DEPARTMENT OF THE INTERIOR
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THE MINERAL RESOURCE POTENTIAL OF THE WADI AL JARIR AND AL JURDHAWIYAH QUADRANGLES, SHEETS 25/42 C AND 25/42 D, KINGDOM OF SAUDI ARABIA

by

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ABSTRACT

Areas with potential for metallic mineral deposits in the Wadi al Jarir and Al Jurdhawiyah quadrangles, northeastern Arabian Shield, have been identified by reconnaissance rock geochemistry, inspection of ancient prospects, and interpretation of previous work.

The ancient prospects of Abraq Shawfan, Abraq Shawfan South, Ad Du'ibi, Ad Du'ibi West, and Ad Dirabi are not recommended for further study. The Baid al Jimalah East ancient lead-silver mine should be drilled to investigate its mineral potential at depth and to determine its apparent relationship to the nearby Baid al Jimalah West tungsten-tin prospect. High precious metal and copper contents confirmed at the Jarrar ancient prospect suggest additional study.

Preliminary results of core and percussion drilling at the Baid al Jimalah West tungsten-tin prospect indicate that the mineralized rocks decrease in grade with depth and are not suitable for current economic exploitation.

Geochemically anomalous areas in both plutonic and layered volcanic and clastic terrane are possible sites of significant base metal, molybdenum, tin, tungsten, and rare-earth element mineralization.

1/ U.S. Geological Survey Saudi Arabian Mission

INTRODUCTION

Purpose and location

This report describes the results of a reconnaissance program in the Precambrian terrane of the Wadi al Jarir and Al Jurdhawiyah quadrangles (sheets 25/42 C and D), northeastern Arabian Shield, designed to identify areas that appear to have potential for metallic ore deposits. These quadrangles are located between lat 25°00' and 25°30' N., long 42°00' and 43°00' E., about 535 km northeast of Jiddah (fig. 1).

Previous mineral exploration

Mytton (1970) conducted a reconnaissance survey for mineral deposits in the 1:500,000-scale Wadi ar Rimah quadrangle, which includes the Wadi al Jarir and Al Jurdhawiyah quadrangles. He collected 37 samples of wadi sediments, detrital magnetite, and heavy-mineral concentrates from widely separated areas in the Al Jurdhawiyah quadrangle. A tungsten content of 40 ppm was measured in the magnetic fraction from one wadi-sediment sample collected from the northern slope of Jabal Kutayfah. Mytton (1970) also reported on several small ancient mines in the Al Jurdhawiyah quadrangle, the Abraq Shawfan, Baid al Jimalah East, Maqawqi (Ad Dirabi), and Jarrar mines. Later, Muller (1975) described and resampled Jarrar, Baid al Jimalah East, and Abraq Shawfan, and located a previously unreported ancient working, Ad Du'ibi, and a copper-bearing shear zone, Jabal Kutayfah.

Muller (1975) also conducted reconnaissance mapping and mineral exploration in the Al Jurdhawiyah quadrangle. In addition to sampling the ancient prospects mentioned above, he sampled the wadi drainage in a 25-km^2 area of altered felsic rocks around Jabal Jarrar (lat 25°27'03" N., long 42°19'35" E.). None of the 100 wadi-sediment samples was anomalous.

The Riofinex Geological Mission (1979a, p. 136; 1981a, p. 7; Begg, 1981) has been studying the Ad Dirabi and Baid al Jimalah mines. It is also participating in a drilling program on the Baid al Jimalah West tungsten prospect (Riofinex Geological Mission, 1981b, p. 12; Cox, 1982), which was discovered and described by Cole and others (1981).

Samater (1982, 1983), J. E. Elliott (written commun., 1981), D. B. Stoeser (written commun., 1981), and J. C. Cole (written commun., 1981), all of the U.S. Geological Survey (USGS), collected reconnaissance wadi-sediment and rock samples (plate 1). Their tabulated data were visually scanned to identify those samples that appear to have unusually high geochemical values. Those samples are referred to as "anomalous" and are listed in tables 1 and 2. Stuckless and

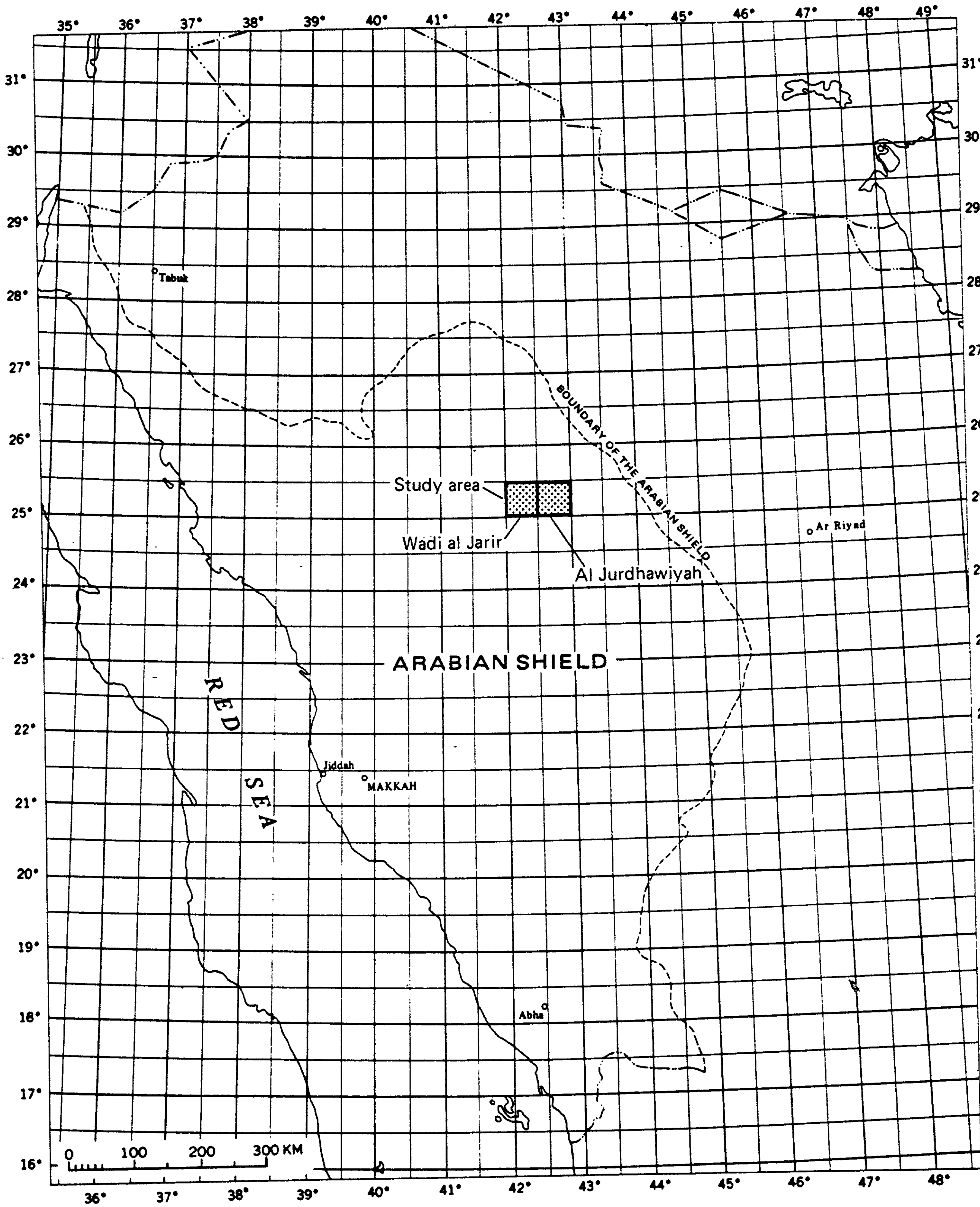

Figure 1.--Index map of the Arabian Shield showing the location of the study area, Wadi al Jarir (sheet 25/42 C) and Al Jurdhawiyah (sheet 25/42 D) quadrangles.

others (unpub. data) sampled Jabal Aban al Ahmar in the northern part of the Al Jurdhawiyah quadrangle to determine the potential of the pluton as a site of significant magmatic uranium mineralization.

Present study

This study is based on reconnaissance geological mapping of the Al Jurdhawiyah (Cole, in press) and Wadi al Jarir quadrangles (Young, 1982), reconnaissance geochemical sampling (Samater, 1982), and unpublished geochemical data (J. C. Cole, written commun., 1981; J. E. Elliott, written commun., 1981; D. B. Stoeser, written commun, 1981). Additional rock samples for geochemical analysis were selected from an inventory collected by Young.

Additional samples were collected by the author during low-level helicopter traverses in the search for rock alteration as indicated by discoloration or bleaching. Known locations of mineralized rock were evaluated by field inspection or by reference to previously published evaluations. The USGS-DGMR (Directorate General of Mineral Resources) chemical laboratory performed emission spectrographic and atomic absorption analyses on these samples by use of standard methods. X-ray fluorescence analyses for rubidium and strontium were performed by the author and by F. E. Elsass and A. H. El Bazli. Copper, lead, zinc, gold, silver, and nickel contents were determined by use of standard atomic absorption methods.

This investigation was made in accordance with a work agreement between the Saudi Arabian Ministry of Petroleum and Mineral Resources and the U.S. Geological Survey. Chemical analyses from K. J. Curry (USGS-DGMR laboratory), F. E. Elsass (USGS XRF laboratory), G. I. Selner (USGS computer section), and A. H. El Bazli (USGS technician) is gratefully acknowledged.

DATA STORAGE

Mineral localities referred to in this report are recorded in the Mineral Occurrence Documentation System (MODS) data bank, and each is identified by a unique five-digit locality number. Data regarding samples of geologic material are recorded in the Rock Analysis Storage System (RASS) data bank, and each sample is identified by a unique six-digit number. Inquiries regarding either data bank may be made through the Office of the Technical Advisor, Saudi Arabian Deputy Ministry for Mineral Resources, Jiddah. No data files were established for this report.

Table 1.--Trace element analyses of anomalous wadi-sediment samples and heavy-mineral concentrates from wadi-sediment samples, Wadi al Jarir and Al Jurdhawiyah quadrangles

[From Samater, 1982. Leaders indicate not anomalous. All data are emission spectrographic analyses, in parts per million. 159-series are heavy-mineral concentrates of wadi-sediment samples. 149-series samples are -30+80 mesh fractions of wadi-sediment samples]

Sample number	Cu	Pb	Sn	W	Rock unit (or location)
			Wadi al Jarir quadrangle		
149068	-	150	-	-	gdmg
149078	-	500	-	-	gdmg
149112	-	150	-	-	gdmg
159288	-	-	150	-	mgy
159318	-	-	30	-	mgy
159324	-	-	200	-	mgy
159340	-	-	30	-	to
159344	-	-	30	-	gdmg
159360	-	-	30	-	gdmg
159482	-	-	50	-	mgy
			Al Jurdhawiyah quadrangle		
159305	200	3,000	-	-	Near MODS00960, 02661
159311	-	700	-	-	Near MODS00960, 02661
159313	-	150	-	-	Near MODS00960, 02661
159315	200	500	-	-	Near MODS00960, 02661
159317	-	-	100	-	Near MODS00960, 02661
159321	-	-	>1,000	1,500	Near MODS00960, 02661
159331	200	-	-	-	bhgg
159345	-	-	50	-	jcv
159347	-	-	50	-	jcv
159586	200	-	-	-	bhgd
159646	300	-	-	-	jcv
159684	700	-	-	-	jcv
159746	200	-	-	-	bht

Table 2.--Trace element analyses of anomalous rock samples from the Wadi al Jarir and Al Jurdhawiyah quadrangles

[Leaders indicate not anomalous. All data are by emission spectrographic analysis, results in parts per million. 128-series, Stoeser, written commun., 1981; 152-series; Cole, written commun., 1981]

Sample number	Cu	Pb	Zn	Cr	Y	Nb	Zr	Sn	Mo	F
					Wadi al Jarir quadrangle					
128405	-	100	-	-	-	-	-	-	-	-
					Al Jurdhawiyah quadrangle					
128367	700	-	-	-	-	-	-	-	-	-
152028	-	100	-	-	70	-	-	-	-	-
152037	150	-	-	-	-	-	-	-	-	-
152045	-	-	-	-	150	100	>1,000	-	-	-
152049	300	150	-	-	70	1,500		150	-	-
152050	-	-	-	-	70	-	-	-	-	-
152057	-	-	-	-	-	-	-	-	15	-
152071	150	-	-	-	-	-	-	-	-	-
152262	-	300	-	500	-	-	-	-	-	-
152264	-	150	-	-	-	-	-	-	-	-
152267	-	100	-	-	-	-	-	-	-	-
152295	150	-	-	-	-	-	-	-	-	-
152307	-	500	300	-	-	-	-	-	-	-
152370	-	100			300	300	1,000	20	20	1,700
152388	150	-	-	-	-	-	-	-	-	-
152390	300	300	-	-	-	-	-	-	-	-

GEOLOGIC SETTING

The geology of the Wadi al Jarir and Al Jurdhawiyah quadrangles has been described by Muller (1975), Cole (in press), and Young (1982), and the geologic history of this area in relation to the Arabian Shield has been summarized by Kleinkopf and Cole (in press).

Volcaniclastic siltstone and subgraywacke of the Murdama group and volcanic conglomerate, breccia, and flow rocks of the overlying Al Jurdhawiyah group have been intruded by calc-alkaline and peralkaline granitic plutons and minor gabbro and diorite. Murdama group sedimentary rocks derived from layered and plutonic rocks were deposited in a subsiding marine basin, whereas Al Jurdhawiyah sedimentary and flow rocks may have been deposited subaerially near eruptive centers.

Tonalite and granodiorite plutons in the area are older than the rocks of the Al Jurdhawiyah group and may be from 650 to 690 Ma old. Quartz diorite and leucotonalite intrusions are younger than the rocks of the Murdama group and perhaps older than the rocks of the Al Jurdhawiyah group. Granodiorite-monzogranite and granodiorite intrusive rocks are younger than all the layered rocks and may be from 610 to 640 Ma old. Perthite granite and peraluminous microcline-albite granite are the youngest plutonic rocks in the area and are approximately 575 Ma old.

MINERALIZED AREAS IN THE WADI AL JARIR QUADRANGLE

Young (1982) observed indications of ancient mining or prospecting activity in the northwestern corner of the Wadi al Jarir quadrangle that may be the eastern part of Sukhaybarat Al Gharbiyah (MODS 00405) in the adjacent Jabal Mawan quadrangle (Aguttes and Chaumont, 1974). Significant mining activity appears to have occurred in ancient times at lat 25°27'44" N., long 42°00'15" E., where there are many shallow sand-filled pits and associated dumps, numerous broken grinding stones, and traces of slag over an area of about 0.1 km^2. The metals of interest are not readily apparent, but a composite sample of vein-quartz float (183097) contained 125 ppm lead and 5.8 ppm silver, and a composite sample of ferruginous sheared rock (183098) contained 235 ppm lead and 2.0 ppm silver. Two kilometers south of the mining area is a small ancient prospect where a composite sample of quartz float (183099) contained 265 ppm lead and 4.9 ppm silver.

MINERALIZED AREAS IN THE AL JURDHAWIYAH QUADRANGLE

Abraq Shawfan ancient gold prospect

Shallow, sand-filled ancient workings in quartz veins, named Abraq Shawfan (MODS 00961), were described by Mytton (1970) and Muller (1975). The prospect covers an area of 6 km^2 and is located at lat 25°04'54" N., long 42°33'36" E. Thin veins of quartz in the volcaniclastic rocks of the Murdama group and in an intrusive granodiorite porphyry strike northwest. Mytton collected a sample of quartz containing 3.4 ppm gold and traces of copper, lead, and zinc. J. C. Cole (written commun., 1981) collected a composite sample (152307) from dump material containing 500 ppm lead and 300 ppm zinc.

The author resampled this prospect and collected composite samples of quartz, Murdama sandstone, and granodiorite. The quartz sample (170858) contained 0.08 ppm gold, 1.4 ppm silver, and less than 80 ppm each copper, lead, and zinc. Two samples of Murdama group rock (170859 and 157068) contained 0.2 and 0.68 ppm gold, 1.3 and 3.3 ppm silver, 90 and 200 ppm zinc, and 35 and 50 ppm copper, respectively. Sample 157068 also contained 500 ppm lead. The granodiorite sample (157069) contained 0.28 ppm gold, 1.1 ppm silver, 300 ppm copper, and 25 ppm each lead and zinc.

Abraq Shawfan South prospect

Another minor ancient prospect is located 3.1 km south-southeast of the Abraq Shawfan prospect. Samples of granodiorite porphyry (157070) and Murdama group sandstone (157071) contained only traces of precious and base metals.

Baid al Jimalah East ancient mine

Fakhry (1941), Mytton (1970), Muller (1975), Begg (1981), and Cole and others (1981) described ancient workings named Baid al Jimalah (Bede el Gemala) (MODS 00960), located at lat 25°09'20" N., long 42°42'05" E., where many trenches, stone ruins, and slag piles testify to a once-active mining and ore-processing community. Within an area of about 5 km^2, over 30 excavations were dug into mineralized quartz veins in the basal volcanic conglomerate of the Al Jurdhawiyah group. The main excavation in this area is a trench about 180 m long, several meters wide, and several meters deep that cuts into a quartz vein in the volcaniclastic rocks.

Using published analyses and analyses from additional sampling, Cole and others (1981) determined that the most highly mineralized rock contained 3.4 percent lead, 2.5 percent zinc, 880 ppm silver, and 3.4 ppm gold. Begg (1981) reported samples of ferruginous quartz containing as much as 4.3 percent lead. The author collected composite samples of vein quartz, altered volcaniclastic rock adjacent to the vein, and volcaniclastic rock a few meters from the trench (table 3).

The data in table 3 suggest that the mineralized area does not extend much beyond the main trench, in which metals occur at background levels (157051 and 157054). Gossanous volcaniclastic rocks (157055 and 157160) from the trench are highly enriched in lead, zinc, copper, silver, and tin. Sheared, nonferruginous volcaniclastic rocks (157052 and 157053) adjacent to a quartz vein contain significant amounts of base metals, precious metals, and tin and a trace of molybdenum.

Geologists of the Riofinex Geological Mission have mapped this prospect, and they have determined that the tonnage potential is small (1981a, p. 7). Begg (1981) concluded that the gold resource potential of this prospect is nil and that its lead-silver potential is very small.

Ad Du'ibi ancient prospect

Muller (1975) described the small Ad Du'ibi ancient working (MODS 00955) as being in a quartz vein that cuts volcaniclastic rocks of the Al Jurdhawiyah group, at lat 25°13'30" N., long 42°42'18" E. Some pyrite and malachite were seen, but the vein was not sampled. The author collected two composite samples of vein quartz (170848 and 157065) and a composite sample of adjacent country rock (170849). All three samples contained only trace amounts of base and precious metals.

Ad Du'ibi West ancient prospect

A small ancient prospect consisting of one small pit is 3.4 km west-northwest of the Ad Du'ibi prospect. Samples of quartz float (170846) and associated volcanic rock float (170847) contained only trace amounts of precious and base metals.

Ad Dirabi ancient mine

The ancient workings named Ad Dirabi (Ad Drabbi, Magawgi) (MODS 00957), located at lat 25°16'48" N., long 42°40'30" E., have been described by Muller (1975), Mytton (1970), and Begg (1981). Five thin quartz veins having outcrop lengths of as much as 260 m within an area 200 m wide and 500 m long cut volcaniclastic rocks of the upper Al Jurdhawiyah group. Bedrock is not exposed, but dump samples contained trace pyrite, chrysocolla, chalcopyrite, and malachite.

Table 3.--Trace element analyses of volcaniclastic rocks and vein-quartz samples from the main trench of the Baid al Jimalah East ancient mine, Al Jurdhawiyah quadrangle

[All data are in parts per million. N = not detected; leaders indicate no data available. Samples 157051-055: gold, silver, copper, and zinc by atomic absorption analysis; lead, tin, and molybdenum by emission spectrography. Samples 157160-162: all elements by atomic absorption analysis]

Sample number	Rock type	Au	Ag	Cu	Pb	Zn	Sn	Mo	W
157051	Volcaniclastic rock with disseminated pyrite, collected near trench	0.08	0.7	30	15	60	N	N	N
157052	Sheared volcaniclastic rock, collected next to quartz vein	.22	38.0	250	3,000	1,750	500	20	N
157053	Sheared volcaniclastic rock, collected next to quartz vein	.10	5	75	300	250	150	N	N
157054	Volcaniclastic rock collected near trench	.10	1.2	25	50	70	N	N	N
157055	Gossanous volcaniclastic rock collected in trench	1.4	305	450	>20,000	450	200	N	N
157160	Gossanous volcaniclastic rock collected next to quartz vein	.3	65	270	4,650	1,750	-	-	-
157161	Vein quartz	.10	6.8	40	65	1,250	-	-	-
157162	Slag	.10	24	1100	33,500	25,000	-	-	-

Two quartz samples collected by Mytton (1970) contained 3.4 and 4.3 ppm gold, 2.8 and 36 ppm silver, 2,000 and 1,500 ppm copper, and 1,000 ppm lead each. The Riofinex Geological Mission (1979a, p. 136) reported five grab samples that contained as much as 2.3 ppm gold, 19 ppm silver, and anomalous copper and lead. Later, Riofinex reported gold contents of as much as 12 ppm (1979b) and mapped the prospect but determined that the small size of the prospect did not warrant trenching (1981a, p. 7). One composite sample of clastic rock (157064) collected during this study contained trace amounts of copper and zinc and 0.1 and 0.6 ppm gold and silver, respectively. A composite sample of quartz (170844) contained only trace amounts of base and precious metals. These composite chip samples did not confirm the high values reported for the selected grab samples collected by Riofinex.

Jarrar ancient mine

The Jarrar ancient workings (MODS 00958) consist of three trenches in an area 800 m long by 500 m wide that is located at lat 25°23'24" N., long 42°47'21" E. (Mytton, 1970; Muller, 1975). Quartz veins as thick as 15 cm, which intrude andesite of the lower Al Jurdhawiyah group, can be seen in only two of the trenches. Visible gold and malachite were recorded by Mytton, and four selected grab samples contained as much as 72 ppm gold, 65 ppm silver, 2,000 ppm copper, and 2,500 ppm lead. Muller could not confirm the mineralization and did not resample the workings.

Two composite samples collected during this survey consisted of vein quartz and volcanic rock from one of three shallow trenches. The quartz sample (170837) contained 184 ppm gold, 6 ppm silver, and 250 ppm copper. The volcanic rock sample (170838) contained only trace amounts of these elements.

Jabal Kutayfah mineral occurrence

Muller (1975) reported a mineral occurrence called Jabal Kutayfah (MODS 00956), located at lat 25°09'36" N., long 42°51'27" E., that consists of veins several centimeters thick and as much as 75 m long. He observed traces of chrysocolla and malachite. Copper, lead, and zinc contents of one composite sample were 2,100, 600, and 500 ppm, respectively. This mineralized occurrence was not visited because of its small size and lack of reported precious metals.

Baid al Jimalah West tungsten deposit

A significant deposit of wolframite (MODS 02661) at lat 25°09'20" N., long 42°41'00" E., has been described by Cole and others (1981). Wolframite is found in quartz veins associated with an altered zone of biotite microcline-albite granite. In addition to coarsely crystalline wolframite, the mineral deposit contains minor cassiterite, scheelite, chalcopyrite, molybdenite, and fluorite. The altered granite is enriched in rubidium, lithium, fluorine, and beryllium.

The Riofinex Geological Mission and the USGS have been conducting a cooperative program of drilling and geophysical exploration to evaluate the prospect and to discover extensions of known mineralized rocks (Cox, 1982). Results from six diamond drill holes suggest that the altered granite may be in the form of irregular dike networks and sills with shallow to moderate dips to the north-northeast. Two diamond drill holes, BAJ-1 and BAJ-6, intersected mineralized quartz veins with isolated values of as much as 0.9 percent WO_3, but the overall intersection of granite penetrated had a logarithmic mean grade of 0.1 percent WO_3. The other four drill holes intersected fewer quartz veins, and the amount of mineralized rock, as indicated by the presence of wolframite and scheelite, appears by visual examination to be much less than was found in BAJ-1 (P. Lofts, Riofinex Geological Mission, oral commun., 1981). Visual examination of chips of altered granite and mineralized quartz veins from 16 percussion drill holes of shallower depth than BAJ-1 and BAJ-6 suggests that the tungsten concentration is near the surface (P. Lofts, oral commun., 1981).

An orientation survey was done during this resource evaluation program to determine the most useful trace element indicators of altered granite and mineralized rock (Cole and others, 1981). Sixty-four composite samples of altered granite (157095-128, 157130-157, 157159, 157163) were analyzed for rubidium, strontium, fluorine, lithium, arsenic, tin, and tungsten. The range of values are rubidium, 42 to 490 ppm; Rb/Sr, 1 to 23; fluorine, 1,320 to 8,800 ppm; lithium, 29 to 1,410 ppm; arsenic, 20 to 600 ppm; tin, 0 to 300 ppm; and tungsten, 0 to 6,400 ppm. These values are clearly higher than would be obtained for unmineralized and unaltered granite and are useful indicators for this type of mineralization.

REGIONAL GEOCHEMISTRY

Plutonic terrane

Nearly 300 samples of plutonic rocks were available for trace element chemical analysis. Copper, lead, zinc, molybdenum, tin, tungsten, thorium, yttrium, niobium, zirconium, rubidium, beryllium, lanthanum, and Rb/Sr ratio data were visually scanned to detect anomalously high values in skewed or bimodal distributions. Twenty-seven samples were considered to be anomalous (table 4).

Twelve anomalous samples are from parts of the biotite- and hornblende-bearing perthite granite and flanking arfvedsonite perthite granite of the Aban al Ahmar pluton at the northern border of the Al Jurdhawiyah quadrangle (area A, plate 1). This group of samples is anomalous in lead (350 ppm), zinc (150-400 ppm), molybdenum (50-100 ppm), tin (10-15 ppm), niobium (50-100 ppm), yttrium (100-200 ppm), zirconium (>1,000 ppm), beryllium (15 ppm), and lanthanum (100-150 ppm). To the south, a small area (area B, plate 1) of arfvedsonite granite is also anomalous in these trace elements, including tin and niobium contents of as much as 150 ppm and 1,500 ppm, respectively, In addition, the copper (150-1,500 ppm) and thorium (62 ppm) contents and the Rb/Sr ratio (1.8-9.0) are anomalous, and a fluorine content of 1,700 ppm was observed. A handheld scintillometer (43.1-cm^3 NaI crystal) gave readings of from 200 to 400 counts per second at sample localities 157090, 157091, and 157092. Stuckless and others (unpub. data) determined that the pluton has a high uranium content.

Although all of Aban al Ahmar has been mapped as a composite alkalic pluton, only about one-third of it in the Al Jurdhawiyah quadrangle seems to contain the trace element geochemistry that characterizes alkalic rocks. Areas A and B (plate 1) show some enrichment in trace elements associated with calc-alkaline granites (Taylor, 1964, 1966, 1968), but the levels of these elements do not compare with those of other peralkaline granites (Drysdall, 1979; Radain and Kerrick, 1979; Douch and Drysdall, 1980; Harris and Marriner, 1980). Although the pluton has a relatively high uranium content (Stuckless and others, unpub. data) it is also characterized by low Th/U and high U/K ratios that suggest that the pluton is not a magmatic uranium province. Drysdall (1979) suggested that areas of peralkaline arfvedsonite granite merit close attention as potential sites of mineralized microgranite. The Aban al Ahmar composite pluton appears to be in this category, and further exploration should be centered on areas A and B as defined by the trace element geochemistry of the rocks.

An area of granodiorite porphyry in the southeastern corner of the Al Jurdhawiyah quadrangle has been defined as anomalous in copper and molybdenum (area C, plate 1; table 4). Seven samples (170747, 170748, 170750, 170751, 170758-760) contained anomalous copper (110-500 ppm), and one of these samples (170751) contained 50 ppm molybdenum. Malachite staining was seen at the outcrop where the latter sample was collected. Thus, the area seems to have potential as a site of disseminated copper-molybdenum mineralization.

A single sample (170754) collected about 7 km east of anomalous area C (plate 1) contained 210 ppm copper. Granodiorite porphyry in an area of about 20 km^2 around this

Table 4.--Analyses of plutonic rocks having anomalous trace element contents, Wadi al Jarir and Al Jurdhawiyah quadrangles

[All data are in parts per million. Leaders indicate not anomalous. Locations shown on plate 1. Copper, lead, and zinc by atomic absorption analysis; rubidium, strontium, thorium by X-ray fluorescence; molybdenum for sample 148184 by X-ray fluorescence; all remaining elements by emission spectrography]

Sample number	Cu	Pb	Zn	Mo	Sn	Be	La	Nb	Y	Zr	Th	Rb	Rb/Sr
Wadi al Jarir quadrangle													
148184	800	-	-	90	-	-	-	-	-	-	-	-	-
170517	130	-	-	-	-	-	-	-	-	-	-	-	-
170579	165	-	-	-	-	-	-	-	-	-	-	-	-
Al Jurdhawiyah quadrangle													
157090	150	-	-	70	30	15	150	1,500	700	>1,000	62	-	1.8
157091	1,500	-	-	-	15	-	-	150	150	>1,000	-	242	9.0
157092	-	-	-	-	-	-	-	50	150	-	-	-	-
170694	-	-	-	50	-	15	-	-	-	-	-	-	-
170699	-	-	200	-	-	-	100	50	100	1,000	-	-	-
170700	-	-	250	-	-	-	-	-	-	-	-	-	-
170707	-	-	150	-	-	-	-	50	100	-	-	-	-
170715	-	-	200	-	-	-	-	-	100	-	-	-	-
170732	-	-	150	-	15	15	-	100	200	>1,000	-	-	-
170733	-	-	-	-	10	-	100	50	100	>1,000	-	-	-
170737	-	-	-	-	10	15	100	-	-	-	-	-	-
170738	-	-	-	-	10	-	150	50	100	1,00	-	-	-
170739	-	-	-	-	-	15	100	50	-	>1,000	-	-	-
170741	-	350	500	100	10	-	150	100	-	-	-	-	-
170747	190	-	-	-	-	-	-	-	-	-	-	-	-
170748	110	-	-	-	-	-	-	-	-	-	-	-	-
170750	110	-	-	-	-	-	-	-	-	-	-	-	-
170751	500	-	-	50	-	-	-	-	-	-	-	-	-
170754	210	-	-	-	-	-	-	-	-	-	-	-	-
170758	110	-	-	-	-	-	-	-	-	-	-	-	-
170759	125	-	-	-	-	-	-	-	-	-	-	-	-
170760	115	-	-	-	-	-	-	-	-	-	-	-	-
170789	140	-	-	-	-	-	-	-	-	-	-	-	-
170795	170	-	-	50	-	-	-	-	-	-	-	-	-

sample should be tested geochemically to determine if significant amounts of copper-mineralized rocks are present.

Cole (in press) observed chalcopyrite, bornite, pyrite, and secondary copper carbonate minerals in outcrops of biotite-hornblende granodiorite (map unit bhgd) in the northeastern corner of the Al Jurdhawiyah quadrangle. Similar mineralized rocks were also observed during the present study at the locations of samples 157058 and 157059 (area D, plate 1; table 4). Both samples contained only background amounts of copper, but sample 157058 contained 70 ppm tungsten. Sample 170789 from the same unit about 6 km to the southeast contained anomalous copper (140 ppm). A heavy-mineral-concentrate sample (159586) from a wadi-sediment sample collected by Samater (1982, 1983) contained an anomalous amount (200 ppm) of copper.

Several anomalous samples were collected from widely scattered locations in the granodiorite-monzogranite of the Wadi al Jarir quadrangle (plate 1; table 4). Two rock samples collected from the same general area contained 800 ppm copper and 92 ppm molybdenum (148184) and 165 ppm copper (170579). Rock sample 170517 collected about 18 km to the northwest contained 130 ppm copper and sample 128405, collected 22 km to the southeast, contained 100 ppm lead. Samples of total wadi sediment collected in the north-central part of this batholith (Samater, 1982, 1983; samples 149068, 149078, 149112) contained 150, 500, and 150 ppm lead, respectively.

Near the Abraq Shawfan South prospect in the southwestern corner of the Al Jurdhawiyah quadrangle, a sample of Murdama group sandstone contained 700 ppm copper (sample 128367; area F, plate 1; table 2). This high copper content may be attributed to the sample's proximity to two exposures of granodiorite porphyry, one of which shows mineralization at the Abraq Shawfan prospect.

Cole (1981; written commun., 1981) reported a skarn zone in the southeastern corner of the Al Jurdhawiyah quadrangle in which granodiorite porphyry intrudes marble. A skarn sample (152388) contained 150 ppm copper, and a porphyry sample (152390) contained 300 ppm copper, 300 ppm lead, and 20 ppm molybdenum. A rapid inspection of this area failed to reveal any mineralization, and two composite samples (170819, 170820) that were collected contained only trace amounts of base metals and 2 ppm silver.

Along the east-central edge of the Al Jurdhawiyah quadrangle three samples collected within a small area of microdiorite porphyry (152262), garnet-bearing rhyodacite porphyry (152267), and clastic rock (152264) are enriched in lead, containing from 100 to 300 ppm (Cole, written commun., 1981; table 2). A second sample collected at location 152267 contained no significant lead. Two other isolated samples (152295, 152071) contained 150 ppm copper.

Volcanic and sedimentary terrane

Low-level helicopter traverses were flown over volcanic terrane in the Al Jurdhawiyah and Wadi al Jarir quadrangles to locate zones of alteration as indicated by discoloration or bleaching. During the traverses, 212 composite rock samples were collected for trace element analysis. Visual scanning of the data for skewed or bimodal distributions indicated six of these samples to be chemically anomalous. Sample 170666 contained 850 ppm copper and 1,600 ppm zinc and was collected from the upper andesite flow and fragmental unit of the Al Jurdhawiyah group in the north-central part of the Al Jurdhawiyah quadrangle. About 7 km to the east and from the same unit, sample 170710 contained 200 ppm zinc. A sample (157083) from the volcanic conglomerate unit of the Al Jurdhawiyah group in the east-central part of the Al Jurdhawiyah quadrangle contained 130 ppm copper.

Sample 148281 is from Murdama group sandstone and was collected near its contact with intrusive monzogranite-granodiorite in the west-central part of the Wadi al Jarir quadrangle; its copper content of 130 ppm may be a metasomatic effect. A sample of calcareous phyllite (148468) collected near the western edge of the quadrangle, contained 130 ppm zinc and a sample of Murdama group graywacke (170557), collected 14 km to the southeast, contained 450 ppm zinc.

Pan concentrates of eight wadi-sediment samples collected by Samater (1982, 1983) contained 30 ppm or more tin (table 1). Two samples (159317 and 159321) were collected near the Baid al Jimalah West tungsten prospect and East ancient mine. Four (159288, 159318, 159324, and 159482) samples were collected from locations in Murdama group graywacke in the Wadi al Jarir quadrangle, and two samples (159345 and 159347) were collected from the Al Jurdhawiyah group volcaniclastic conglomerate unit in the Al Jurdhawiyah quadrangle. X-ray diffraction analysis suggests that cassiterite may be present in samples 159318, 159324, 159344, 159345, 159347, and 159482 (I. M. Naqvi, USGS, oral commun., 1981).

Cole and others (1981) observed that tin as cassiterite is common in mineralized veins and altered granite at the Baid al Jimalah West tungsten prospect and in mineralized rock from the nearby ancient lead-zinc-silver mine. Tin also appears in trace amounts in Murdama group fluorite-bearing hornfels at its contact with the tungsten-bearing altered granite. The occurrence of tin in rocks near the mineralized intrusion and in related quartz veins suggests that tin may be a useful pathfinder element for the detection of similar mineralized granites and veins not exposed by erosion. Samples 159288, 159318, and 159324, which contained as much as 200 ppm tin, may indicate slightly mineralized hornfelsed zones associated with mineralized intrusions at depth. The importance of these three locations is supported by tin contents of 30 ppm in samples of heavy-mineral concentrates (159340, 159344, and 159360) from three nearby locations in exposed tonalite and granodiorite-monzogranite. Perhaps all six samples define a tin locality (area E, plate 1).

CONCLUSIONS

Several areas of quartz veins containing base and precious metals have been studied for their resource potential (plate 1). Samples from Abraq Shawfan area in the Al Jurdhawiyah quadrangle have been reported to contain as much as 3.4 ppm gold, 3.3 ppm silver, and 200 ppm zinc, but analysis of samples collected during this study could not duplicate these values. This factor, as well as the apparent small size of the deposit, removes it from consideration as a significant potential resource.

This study confirms the high values for lead, zinc, copper, and silver reported from the Baid al Jimalah East ancient lead-silver mine, but the mineralization appears to be limited to quartz veins and selvage. The Riofinex Geological Mission (1979a, 1981a) and Begg (1981) have determined that the potential tonnage is too small to justify additional exploration. This appraisal does not consider that mineralized rocks may increase or change with depth. Cole and others (1981) have suggested a genetic relationship between the ancient mine and the nearby Baid al Jimalah West tungsten deposit on the basis of chemical similarities. If their hypothesis is correct, tin-tungsten oxides may be below the lead-zinc sulfide deposit within an intrusive granite body similar to the host of the tungsten deposit located 2 km to the west. Drilling is required to test this hypothesis.

The Abraq Shawfan South, Ad Du'ibi, and Ad Du'ibi West ancient prospects were sampled, but only trace amounts of base and precious metals were found. These results and the small sizes of the prospects do not support additional exploration.

The high base and precious metal contents reported for selected grab samples from the Ad Dirabi ancient mine could not be duplicated in composite samples collected during this study. The Riofinex Geological Mission (1981a) concluded that the prospect is not large enough to justify further study, and the results of the present study indicate that the prospect probably has little economic potential.

High base and precious metal contents were reported from the Jarrar ancient mine, and a composite sample of quartz chips collected during the present work contained 184 ppm gold, 6 ppm silver, and 250 ppm copper. Composite samples collected at the Jarrar ancient mine confirm the presence of base and precious metals. Several trenches within a 0.5-km^2 area suggest the possibility of a sizable group of deposits that merits further study.

High lead and silver contents have been found in rock and vein quartz samples from the Sukhaybarat Al Gharbiyah prospect in the northwestern part of the Wadi al Jarir quadrangle. Geophysical methods will be required to further evaluate these areas.

Only a few analytical results are available for inclusion in this report from the extensive drilling program conducted at the Baid al Jimalah West tungsten prospect by the Riofinex Geological Mission. Limited data suggest that the grade of WO_3 decreases with depth and that the overall grade of WO_3 is low. The deposit may have a moderate tonnage-low grade resource potential, but determination of this potential requires the evaluation of auger-drill and geophysical survey data and additional detailed sampling along closely spaced trenches.

Two areas of interest (areas A and B, plate 1), as defined by 12 anomalous rock samples collected during a reconnaissance geochemical survey in plutonic terrane, are in the Aban al Ahmar granite pluton in the Al Jurdhawiyah quadrangle. This group of samples contained anomalous levels of base metals, molybdenum, tin, niobium, and yttrium. Although the levels of anomalous elements are not unusually high, the alkaline-peralkaline character of the pluton suggests that the two areas merit detailed study.

The large area (area C, plate 1) of granodiorite porphyry in the southern part of the Al Jurdhawiyah quadrangle has been defined by seven rock samples that contained anomalous amounts of copper. One of these samples also contained molybdenum. A single rock sample collected 7 km east of area C also contained anomalous copper. The area should receive additional study in an attempt to locate significant disseminated copper-molybdenum sulfide minerals.

In the northern part of the Al Jurdhawiyah quadrangle, copper was detected by analyses of rock and wadi-sediment samples in another area (area D, plate 1) of copper-mineralized granodiorite. One rock sample from this area contained tungsten. A rock sample of tonalite collected about 8 km northeast of area D contained anomalous amounts of copper and molybdenum. Both areas may contain significant disseminated copper and molybdenum sulfide minerals and tungsten and warrant further investigation.

Only two isolated occurrences of copper and molybdenum were found in the granodiorite-monzogranite in the north-central part of the Wadi al Jarir quadrangle. Three isolated samples of wadi-sediment heavy-mineral concentrates from this area contained anomalous lead.

A reconnaissance rock-geochemistry survey was performed in areas of layered volcanic and sedimentary rocks (plate 1). The significance of six widely scattered samples that contained anomalous amounts of copper or zinc remains to be determined.

A wadi-sediment survey (Samater, 1982, 1983) has revealed a large area (area E, plate 1) in the southern part of the Wadi al Jarir quadrangle, a locality in the middle of the Al Jurdhawiyah quadrangle, and a locality in the southwestern corner of the Wadi al Jarir quadrangle that contain anomalous amounts of tin in sedimentary terrane. X-ray diffraction analysis suggests that the tin may be in the form of cassiterite. Because tin has been observed in the contact metamorphic zone of Murdama group clastic rocks adjacent to the altered granite of the Baid al Jimalah West tungsten-tin prospect, anomalous amounts of tin found elsewhere in clastic sedimentary rocks may be indicative of similar mineralized, altered granites at depth. A study of these anomalous areas, including a search for fluorite-bearing hornfels, detailed wadi-sediment and rock-geochemistry surveys, and geophysical surveys, is recommended.

Area F (plate 1) in the Al Jurdhawiyah quadrangle, which includes the Abraq Shawfan ancient prospect and a rock sample of Murdama group sandstone containing 700 ppm copper, is recommended for additional study. A small skarn zone in the southeastern corner of the quadrangle should also be investigated.

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