THE MINERAL RESOURCE POTENTIAL OF THE THANIYAH AND AL UFAYRIYAH QUADRANGLES, SHEETS 20/42 C AND 20/42 A, KINGDOM OF SAUDI ARABIA

by

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ABSTRACT

Areas with mineral resource potential in the Thaniyah and Al Ufayriyah quadrangles in the central Precambrian Shield of Saudi Arabia have been identified by reconnaissance rock geochemistry and inspection of ancient prospects.

Locally anomalous areas in plutonic terrane have been defined as possible sources of tin, molybdenum, or base metal mineralization. The survey over layered volcanic terrane identified several areas of anomalous copper and zinc. One ancient copper prospect with gossan in the west-central part of the Thaniyah quadrangle merits additional study.

INTRODUCTION

Purpose and location

This report describes the results of a reconnaissance survey designed to evaluate the mineral resource potential of the Thaniyah (sheet 20/42 C) and Al Ufayriyah (sheet 20/42 A) quadrangles, Kingdom of Saudi Arabia (fig. 1). These quadrangles are located in mostly Precambrian terrane between lat 20° and 21° N., long 42°00' and 42°30' E., about 350 km east-southeast of Jiddah.

Previous mineral exploration

Whitlow (1966, 1971) and Theobald (1970) conducted reconnaissance wadi-sediment surveys in areas that included the Thaniyah and Al Ufayriyah quadrangles. The results of these surveys influenced the planning of geochemical work in the present study.

Schmidt (in press) reported chemical analyses of samples collected from several quartz veins in the Al Ufayriyah quadrangle at about lat 20°45' N., long 42°25' E. He also reported the discovery, in the same area, of a small deposit of contact-metamorphic nontitaniferous magnetite.

During reconnaissance mapping, Greene (1982a, 1983) discovered an apparently unreported ancient mine or prospect at lat 20°17'50" N., long 42°09'40" E., in the Thaniyah quadrangle (MODS number requested). He noticed malachite-

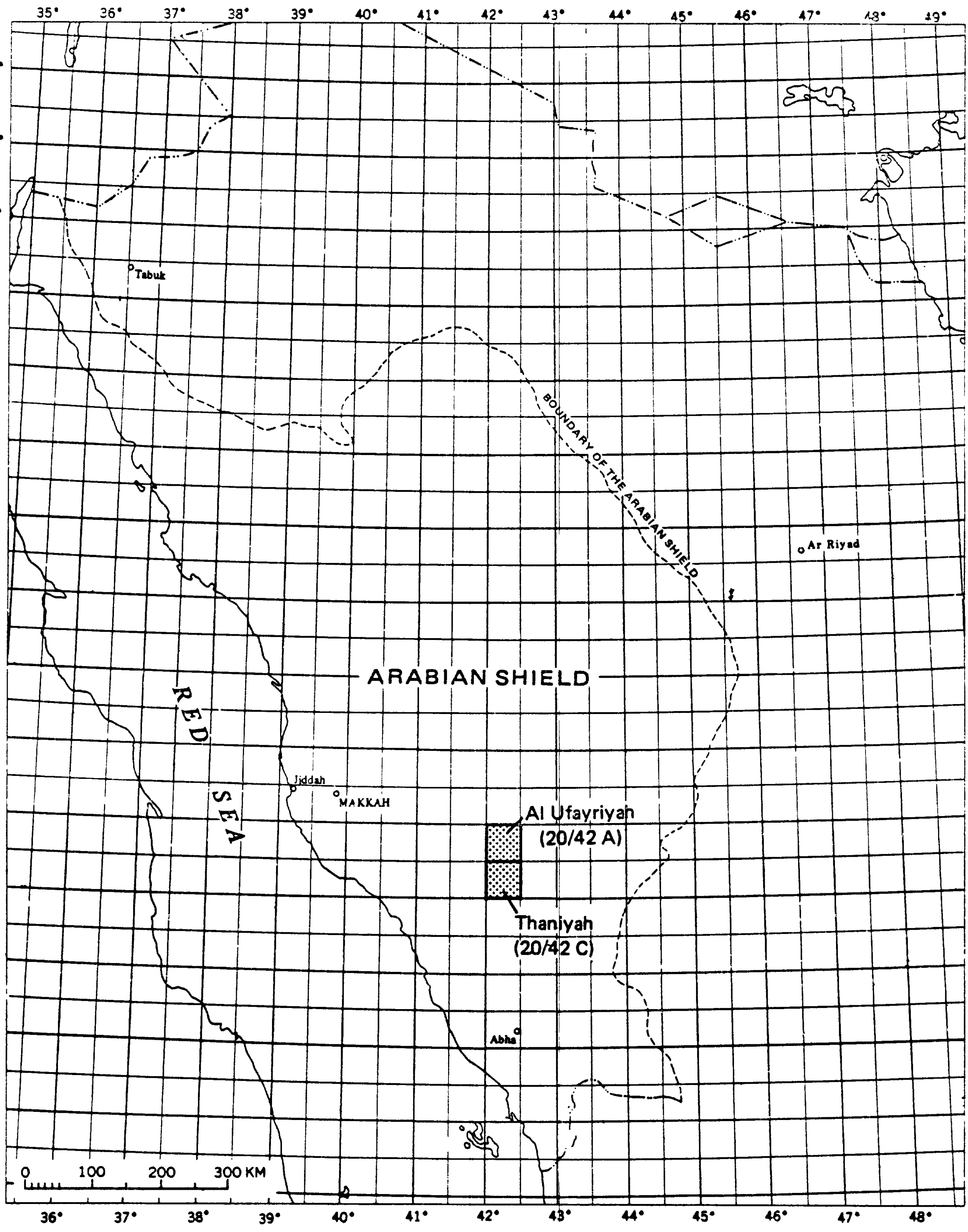

Figure 1.--Index map of the Arabian Shield showing the location of the study area in the Thaniyah and Al Ufayriyah quadrangles.

stained gossanous material near a shallow shaft but did not collect samples for chemical analysis.

Cheeseman (1982) conducted a wadi-sediment geochemistry survey in a belt of layered metavolcanic rocks located along the western edge of the Thaniyah quadrangle, in the adjacent Al Aqiq, Biljurshi, and Wadi Tarj quadrangles, and in the two quadrangles to the south. In his report he also described the results of an INPUT airborne-electromagnetic survey that had been performed by Geoterrex Limited over the same area. His report is available for inspection at the office of the Saudi Arabian Directorate General of Mineral Resources, Jiddah.

Present study

The present study is based on reconnaissance geologic mapping of the Thaniyah and Al Ufayriyah quadrangles by Greene (1982a,b, 1983). Samples for a reconnaissance rock geochemistry program were selected from rocks in inventory collected by Greene. Additional samples were collected during low-altitude helicopter traverses to search for gossans and alteration zones. Known areas of mineralized rocks were evaluated either by field inspection or by referral to previously published evaluations when these appeared adequate.

An X-ray fluorescence spectrometer was used to determine the molybdenum, rubidium, strontium, yttrium, niobium, zirconium, and thorium contents of rock samples. These analyses were performed by the author and by F. Elsass and A. H. El Bazli. Copper, lead, zinc, gold, and silver contents were determined by use of standard atomic absorption methods at the Directorate General of Mineral Resources (DGMR)-U.S. Geological Survey (USGS) laboratory in Jiddah.

The work on which this report is based was performed in accordance with an agreement between the Saudi Arabian Ministry of Petroleum and Mineral Resources and the U.S. Geological Survey. Assistance from K. J. Curry (DGMR-USGS laboratory), F. Elsass (XRF operation), G. I. Selner (data processing), and A. H. El Bazli (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 locality is identified by a unique five-digit number. No MODS localities were entered or updated as a result of this study. A MODS number has been requested for an ancient mine in the Thaniyah quadrangle, at lat 20°17'50" N., long 42°09'40" E. 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 five- or six-digit number. Inquiries regarding either bank may be made through the Office of the Technical Advisor, Saudi Arabian Deputy Ministry for Mineral Resources, Jiddah.

PRECAMBRIAN GEOLOGY OF THE THANIYAH AND AL UFAYRIYAH QUADRANGLES

The following summary of the Precambrian geology of the Thaniyah and Al Ufayriyah quadrangles is adapted from Greene (1982a,b, 1983) who mapped these quadrangles at the reconnaissance level (plate 1). Unit symbols are included in parentheses for ease of reference. Subsequent geochemical studies reported herein are based on his geological observations.

Metavolcanic layered rocks

A belt of metavolcanic rocks (mw) along the western edge of the Thaniyah quadrangle and southwestern edge of the Al Ufayriyah quadrangle consists of flow rocks, tuff, and breccia ranging in composition from basalt to rhyodacite. The most common rocks are andesite and dacite. The sequence is believed to be submarine in origin because of the presence of flow and fragmental groundmass textures and pillows in the adjacent Al Aqiq quadrangle (Greenwood, 1975).

Flow rocks and tuff ranging from andesite to basalt in composition are in the central part (mc) and along the eastern edge (me) of the Thaniyah quadrangle. Dacite is interlayered with andesite and basalt in a small unit (ml) along the east-central edge of the quadrangle.

Metavolcanic and metasedimentary rocks (mc) in the southwestern part of the Al Ufayriyah quadrangle are continuous with those of similar composition in the Thaniyah quadrangle to the south. They include well-bedded, tuffaceous sedimentary rocks of andesitic composition, massive andesite tuff, and some andesite flow rocks. A small area of rhyolite (rh), perhaps an ash-flow tuff, is about 4 km west of this belt.

Metavolcanic and metasedimentary rocks (me) in the eastern part of the Al Ufayriyah quadrangle are similar to those in the Thaniyah quadrangle, although they are separated by a granite pluton. This belt of rocks continues northward into the Harrat Nawasif quadrangle (Greene, in press). The rocks include andesite, basalt, amphibolite, and tuffaceous sedimentary rocks.

Plutonic rocks

A belt of several bodies of gabbro (gab) extends from the middle of the eastern boundary of the Thaniyah quadrangle northwest to the south-central edge of the Al Ufayriyah quadrangle. Diorite and gabbro (dg) crop out in a prominent hill near the center of the Thaniyah quadrangle.

Diorite and quartz diorite (dq) are common in the western half of the Thaniyah quadrangle; they have been intruded by tonalite and pink granite (tog) and are the oldest rocks of the An Nimas batholith. Similar rocks (dq, dqt, dqg) are found at several locations in the southern half of the Al Ufayriyah quadrangle. Most of these rocks are associated with metavolcanic rocks.

A large part of the Thaniyah quadrangle and part of the Al Ufayriyah quadrangle are underlain by tonalite and quartz diorite (to). These rocks represent the younger phase of the An Nimas batholith and postdate the diorite and quartz diorite (dq), diorite and tonalite (dqt), and diorite and granite (dqg) units. Cataclastic tonalite gneiss (tgn) is found at two locations in the Thaniyah quadrangle: one occurrence is 8 km long in the south-central part of the quadrangle and the other is 21 km long and on strike to the north-northwest of the first.

Graphic granite and rhyolite (ggr) underlie a large mountainous area in the northeastern part of the Thaniyah quadrangle, large areas in the south-central and southeastern parts of the Al Ufayriyah quadrangle, and an area in the southwestern corner of the Al Ufayriyah quadrangle. The granite contains slightly perthitic potassium feldspar and minor plagioclase. Locally, traces of alkali amphibole are present. A small granite intrusion (grr) containing trace amounts of alkali amphibole is located in the northwestern corner of the Thaniyah quadrangle.

Two-mica granites (big) crop out in two areas near the center of the Thaniyah quadrangle and at one location near the northeastern corner. The granite contains trace amounts to 1 percent muscovite and trace amounts of biotite. Granite and granodiorite (ggd) crop out in three small areas in the south-central part of the Thaniyah quadrangle.

A coarse-grained biotite granite (bg) is located along the southern edge of the Al Ufayriyah quadrangle, and medium- to coarse-grained monzogranite (grw) underlies an area to the north.

A perthite granite (grs) that underlies a small area near the northeastern corner of the Al Ufayriyah quadrangle is part of the perthite granite of Jabal Suily, which extends into the Harrat Nawasif (Greene, in press), Ranyah (Greene, [illegible]), and Wadi al Miyah (Schmidt, in press) quadrangles. The rock is a salmon-pink, slightly porphyritic granite containing cloudy, perthitic potassium feldspar. Mafic minerals include local alkali amphibole. A minor phase of this granite is a dark-reddish-brown, fine-grained granite (grf), which has a mineralogy similar to the perthite granite.

MINERALIZED ROCKS IN THE THANIYAH QUADRANGLE

During geologic mapping, Greene (19[illegible], [illegible]) located an ancient mine at lat 20°17'50" N., long 42°09'40" E. (MODS number requested). Five shallow pits and a 1-m-deep shaft are aligned along 140 m of sheared tonalite and mafic dike rock. Nearby, there are 12 slag heaps and several ruins of stone buildings. Some of the mafic rock is highly ferruginous and contains traces of malachite and chrysocolla. A sample of slag contained 10,000 ppm copper. During the present survey, three composite chip samples of mafic rock without visual signs of mineralization were collected from the pits and shaft. These samples contained less than 0.24 ppm gold, less than 1.4 ppm silver, less than 70 ppm zinc, and 60, 750, and 2,500 ppm copper.

Cheeseman (1982) listed several small mineral occurrences in the western belt of volcanic rocks (table 1). These will be discussed in the section on regional rock geochemistry.

MINERALIZED ROCKS IN THE AL UFAYRIYAH QUADRANGLE

Gold

Schmidt (in press, p. 80) recognized several small gold-bearing quartz veins cutting hornblende metadiorite between lat 20°40' N., long 42°28' E., and lat 20°47' N., long 42°23' E. He collected from seven localities grab samples that contained as much as 89 ppm gold (table 2). Five of these localities were visited by the author for resampling (plate 1), and the gold and silver contents of composite chip samples of quartz and wall rock are shown in table 2 for comparison with Schmidt's data (table 2). The conclusion by Schmidt that these quartz veins may carry significant gold and silver could not be verified by this additional sampling, and the quartz veins do not appear to be unusually rich in these metals.

Iron

Schmidt (in press, p. 76) reported a local occurrence of nontitaniferous magnetite, measuring 30 m wide and 300 m long, in garnet gneiss at lat 20°47'36" N., long 42°22'52" E. The

Table 1.--Mineralized locations in the Thaniyah quadrangle

[After Cheeseman (1982). All results in parts per million. Leaders indicate no data available. Locations on plate 1]

Location number	Latitude (north)	Longitude (east)	Copper	Zinc	Lead	Silver	Gold	Remarks
33	20°03.5'	42°00.5'	175	85	55	1.6	0.08	Small ancient working in a siliceous, ferruginous rock, 20-50 cm wide
49	20°09'	42°00'	16000	1000	--	--	--	Malachite occurrence
50	20°09'	42°00.5'	8000	--	--	--	--	Malachite occurrence
51	20°09.5'	42°00.5'	275	--	--	--	--	Small ancient working. Trench 8 m long with quartz
57	20°06'	42°00.5'	950	1500	20	4	.05	Minor ferruginous zone in rhyolitic rock, 5-10 cm wide, 7 m long
60	20°03'	42°00.5'	750	375	995	--	--	Disseminated pyrite in limonite concentrations. Largest limonite concentration, 1 m wide and 10 m long
61	20°02'	42°01.5'	2950	9500	120	5	2.7	Several ferruginous zones in rhyolite in an area, 50 m long and 30 m wide. Small ancient working

Table 2.--Gold and silver contents of quartz-vein and wall-rock samples from the northwestern part of the Al Ufayriyah quadrangle

[Results in parts per million. Analyses by atomic absorption. Type: WR, wall rock; Q, quartz. Locality numbers and data for samples from 73000-, 83000-, and 86000-sample number series from Schmidt([illegible]); 170000-sample number series collected by Fenton. Localities 5-9 shown on plate 1. Localities 2 and 4 were not resampled and data are presented for informative purposes only]

Locality number	Sample number	Gold	Silver	Type
2	73238	5.8	2.9	Q
2	83597	4.4	1.1	WR
4	73217	8.9	7.7	Q
4	73218	2.4	0.2	Q
5	83604	83	.5	Q
5	170500	0.3	<.5	Q
5	170501	.6	1.2	WR
6	83599	31	0.9	Q
6	170499	.5	<.5	Q
7	73233	.2	2.0	Q
7	83598	4.8	5.8	Q
7	170497	.3	.9	Q
7	170498	.1	1.4	WR
8	86300	44.4	2.4	Q
8	170491	.7	.6	Q
8	170492	.5	<.5	Q
8	170493	.5	1.4	WR
8	170494	.08	1.3	WR
9	83601	81	8.7	Q
9	170495	.4	2.3	Q
9	170496	.08	1.2	WR

magnetite is generally disseminated, but there are concentrations in layers less than 1 cm thick. No indication of significant copper was found at this locality.

REGIONAL ROCK GEOCHEMISTRY

There is an ever-increasing body of literature describing the successful use of reconnaissance trace element geochemistry of rock samples in the detection of precious metal, base metal, tin, tungsten, molybdenum, and yttrium-niobium-thorium-rare earth element mineralization (Fenton, 1982). Rock geochemistry was used to determine the mineralization potential of the Thaniyah and Al Ufayriyah quadrangles. Plate 1 shows sample locations and potentially favorable mineral resource areas as delineated by rock geochemistry.

Plutonic rocks

A total of 559 samples of plutonic rocks was available for trace element analysis. Copper, lead, zinc, gold, silver, molybdenum, thorium, yttrium, niobium, and zirconium contents and Rb/Sr ratios were visually scanned to identify anomalously high values; published data from mineralized areas were used as standards for comparison (tables 3 and 4). By this method, only 11 samples are considered anomalous (table 5).

Eight samples anomalous in molybdenum, yttrium, and zirconium are from the graphic granite (ggr) in the Al Ufayriyah quadrangle, which Greene(1982b, 1983) describes as slightly alkalic. Another anomalous sample from this unit is in the Thaniyah quadrangle. One of these samples (170126) is within a 5-minute quadrangle area that was identified by Theobald (1970) as anomalous in tin and moybdenum, based on results of a regional wadi-sediment geochemistry survey.

The two samples anomalous in base metals are from the two-mica granite (big) in the center of the Thaniyah quadrangle. One of the samples (157503) is at the edge of a significant airborne radiometric anomaly (plate 1; Consortium Members, 1966).

Layered rocks

Copper and zinc data for 339 samples of layered metavolcanic rocks were visually scanned to identify anomalously high values. Of these, 26 samples were considered anomalous (plate 1).

Ten of the 26 anomalous samples (table 6) are from the western belt of layered metavolcanic rocks (mw) in the Thaniyah quadrangle (plate 1, area A). These anomalous samples, which have copper contents from 110 to 5,000 ppm and zinc

Table 3.--Trace element contents of specialized (tin) granites and normal granites [All results in parts per million. Leaders indicate no data available. Values present averages except for (5) and (6), which are means shown with ranges of values in parentheses. References: (1) Tischendorf (1977); (2) Gerasimovsky (1974); (3) Taylor (1964, 1966, 1968); (4) Tischendorf (1977, 1979); (5) Sheraton and Black (1973); (6) Olade (1980); (7) Groves (1972)]

	Normal granites			Specialized (tin) granites			
	(1)	(2)	(3)	Average (4)	NE Queensland, Australia (5)	Nigeria (6)	Tasmania, Australia (7)
Rb	200	200	145	580±200	366 (291-427)	405 (180-860)	1035
Sr	--	--	285	--	59 (26-88)	(15-100)	5
Nb	--	20	20	--	--	130 (50-300)	--
Y	--	--	40	--	--	200 (35-480)	--
Zr	--	200	180	--	--	260 (110-610)	--
Th	--	--	17	--	26 (14-46)	50	--
Cu	--	--	10	--	7 (6-8)	--	--
Pb	--	--	20	--	-	--	--
Zn	--	--	40	--	49 (32-79)	(75-860)	--
Mo	--	--	2	3.5±2	--	--	--
Rb/Sr	--	--	0.5	--	8 (4-16)	--	207

Table 4.--Trace element contents of peralkaline granitic rocks, Kingdom of Saudi Arabia [All results in parts per million. Leaders indicate no data available. Means are shown with ranges of values in parentheses. References: (1) Radain and Kerrich (1979); (2) Drysdall (1979), Douch and Drysdall (1980); (3) Drysdall (1979); (4) Harris and Marriner (1980); (5) Harris and Marriner (1980), Drysdall (1979)]

	Average (1)	Jabal Tawlah(2)	Wadi Qaraqir(3)	Ghurrayyah (4)	Jabal Sayid(5)
Rb	356	--	--	(2718-3319)	--
Sr	11	--	--	(58-234)	<200
Nb	126	3244	530 (293-1025)	(1938-3311)	70
Y	201	6460	1066 (490-1900)	(552-2559)	(50-300)
Zr	1653	3730	6600 (2000-8900)	(2070-8830)	(700->1000)
Th	--	912	80 (37-194)	(160-625)	--
Zn	--	3071	105 (84-152)	--	(40-160)
Rb/Sr	32	--	--	(11-57)	--

Table 5.--Plutonic rocks from the Thaniyah and Al Ufayriyah quadrangles containing anomalous amounts of trace elements

[Molybdenum, yttrium, and zirconium analyses by X-ray fluorescence; all others by atomic absorption analysis. All results in parts per million. Leaders indicate sample not anomalous in element. Sample locations shown on plate 1. Rock units: ggr, graphic granite and rhyolite; big, two-mica granite; see text for description]

Sample number	Molybdenum	Yttrium	Zirconium	Copper	Lead	Zinc	Silver	Rock unit
			Thaniyah quadrangle					
157503	--	--	--	--	150	200	--	big
170278	--	--	--	165	--	--	--	big
170340	17	112	328	--	--	--	--	ggr
			Al Ufayriyah quadrangle					
170126	17	142	517	--	--	--	--	ggr
170133	21	177	584	--	--	--	--	ggr
170152	18	134	531	--	--	--	--	ggr
170166	23	122	390	--	--	--	--	ggr
170173	16	124	537	--	--	--	--	ggr
170200	25	151	545	--	--	--	--	ggr
170444	20	109	332	--	--	--	--	ggr
170452	19	103	333	--	--	--	--	ggr

Table 6.--Volcanic rocks from the Thaniyah and Al Ufayriyah quadrangles containing anomalous amounts of copper and zinc

[All results in parts per million. Leaders indicate sample not anomalous in element. Sample and area locations are shown on plate 1.

Potentially favorable resource area	Sample number	Copper	Zinc
A	157905	--	200
	157917	150	--
	157919	--	155
	157923	110	--
	157924	125	--
	157926	120	--
	157931	120	--
	157935	205	--
	170247	5,000	--
	170262	--	200
B	161102	--	155
	161103	--	200
	161109	190	200
	170395	145	--
C	157641	205	--
	170306	--	200
	170311	650	750
Other samples	161799	165	--
	170089	500	--
	170098	130	130
	170207	145	--
	170369	185	--
	170378	200	--
	170439	130	--
	170471	155	--

contents from 155 to 200 ppm, identify a northern extension of the Wadi Shwas mineralized zone (Ozawa and others, 1978; Kato and Fujii, 1979) that extends from the south into volcanic and sedimentary rocks of the Thaniyah quadrangle.

Cheeseman (1982) listed seven small mineralized locations in this part of the Thaniyah quadrangle (table 1), and the Hajal prospect (MODS00649) is less than 4 km south of the Thaniyah quadrangle at lat 19°58' N., long 42°01' E. (Ozawa and others, 1978). The eastern zone of this prospect consists of gossan and a malachite-stained shear zone, about 3 m wide and 100 m long, in a dacite and rhyolite unit. The western zone consists of a malachite-stained gossan, 2 m wide and 80 m long, in similar rock. Copper and zinc contents of 13 samples of massive gossan and ferruginous rocks from the prospect ranged from 210 ppm to 5,470 ppm and 140 ppm to 1,450 ppm, respectively (Kato and Fujii, 1979), and drilling has intersected wide zones of disseminated pyrite containing insignificant amounts of base metals (Cheeseman, 1982).

Cheeseman (1982) collected wadi-sediment samples from the western belt of metavolcanic rocks (mw) in the Thaniyah quadrangle for atomic absorption analysis. The samples were collected at 500-m intervals and were divided into -10+20-mesh and -20+40-mesh fractions. Using the analytical results, Cheeseman defined four copper-zinc or copper-zinc-lead anomalous zones in the Thaniyah quadrangle that are associated with known mineral occurrences (table 1, mineralized locations 33, 57, 60, 61).

The INPUT airborne-electromagnetic survey performed over the western belt of layered rocks in the Thaniyah quadrangle used a line spacing of 250 m and a ground clearance of 120 m (Wynn and Blank, 1979). Although this spacing was considered to be adequate, the survey did not produce any anomalous responses.

Four rock samples from the central belt of metavolcanic and metasedimentary rocks (mc) along the border between the Thaniyah and Al Ufayriyah quadrangles (plate 1, area B) contained anomalous amounts of copper (145 to 190 ppm) and zinc 155 to 200 ppm). Three rock samples from the eastern belt of metavolcanic and metasedimentary rocks contained anomalous amounts of copper and zinc, with copper contents as high as 650 ppm and zinc contents as high as 750 ppm (plate 1, area C). Eight other unrelated rock samples from the layered volcanic rock areas are anomalous in copper and (or) zinc (table 6, plate 1).

CONCLUSIONS

The Thaniyah and Al Ufayriyah quadrangles contain several sites of minor base and precious metal mineralization. Composite chip samples of quartz and wall rock from quartz veins located between lat 20°47'14" N., long 42°23'26" E., and lat 20°45'05" N., long 42°25'24" E., and reputed to contain significant gold and silver (Schmidt, in), contained negligible amounts of precious metals. Both Schmidt (oral commun., 1981) and this author conclude that additional study of these veins appears to be unjustified.

There is abundant evidence of ancient copper mining along a shear zone at lat 20°17'50" N., long 42°09'40" E. Copper mineralization is visible, ferruginous rock (gossan?) is present, and two composite chip samples from the zone contained 750 and 2,500 ppm copper. This combined evidence suggests that additional study of the prospect is warranted.

The minor occurrence (Schmidt, in press) of nontitaniferous magnetite in garnet gneiss at lat 20°47'36" N., long 42°22'52" E., was not resampled in this study. A determination of the market demand and grade and tonnage requirements for this type of material should be made before any additional exploration activity is undertaken.

Only 11 of 559 samples collected in plutonic terrane are considered anomalous (table 5, plate 1). Nine samples from slightly alkalic graphic granite and rhyolite in the Al Ufayriyah and Thaniyah quadrangles are anomalous in molybdenum, yttrium, and zirconium. An earlier wadi-sediment survey detected anomalous amounts of tin and molybdenum in rocks from part of this unit (Theobald, 1970). Anomalous amounts of copper and zinc were found in samples of a two-mica granite in the middle of the Thaniyah quadrangle; one of the samples is associated with an airborne radiometric anomaly (Consortium Members, 1966). Both of these anomalous areas should be evaluated further by detailed wadi-sediment surveys and analysis of heavy-mineral concentrates.

A total of 26 of 339 rock samples collected in the belts of layered volcanic and sedimentary rocks contained anomalous amounts of copper or zinc. These data identify a northeastern extension of the Wadi Shwas mineralized zone into an area along the western border of the Thaniyah quadrangle in which an earlier INPUT airborne-electromagnetic geophysical survey (Wynn and Blank, 1979) had not defined any anomalous zones. A wadi-sediment survey conducted by Cheeseman (1982) shows that base metal anomalies in this area are associated with very small occurrences of mineralized rocks, and Cheeseman believes that the total exploration effort has been thorough enough to support the conclusion that the mineral potential of the area is low. The author agrees that further exploration is not warranted in the Wadi Shwas zone but believes that additional study is warranted in areas of volcanic rock in which anomalies have been defined by rock geochemistry (plate 1).

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