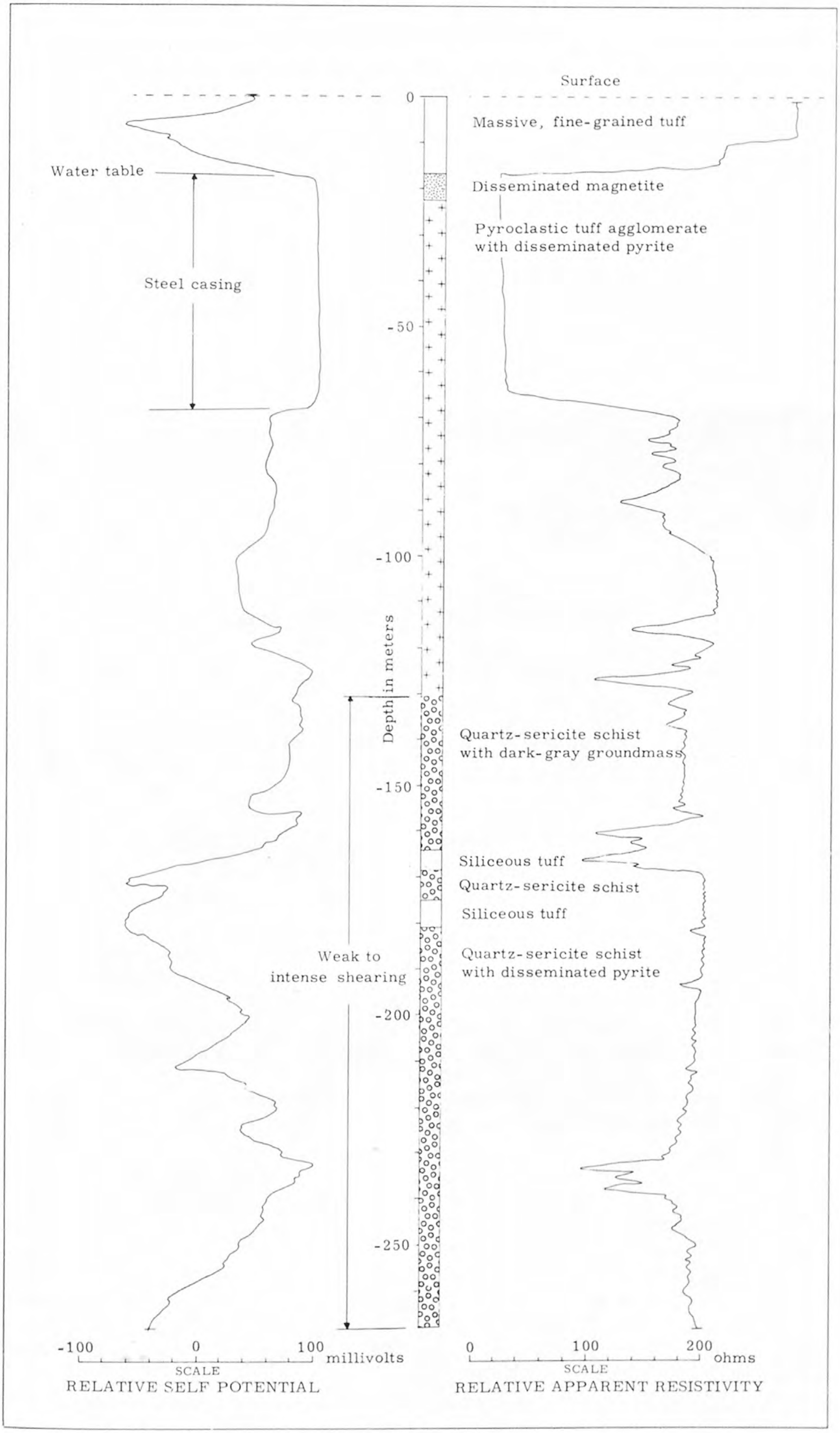

Figure 5. - Log of diamond drill hole Kb-3 showing relationship of electric logs to lithology.

CONCLUSIONS AND RECOMMENDATIONS

Primary metallization at Umm Al Khabath consists of chalcopyrite and sphalerite with trace quantities of silver and gold related to a distinct period of quartz veinlet stock-working silicification, sericitization, and pyritization. Metal content within the altered rock is erratic and higher concentrations are mainly confined to zones of high pyrite content. The alteration and related metallization were later events in the geologic history of this region. The origin of the deposits was probably by deposition from waters derived from deep-seated sources; migrating upward along the shear zone; perhaps during a late metamorphic stage. A partial geologic history of the mineralized belt is summarised below:

Youngest

A - Period of minor shearing and development of hydrothermal(?) talc along shears.

B - Emplacement of andesitic dikes. This event may have preceded the shearing and alteration .

C - Emplacement of milky white quartz veins.

D - Emplacement of quartz veinlet stockworks with associated silicification, sericitization, pyritization, and metallization in the main shear zone. This event crosscuts and obliterates the mylonite.

E - Shearing along north-trending surfaces with development of foliation and schistosity in all lithologies and intense mylonite in the shear zones.

F - Emplacement of diorite dikes and quartz veins along north-east trending fractures.

G - Development of foliation and presumably metamorphism of the Baish Group basaltic tuffs and agglomerates.

Oldest

The surface geochemical copper and zinc anomalies along the main sheared and altered zone are supergene hydromorphic and reflect more the presence of an alkaline environment than an underlying metalliferous deposit. The metals may have migrated long distances along the shear zone before being precipitated in the alkaline, near surface environment. Geophysical electromagnetic (EM) anomalies outline the zone of shearing and the SP anomalies probably outline the areas of strongest pyritization and associated alteration.

Investigations at Umm Al Khabath have identified geological factors that should be considered in any future exploration in the general area. Any surface anomalies of copper and zinc must be evaluated carefully in terms of the environment of secondary transportation and deposition. Selective sampling of altered and gossan zones from shallow trenches may give more accurate approximations of the metal content of the unweathered rock. However, in the case of copper and zinc, they would be depleted if the environment were acidic and enriched if it were alkaline. Other pathfinder elements such as Ba, Au, Ag, and the Fe/Mg ratio as suggested by Allcott (written commun.) may prove to be more useful. Although electromagnetic (EM) anomalies generally outline sheared zones, a SP anomaly may outline massive sulfides, finely disseminated sulfides, (weathering) graphitic schists, pyritiferous slates, ferruginous jasper dikes, or iron-bearing beds. Other electrical geophysical methods may prove to be more useful.

The fact that large zones of mineralization or massive sulfide bodies were not detected by drilling Umm Al Khabath does not negate their presence in the general area. The results of work at Umm Al Khabath suggest that if massive or disseminated sulfide deposits do occur in the Baish Group rocks an integreated program of geochemistry, geophysics, lithofacies studies, and regional geology will be needed to detect them.

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APPENDIX - Analytical results

Surface sample locations are given on fig. 1, and drill-core sample intervals and depths are on logs on file at the Directorate General of Mineral Resources. This listing contains results of the following:

I. Surface composite chip samples

A. Along 10 m sample intervals across main sheared and altered zones.

B. Selected gossan samples that correspond to sample set A.

C. From trenches across ancient workings, atomic absorption results.

D. From trenches across ancient workings, spectrographic results.

E. At 20 m intervals along traverses across structure, atomic absorption results.

F. At 20 m intervals along traverses across structure, colorimetric and atomic absorption results.

II. Subsurface split drill-core samples

A. Drill hole Kb-1, atomic absorption results

B. Drill hole Kb-2, atomic absorption results

C. Drill hole Kb-3, atomic absorption results

D. Drill holes Kb-1, Kb-2, and Kb-3, spectrographic results.

I. Surface composite chip samples

A. Along 10 m sample intervals across main sheared and altered zone, atomic absorption results.

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba 1/ ppm	Fe/Mg 1/ ratio	As ppm	Mn ppm
98,300	.11	.7	.03	-	.02	700	3		680
98,301	1.36	38.2	.65	.03	.16				1,300
98,302	.11	.7	-	-	.01				80
98,303	.11	2.3	.43	.06	.69				900
98,304	.11	.8	.25	-	.25				490
98,305	.16	.6	.09	-	.05				400
98,306	.09	.4	.02	-	.06				470
98,307	.10	.9	.18	-	.10				560
98,308	.11	.7	.70	-	.87			35	365
98,309	.13	.6	.03	-	.14				1,870
98,310	.09	.5	1.25	-	.03	700	7		530
98,311	.05	.4	.03	-	.06				900
98,312	.34	17.6	.26	.08	.37				770
98,400	.09	5.0	.01	.01	.01				95
98,401	.09	7.2	.11		.03				170
98,402	.20	6.8	.05	.03	.16				330
98,403	6.40	21.4	.06	.17	.17				350
98,404	.12	5.6	1.25	.07	.37				140
98,405	.08	1.9	1.80	-	.25				600
98,406	.68	13.4	.23	.11	.44				1,440

I. Surface composite chip samples

A. Along 10 m sample intervals across main sheared and altered zone (cont'd.)

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1/] ppm	Fe/Mg[1/] ratio	As ppm	Mn ppm
98,407	.14	1.6	.13	.08	1.73				870
98,408	.06	2.2	.04	-	.15				790
98,409	.68	8.0	.70	-	.29			20	330
98,410	.12	2.0	1.35	-	.06				50
98,411	1.56	3.2	1.40	.07	.11				190
98,412	.08	.9	.01	-	.01				70
Mean	.51	5.83	.43		.25				568
Range	.05-6.40	.40-38.2	.01-1.88		.01-1.73				80-1,870

1/ Spectrographic analyses

I B. Selected gossan samples that correspond to sample set A. Atomic absorption results.

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1/] ppm	Fe/Mg[1/] ratio	As ppm	Co ppm	Mn ppm
98,300	8.00	244.0	7.12	.27	.53	1,000	4			710
98,301	4.20	49.2	2.50	.03	.27					90
98,302	1.30	9.6	2.25	.08	.21					470
98,303	17.60	276.0	1.25	.15	.82			350		50
98,304	7.50	212.0	2.95	.20	.90			400		1,000
98,305	.09	1.0	.03	-	-					630
98,306	.16	.7	.15	-	-					810
98,307	.14	1.2	2.25	-	.12					130
98,308	.12	1.0	8.75	-	.03					370
98,309	.14	9.6	26.25	-	.16			120		120
98,310	3.00	188.0	7.50	.16	2.50	500	4			240
98,311	.15	56.0	23.75	.51	3.78					710
98,312	.46	120.0	4.62	.70	6.00					400
98,400	.05	5.6	.04	-	.03				70	50
98,401	6.13	108.0	3.75	.57	.67				125	1,370
98,402	.04	6.0	6.88	.04	1.95				65	140
98,403	.08	10.8	6.25	.07	5.55				75	335
98,404	.10	7.6	4.30	.04	1.09				85	620
98,405	.82	55.0	6.50	.34	.88				120	710
98,406	.06	98.0	6.25	.03	1.40				70	400

I B. Selected gossan samples that correspond to sample set A (cont'd.)

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1/] ppm	Fe/Mg[1/] ratio	As ppm	Co ppm	Mn ppm
98,407	.04	396.0	1.40	.20	4.70				85	810
98,408	.11	18.4	6.75	.01	.62				60	1,100
98,409	.08	1.2	4.37	-	.62				35	480
98,410	.10	1.1	4.50	-	.06				35	320
98,411	.88	276.0	1.00	.06	5.60					340
98,412	.13	17.0	12.50	.74	.03					20
Mean	1.98	83.4	5.92	.17	1.48					477.88
Range	.04-17.60	.7-396.0	.04-26.25	(-)-.74	(-)-6.00					20-1,100

1/ Spectrographic analyses

I C. From trenches across ancient workings, atomic absorption results

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Fe/Mg ratio	As ppm	Co ppm	Mn ppm
98,516[1]	.30	9.9	.10	.03	.18	4		7	2,180
98,517[1]	.14	43.2	.22	.15	.21	5		14	580
98,518[1]	.88	21.0	.14	.10	.09	7		18	700
98,519[2]	.08	1.8	.06	-	.12	2		9	670
98,520[1]	.06	1.1	.02	-	.09	3	-	12	300
98,521[1]	.12	5.0	.04	.01	.06	6		17	520
98,522[1]	.34	12.5	.06	.04	.08	4		14	520
98,523[1]	.16	5.0	.14	.02	.22	4		20	1,300
98,524[1]	.08	1.4	.07	-	.18	3		14	200
98,525[1]	.62	5.4	.18	.03	.09	6		14	480
98,526[1]	.09	2.1	.03	-	.03	6		14	520
98,527[2]	.11	1.5	.03	-	.07	4		18	880
98,528[2]	.10	.6	.01	-	-	16		14	200
98,529[2]	.49	7.5	.05	.03	.06	4		14	470
98,530[2]	.04	.9	-	-	.01	6	-	17	820
Mean	.28	7.92	.07		.10	5.33			689
Range	.04-.88	.6-43.2	.01-.18		.01-.22	2-16			200-2,180

1/ one meter sample interval
2/ five meter sample interval

I D. From trenches across ancient workings, spectrographic results

Sample number	Fe %	Mg %	Cu %	Ti %	Ba ppm	V ppm	Y ppm	Zr ppm
98,516 1/	3.0	.7	1.5	.2	G5,000	70	100	70
98,517 1/	1.5	.3	.2	.15	G5,000	50	20	50
98,518 1/	5.0	.7	.2	.3	G5,000	200	50	70
98,519 2/	1.5	.7	.5	.15	G5,000	100	20	20
98,520 1/	1.0	.3	.05	.2	700	70	20	50
98,521 1/	3.0	.5	.1	.2	G5,000	200	50	30
98,522 1/	3.0	.7	.2	.2	G5,000	200	50	70
98,523 1/	2.0	.5	.2	.2	G5,000	70	50	70
98,524 1/	1.0	.3	.05	.15	G5,000	50	30	50
98,525 1/	3.0	.5	<.05	.2	G5,000	200	30	30
98,526 1/	3.0	.5	.1	.2	G5,000	200	50	70
98,527 2/	3.0	.7	.1	.2	G5,000	200	30	50
98,528 2/	5.0	.3	<.05	.2	3,000	200	20	70
98,529 2/	2.0	.5	3.0	.1	G5,000	50	50	50
98,530 2/	3.0	.5	<.05	.2	3,000	200	30	50
Mean	2.67	.51	.42		G5,000	137	40	53
Range	1.0-5.0	.3-.7	<.05-1.5	.1-.3		50-200	20-100	20-70

1/ one meter sample interval
2/ five meter sample interval
G - Greater than value given

I E. At 20 m intervals along traverses across structure, atomic absorption results

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1/] ppm	Fe/Mg[1/] ratio	Co ppm	Ni ppm	Mn ppm
98,340	.10	.7	.03	-	.01	3,000	1	125	50	1,580
98,341	.10	.4	.01	-	.01			80	50	1,440
98,342	.10	.4	-	-	.01			65	25	800
98,343	.10	.4	.02	-	.02			90	25	910
98,344	.10	.4	.01	-	.01			110	50	910
98,345	.10	.6	-	-	-			95	50	900
98,346	.10	.5	.01	-	.01			130	75	930
98,347	.10	.4	-	-	.01			95	25	560
98,348	.06	2.0	.02	-	.14			100	50	810
98,349	.06	1.8	.03	-	.13			125	50	1,870
98,350	2.00	3.6	.15	.01	.03	1,000	1	95	-	155
98,351	-	1.1	.01	-	.21			65	100	520
98,352	-	2.4	.01	-	.20			20	100	1,480
98,353	.06	1.3	-	-	.06			95	25	710
98,354	.05	1.2	-	-	.06			50	25	660
98,355	-	1.6	.01	-	.17			45	50	710
98,356	.27	11.6	.11	.03	.40			55	150	765
98,357	.09	1.5	.03	-	-			125	1,500	445
98,358	-	.8	.01	-	.06			50	50	620
98,359	-	.8	-	-	.02			50	50	765
98,360	-	1.3	.01	.01	.04	5,000	1	40	25	530
98,361	-	1.8	.01	.01	.02			30	50	285
98,362	-	1.0	.01	-	.07			40	50	560
98,363	-	1.0	.01	-	.01			30	50	540
98,364	-	-	-	-	.01			40	50	61[illegible]

I E. At 20 m intervals along traverses across structure, atomic absorption results (cont'd.)

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1/] ppm	Fe/Mg[1/] ratio	Co ppm	Ni ppm	Mn ppm
98,365	-	.8	.01	.02	.03			65	50	560
98,366	-	2.3	-	-	.01			60	25	630
98,367	-	.8	-	-	.01			40	25	490
98,370	.41	5.3	.18	.03	.16	5,000	.6	85	50	2,040
98,371	-	1.1	.01	-	.02			120	50	3,640
98,372	-	1.0	.01	-	.01			80	25	3,840
98,373	-	1.5	.02	-	.04			145	50	4,320
98,374	-	1.4	.01	-	.04			120	100	4,000
98,375	-	2.7	.03	-	.03			70	25	2,520
98,376	-	1.3	.02	-	.04			45	25	2,000
98,377	-	2.1	.18	-	.69			135	100	2,060
98,378	-	3.0	1.50	.06	.09			65	-	200
98,379	.21	4.0	1.85	.03	.41			60	-	2,000
98,380	.18	2.2	.05	-	.40	3,000	1.5	75	50	5,600
98,381	.04	1.0	.02	-	.03			50	25	3,560
98,382	-	1.3	.12	-	.09			60	50	3,120
98,383	-	1.1	.01	-	.11			70	25	4,840
98,384	-	1.0	.02	-	.03			50	50	2,520
98,385	-	1.5	.04	-	.12			50	50	3,260
98,386	-	.8	-	-	.02			45	50	3,000
98,387	-	1.0	-	-	.04			70	25	3,480
98,388	-	.5	.02	-	.11			60	50	3,920
98,389	-	.6	.02	-	.09			50	25	2,220
98,390	-	.5	.03	-	.15	70	1	70	25	2,680
98,391	-	.6	.01	-	.14			50	25	2,400

I E. At 20 m intervals along traverses across structure, atomic absorption results (cont'd.)

Sample number	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ba[1] ppm	Fe/Mg[1] ratio	Co ppm	Ni ppm	Mn ppm
98,392	-	.7	.01	-	.05			50	25	3,000
98,393	-	1.0	-	-	.06			25	25	2,990
98,394	-	1.3	.01	-	.03			50	25	2,400
98,395	-	1.3	.02	.02	.09			60	25	2,680
98,396	-	1.3	-	-	.05			55	25	2,320
98,397	-	1.1	-	-	.03			100	200	2,880
98,398	-	1.1	.02	-	.03			75	25	2,520
98,399	-	.8	.02	-	.03			65	23	2,600
Mean	.07	1.49	.08		.09					1,902
Range	(-)-2.00	(-)-11.6	(-)-1.85		(-)-.41					200-5,600

[1] Spectrographic analyses

I F. At 20 m intervals along traverses across structure, colorimetric and atomic absorption results

Sample number	Na_2O %	K_2O %	SiO_2 %	Fe %
98,360	4.86	1.54	58.08	6.48
98,361	4.32	1.20	65.88	4.69
98,362	5.35	1.39	60.98	6.37
98,363	4.10	1.73	57.62	6.48
98,364	3.10	1.03	58.94	6.81
98,365	3.51	1.10	59.18	6.37
98,366	2.70	1.24	61.48	6.59
98,367	3.84	.87	66.72	5.03
98,370	2.43	1.73	54.18	10.61
98,371	2.70	.48	57.14	10.05
98,372	3.24	.48	55.74	9.49
98,373	.16	.24	42.98	13.18
98,374	.13	.24	49.14	11.17
98,375	5.40	1.13	61.56	8.38
98,376	3.78	2.70	59.86	6.14
98,377	2.21	1.94	46.18	17.53
98,378	1.40	1.55	76.48	6.81
98,379	1.76	2.34	76.18	3.91
98,380	4.46	2.07	47.48	10.95
98,381	4.12	.80	71.02	4.58
98,382	3.86	.99	67.30	4.85
98,383	5.67	1.13	64.10	6.03
98,384	5.18	.94	64.28	6.03
98,385	4.86	.83	63.04	6.03
98,386	3.51	2.13	67.34	4.58
98,387	3.78	1.06	66.68	5.58
98,388	5.40	2.70	61.36	6.14
98,389	3.27	2.70	62.58	5.92
98,390	4.86	.78	66.00	5.36
98,391	4.59	.63	69.80	4.58

I F. At 20 m intervals along traverses across structure, colorimetric and atomic absorption results (cont'd.)

Sample number	Na_2O %	K_2O %	SiO_2 %	Fe %
98,392	3.78	.80	63.54	5.96
98,393	4.38	1.00	66.74	5.36
98,394	2.57	1.20	66.70	5.58
98,395	3.78	1.71	57.32	7.04
98,396	2.70	1.35	62.44	6.14
98,397	.04	2.41	45.28	11.06
98,398	4.35	1.66	58.84	6.81
98,399	5.40	1.24	61.60	6.25
Mean	3.57	1.34	61.1	7.12
Range	.04-5.67	.24-2.70	42.98-76.48	3.91-17.3

II. Subsurface split drill-core samples

A. Drill hole Kb-1, atomic absorption results

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,300	150	151	.15	.4	-	-	-	.9	-	5
101,301	151	152	.12	.4	-	-	-			
101,302	152	153	.15	.4	-	-	-			
101,303	153	154	.15	.4	-	-	-			
101,304	154	155	.18	1.0	.02	-	.12			
101,305	155	156	.15	.7	.01	-	.07			
101,306	156	157	.10	1.4	.01	-	.12			
101,307	157	158	-	.4	-	-	-			
101,308	158	159	.12	.5	-	-	.03			
101,309	159	160	.10	.4	-	.04	.10			
101,310	160	161	-	2.0	.02	-	.23	1.0	-	10
101,311	161	162	-	.7	.01	-	.07			
101,312	162	163	.10	.8	.01	-	.07			
101,313	163	164	.07	.9	-	-	.11			
101,314	164	165	.10	1.7	.01	-	.42			
101,315	165	166	.20	1.0	.02	-	.45			
101,316	166	167	.10	.9	-	-	-			
101,317	167	168	.15	.8	-	-	-			
101,318	168	169	.18	.8	-	-	-			
101,319	169	170	.26	.5	-	-	-			
101,320	170	171	.12	.9	-	-	.01	.22	-	-
101,321	171	172	.23	1.2	-	-	.03			
101,322	172	173	.26	1.6	-	-	.01			
101,323	173	174	.23	.8	-	-	.02			
101,324	174	175	-	1.0	-	-	.02			

II. Subsurface split drill-core samples
A. Drill hole Kb-1, atomic absorption results (cont'd.)

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,325	175	176	.12	2.9	.01	.08	.19			
101,326	176	177	.12	1.2	-	.01	.03			
101,327	177	178	-	.7	-	-	.02			
101,328	178	179	-	.5	-	-	.02			
101,329	179	180	-	.7	-	-	-			
101,330	180	181	.07	.8	.01	-	.27	.14	-	-
101,331	181	182	.07	.9	-	-	.05			
101,332	182	183	.09	1.6	.06	-	.05			
101,333	183	184	.06	1.4	.03	-	.03			
101,334	184	185	.13	.7	.02	-	.01			
101,335	185	186	.13	1.0	-	.01	.26			
101,336	186	187	.09	1.0	.01	-	-			
101,337	187	188	.06	1.0	.01	-	.01			
101,338	188	189	.09	.7	-	-	-			
101,339	189	190	.06	.7	-	-	-			
101,340	190	191	.06	.7	-	-	.02	.51	10	-
101,341	191	192	.17	3.3	.15	-	.03			
101,342	192	193	.06	1.0	.07	-	.02			
101,343	193	194	.06	.7	.02	-	.01			
101,344	194	195	.17	1.6	.07	-	-			
101,345	195	196	.13	.7	.02	-	-			
101,346	196	197	.13	.1	.22	-	.02			
101,347	197	198	.10	.7	.12	-	-			
101,348	198	199	.06	.7	.11	-	.01			
101,349	199	200	.06	.5	.07	-	.01			

II. Subsurface split drill-core samples

A. Drill hole Kb-1, atomic absorption results (cont'd.)

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,350	200	201	.07	1.1	.07	-	.02	.32	5	-
101,351	201	202	.07	1.4	.09	-	.07			
101,352	202	203	.06	1.8	.19	-	.05			
101,353	203	204	.06	1.8	.23	-	.05			
101,354	204	205	.06	.1	.02	-	.18			
101,355	205	206	.06	.1	.02	.01	.12			
101,356	206	207	.07	1.0	.01	-	.06			
101,357	207	208	.30	-	.03	-	.09			
101,358	208	209	.10	.1	.03	-	.21			
101,359	209	210	.06	2.8	.16	-	.35			
101,360	210	211	.06	.1	.05	-	.29	.38	20	10
101,361	211	212	.09	1.0	.01	.01	.12			
101,362	212	213	.09	.7	.01	.01	.13			
101,363	213	214	.07	.4	-	-	.08			
101,364	214	215	.07	.5	-	-	.05			
101,365	215	216	.07	.5	-	-	.12			
101,366	216	217	.10	.5	-	-	.02			
101,367	217	218	.10	3.1	.10	.03	.22			
Mean			.10	.96	.03		.07			
Range			(-)-.26	(-)-3.3	(-)-.23		(-)-.45			

II B. Drill hole Kb-2, atomic absorption results

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,368	180	181	.07	1.9	.04	.02	.62			
101,369	181	182	.06	1.6	.04	.05	.44			
101,370	182	183	.10	2.1	.01	.01	.20	1.02	5	-
101,371	183	184	.08	1.5	-	-	.03			
101,372	184	185	.08	1.1	-	-	.01			
101,373	185	186	.08	.8	-	-	-			
101,374	186	187	-	1.5	-	-	-			
101,375	187	188	.03	5.8	.03	.01	.82			
101,376	188	189	-	3.5	.02	.05	.29			
101,377	189	190	-	2.5	.02	-	.18			
101,378	190	191	.05	3.5	.02	.01	.13			
101,379	191	192	.08	8.0	.19	.02	.32			
101,380	192	193	.30	17.8	.63	.09	2.08	.49	60	-
101,381	193	194	.22	14.0	.45	.06	1.92			
101,382	194	195	-	1.0	-	.03	.18			
101,383	195	196	.08	.7	-	-	.03			
101,384	196	197	.05	.7	-	-	.04			
101,385	197	198	-	.5	-	-	.02			
101,386	198	199	1.06	22.0	.44	.15	2.76			
101,387	199	200	-	1.0	-	-	.01			
101,388	200	201	.08	1.0	.01	-	.03			
101,389	201	202	.05	1.3	-	-	.01			
101,390	202	203	.05	1.1	.02	-	.01	2.20	-	20
101,391	203	204	.08	1.0	-	-	-			
101,392	204	205	.12	1.0	-	-	.01			

II B. Drill hole Kb-2, atomic absorption results (cont'd.)

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,393	205	206	-	.8	-	-	-			
101,394	206	207	.05	1.0	-	-	-			
101,395	207	208	.05	.7	-	-	-			
101,396	208.00	208.56	.05	.7	-	-	-			
101,397	270	271	.05	1.1	.01	-	-			
101,398	271	272	-	.8	-	-	-			
101,399	272	273	-	1.0	-	-	-			
Mean			.09	3.2	.06		.31			
Range			(-)-1.06	0.7-22.0	(-)-.63		(-)-2.76			

II C. Drill hole Kb-3, atomic absorption results

Sample number	Interval (m) From	To	Au ppm	Ag ppm	Cu %	Pb %	Zn %	Ca %	Mo ppm	As ppm
101,400	42.00	43.00	.44	1.40	.01	.01	-	3.30	-	-
101,401	43.00	44.00	.33	1.00	-	-	-			
101,402	44.00	45.86	-	-	-	-	-			
101,403	131.10	133.10	.34	.80	-	-	.01			
101,404	133.10	135.10	.29	.60	-	-	.02			
101,405	137.90	139.90	.29	5.10	-	-	.05			
101,406	143.55	145.55	.19	1.40	-	-	.04			
101,407	149.85	151.85	.30	1.70	.02	.02	.08			
101,408	154.90	156.90	1.88	52.00	.04	.03	.44			
101,409	160.40	162.40	.27	1.40	-	-	.01			
101,410	165.85	167.85	.27	.45	-	.01	.08	5.00	-	20
101,411	172.30	174.30	.14	.55	-	-	.03			
101,412	178.40	180.40	.14	.55	-	-	-			
101,413	184.50	186.50	.14	.80	-	-	-			
101,414	190.55	192.55	.13	.55	-	-	-			
101,415	193.60	195.60	.13	.40	-	-	-			
101,416	199.75	201.75	.10	.35	-	-	-			
101,417	207.60	209.60	.10	.35	-	-	-			
101,418	210.65	212.65	.10	.80	-	-	-			
101,419	216.60	218.60	.13	.55	-	-	-			
101,420	221.40	223.40	.13	.55	-	-	-	2.16	-	-
101,421	227.95	229.95	-	-	-	-	-			
101,422	234.00	236.00	.08	.40	-	-	-			
101,423	240.65	242.65	.08	.40	-	-	-			
101,424	245.90	247.90	.08	.55	-	-	-			
101,425	251.80	253.80	.08	.11	-	-	-			
101,426	257.90	259.90	.08	.35	-	-	-			
101,427	263.85	265.85	-	.40	-	-	-			
Mean			.22	2.63	(-)		.03			
Range			(-)-1.88	(-)-52.0	(-)-.04		(-)-.44			

II D. Drill holes Kb-1, Kb-2, and Kb-3, spectrographic results

Sample number	Fe %	Mg %	Ti %	Mn ppm	Ba ppm	V ppm	Y ppm	Zr ppm
101,300	3.0	1.0	.5	700	700	50	50	70
101,310	2.0	3.0	.3	500	700	50	30	50
101,320	2.0	.5	.5	500	1,000	30	30	70
101,330	2.0	.5	.5	50	500	50	20	70
101,340	3.0	3.0	.7	500	3,000	300	20	50
101,350	5.0	5.0	.7	5,000	1,000	200	30	70
101,360	3.0	3.0	.7	3,000	5,000	100	30	50
101,370	3.0	5.0	.7	3,000	5,000	100	30	50
101,380	7.0	5.0	.5	3,000	3,000	200	20	50
101,390	5.0	5.0	.7	1,000	70	500	20	30
101,400	5.0	2.0	.2	1,000	200	200	10	10
101,410	2.0	.5	.2	1,500	500	30	30	30
101,420	1.5	.5	.2	700	150	30	20	30
Mean	3.35	2.62	.49	1,573	1,600	141	26	48
Range	1.5-7.0	.5-5.0	.2-.7	50-5,000	70-5,000	30-300	10-50	10-70