UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Saudi Arabia Investigation Report
(IR) SA-121

RECONNAISSANCE FOR MINERAL DEPOSITS IN THE PRECAMBRIAN ROCKS OF THE WADI AR RIMAH QUADRANGLE, KINGDOM OF SAUDI ARABIA

by

James W. Mytton
U. S. Geological Survey

1970

PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

RECONNAISSANCE FOR MINERAL DEPOSITS IN THE PRECAMBRIAN ROCKS OF THE WADI AR RIMAH QUADRANGLE, KINGDOM OF SAUDI ARABIA

by

James W. Mytton
U.S. Geological Survey

CONTENTS

Page

Page

ILLUSTRATIONS

RECONNAISSANCE OF MINERAL DEPOSITS IN THE PRECAMBRIAN ROCKS OF THE WADI AR RIMAH QUADRANGLE, KINGDOM OF SAUDI ARABIA

by

James W. Mytton

ABSTRACT

A reconnaissance of the Precambrian area of the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia, included more than 50 ancient mines which are grouped into seven mining districts. The best mineral potential appears to be in the Ad Dawadami district, where silver and lead were formerly mined, and in the southwestern part of the quadrangle in the vicinity of the Nafud al Urayk. Ancient mines in the southwestern part of the quadrangle were probably opened for gold, but the present exploration disclosed tungsten and antimony minerals, and slightly anomalous lead, zinc, and molybdenum. Of these elements the greatest potential appears to be tungsten.

Most ancient mines and the newly discovered mineralized veins are in areas underlain by graywacke intruded by granitic stocks and apophyses. These areas should be further investigated for ore deposits.

INTRODUCTION

The investigation of the Wadi ar Rimah quadrangle (fig.1) was part of a mineral evaluation of the Precambrian rocks of the Arabian peninsula carried on by the U. S. Geological Survey on behalf of the Directorate General of Mineral Resources, Ministry of Petroleum and

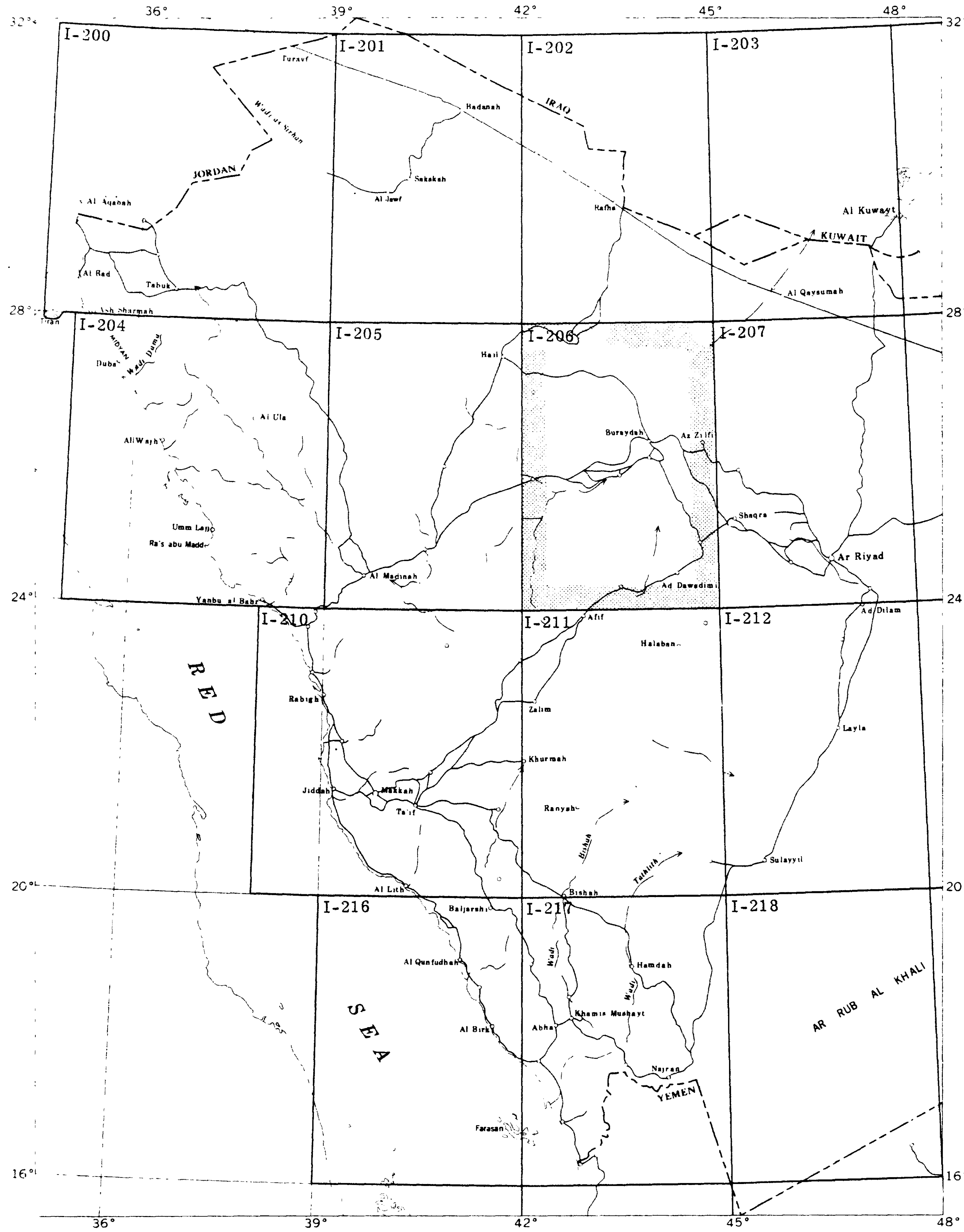

Figure 1. Index map of Arabian peninsula showing location of the Wadi Ar Rimah quadrangle

Mineral Resources, Kingdom of Saudi Arabia.

A geochemical reconnaissance was made of the Precambrian rocks in the area during the fall of 1964 and the spring and summer of 1965. About 4 months were spent investigating the area between Jabal Salma and Jabal al Urd. A few days were spent with Abdulla Ankary of the Ministry of Petroleum and Mineral Resources in the Jabal al Koom and Jabal Ashumta areas (Ankary, 1965a; 1965b). A brief visit was made to the southern part of the Ad Dawadami district where similar studies were conducted (Theobald 19~~65~~70a, 1966 70b; Theobald and others, 19~~66~~70; Mytton, 19~~66~~67a).

During the reconnaissance of the Wadi ar Rimah quadrangle, several ancient mines were examined, and a few were mapped by either pace and compass or tape and compass methods. Mines previously known but incorrectly located were relocated on aerial mosaics and a few mines, not previously reported, were also plotted.

For a geologic map of the area the reader is referred to the map by Bramkamp and others (1963); no attempt was made to change the stratigraphic nomenclature used by them. The major rock units of the region are discussed below in terms of their lithologies rather than by their formal names.

GEOLOGIC SETTING

The geology of the Precambrian rocks of Wadi ar Rimah quadrangle is only briefly discussed in this report. A more detailed description of the geology of the area is given by Bramkamp and others (1963). No attempt was made by me to unravel the complexities of the lithologic units because of the type of investigation and because of the limited number of geological observations that could be made in a short period of time. More detailed reconnaissance mapping supported by petrographic work will be required to solve the stratigraphic and structural problems of this area.

Area north of Wadi ar Rimah

Crystalline rocks:-- The northernmost feature in the part of the Precambrian Shield in the Wadi ar Rimah quadrangle is the great massif referred to as Jabal Salma. It extends more or less northeasterly for about 50 kilometers. The massif is a red and medium-grained granite. In the northern part of the massif the granite is virtually devoid of dark minerals and could be termed feldspathic granite. To the south the rock changes to biotite granite which is lighter in color and coarser grained than the granite to the north. South of Jabal Salma this young red granite is in contact with an older gray granite, and large apophyses extend from the main body of young granite into the older granite. The older granite is light pink to yellowish gray, medium to coarse grained, and generally biotitic. Basalt dikes of Quaternary age cut the older granite in the eastern part of the area.

In addition to basalt dikes, older dikes of both mafic and felsic rocks cut across the granitic terrain throughout its extent south of

Jabal Salma. In the vicinity of As Safra, east-trending dikes of granodiorite and diabase appear to be offshoots of older mafic bodies that post-date the older granite but pre-date the younger northwesterly trending granitic offshoots of the red granite at Jabal Salma. South of As Safra, dikes of both diabase and rhyolite porphyry trend northwest. At one locality northeasterly striking dikes of red, fine-grained granite grading to rhyolite are offset by northwesterly trending left lateral faults occupied by andesite and diabase. A series of prominent dikes of red granite porphyry grading to rhyolite porphyry forms a conspicuous ring-like structure southeast of As Safra. A major swarm of easterly trending granitic dikes form the prominent hills known as Jabal Shurmah at the southern end of this ring structure. Some of the diabase dikes strike parallel to the granitic dikes and are in juxtaposition to them.

Small bodies of diorite grading to gabbro are north of Samirah along the Darb Zubaydah in the vicinity of the small village of Birkah. A few kilometers north of Birkah a hill known as Jabal Uraynibah is chiefly composed of gabbro, but it is locally dioritic. This body of gabbro is cut by easterly trending dikes of light-colored, medium-grained granite, pegmatitic granite, and felsite with which are associated veins of barren quartz.

The youngest granite in the area north of Wadi ar Rimah is the pink, medium- to coarse-grained variety that makes up Jabal Salma, Jabal al Hudub, Jabal Qutn, Jabal Silsilah, and Aban al Asmar. In addition to the pink granite, red rhyolite prophyry grading to granite porphyry is at Jabal Silsilah and Aban al Asmar. The porphyry appears to be later than the granite and may be the same age as the red rhyolite porphyry that makes up Jabal ar Rana to the north and the dikes of red rhyolite porphyry and associated diabase that are throughout the area.

Sedimentary rocks:-- Unconformably overlying the gray granite is a thick sequence of graywacke and conglomerate that makes up Jabal Aba al Liqah, Jabal Hibshi, Jabal al Khidar, Jabal Musawda'ah, and Jabal at Tin, and extends as linear outcrops southwest from Jabal Aba al Liqah to the western boundary of the Wadi ar Rimah quadrangle. This thick succession of strata mostly consists of a basal conglomerate of boulders and cobbles of gray granite, overlain by alternating purple to green argillite and green quartzite and wacke, which in turn are overlain by a thick conglomeratic unit made up of cobbles and pebbles of argillite, quartzite, wacke, felsite, and some granite. The section is best seen at the southern end of Jabal Hibshi. North of Jabal Hibshi the argillite between the units of conglomerate is not well exposed. To the south of Jabal Hibshi the sequence appears to thicken considerably, and nearly a thousand meters of green graywacke occupies the section between the argillites of Jabal al Khidar and the upper conglomeratic unit which makes up part of Jabal Musawda'ah and Jabal at Tin. At the southern end of Jabal Aba al Liqah, graywacke is intruded by offshoots of the red coarse-grained slightly biotitic granite that makes up Al Hudub. The granite is fine to medium grained where it is in contact with the graywacke. Veins of pegmatitic granite and barren quartz are also in the graywacke. Near the contact the graywacke is sheared and the argillaceous matrix is converted to biotite schist that is chloritized and mylonized. The graywacke appears to contain more silica and is pink to white in color along the contact with the granite. Nearly all the biotite in the granite adjacent to the contact has been altered to hematite.

South and east of Jabal at Tin there is a widespread, southerly trending unit of graywacke. It has some similarity to the green graywacke of the linear belt, but it is intruded by gray granite probably of the same age and character as the old gray granite northwest of the belt. The unit of graywacke includes a variety of rocks throughout its extent southward to Wadi ar Rimah. In the hills north of Jabal ar Rana it consists chiefly of alternating graywacke and conglomerate. South of Jabal ar Rana it is a dirty siltstone. South of Jabal al Muwashsham the unit is chiefly graywacke and argillaeous limestone, whereas in the vicinity of Al Fawwarah it consists solely of argillaceous shale. On the west flank of Aban al Asmar the unit is banded graywacke and conglomerate, and some distance to the west of Aban al

Asmar it is argillaceous to tuffaceous wacke.

Where the unit is in contact with the gray granite, the unit has either been sheared and assimilated by the granite or it has been baked. Where it has been sheared, a schistose phase, generally consisting of quartz-biotite schist and some chlorite schist, has developed where the granite is emplaced along bedding planes and fractures and has partly assimilated the country rock. Where it has been baked, a hornfelsic phase has developed in which fine-textured parts of the unit are converted to a dense, aphanitic, epidotized rock; conglomeratic parts have been welded as a result of baking by the granite.

The relationship between the graywacke and conglomerate sequence of Jabal Hibshi, Jabal al Khidar and Jabal at Tin and the widespread graywacke unit to the southeast cannot be readily established, as no formational contacts were observed and the two major units are separated by extensive faults. However, the linear belt of graywacke that post-dates the gray granite would have to be younger than the widespread graywacke unit inasmuch as this unit pre-dates what is considered to be the same granite.

Area south of Wadi ar Rimah

Sedimentary rocks:-- A sequence of graywacke and conglomerate underlies most of the area examined between Wadi ar Rimah and Jabal an Nir. It makes up the rocks of Jabal Habla, Jabal ash Shuban, Jabal Magawgi, Jabal Laym, Jabal Kabsha, Jabal Kuff(?) Jabal Shi'r(?) and Jabal an Nir and flanks the granite cores of Aban al Ahmar and Jabal Shaba. The jabals are separated by extensive granite plutons that are younger than the sedimentary sequence.

At Jabal al Habla, the graywacke which has a regional dip to the north, consists of large crystals of plagioclase, giving the rock a volcanic appearance on a weathered surface. There is a paucity of quartz grains. In places the graywacke is composed of fine- to medium-sized grains of quartz, feldspar, and lithic fragments in a matrix of chlorite with much hematite. Laminated siltstone and conglomerate with pebbles of graywacke are also present. Dikes of red rhyolite porphyry cut the graywacke. Jabal Akkash to the southwest consists almost entirely of conglomerate with boulders of graywacke along with some andesite and rhyolite in a matrix of dark aphanitic graywacke containing many cubic ghosts of pyrite altered to hematite. Near the contact with the granite, the graywacke is dark and aphanitic and has been converted to hornfels. Where the graywacke contains large feldspar grains the rock has the appearance of an andesite porphyry; however, the grains are fragmental and show no zoning. Argillite containing feldspar fragments is also present and is associated with the graywacke. In places the graywacke unit becomes more silty and contains quartz grains along with feldspar fragments and biotite in a silty to argillaceous matrix. Green to purple wacke with much lithic material and some pebble conglomerate is present. The matrix of this rock is often hematitic.

Near Jabal ash Shuhban the graywacke is red to purple, highly silicified, and shows banding. It contains feldspar fragments in a hematitic argillaceous matrix. Jabal ash Shuhban is made up of light-gray, massive, crystalline limestone that forms a synclinal fold plunging to the west and terminating abruptly to the west where the limestone unit is in fault contact with graywacke. To the south, along Wadi Jarrir, tightly folded limestone beds grade into tightly folded siltstone beds. Just north of the syncline the limestone is locally interbedded with green graywacke with pebbles of the same material. The aphanitic limestone grades upward into medium-gray silty limestone which is overlain by graywacke and in turn, overlain by light-gray, silty, crystalline limestone. The graywacke is truncated by Wadi Jarrir to the east and pinches out to the west.

The northern part of Aban al Ahmar contains siltstones grading to argillites and thick massive conglomerate units with a regional dip to the northwest. The cobbles in the conglomerate are composed of argillite and siltstone, and therefore are intraformational. Dark-green graywacke grading to siltstone is also present which is very fine grained, hornfelsic in appearance and in places is highly epidotized, especially near the contact with the extensive granite terrain to the east. In the vicinity of the contact, a mafic granite - almost a granodiorite - with massive gneissic structure is present and probably represents the sheared border phase of the major granite pluton to the east. Andesite sills, some pyrite-bearing and massive, have intruded the graywacke unit in this area. Green andesite similar to the sills is southwest of Aban al Ahmar in the vicinity of Shaib Jarrar. It is composed of hornblende needles in a very fine crystalline groundmass. Sporadic plagioclase crystals are present. The hornblende needles show flow structure.

North of Aban al Ahmar a minor stock of young granite is in contact with a small dark body of gabbro. Near its margin the gabbro grades into diorite which in turn grades into quartz diorite that is sheared at the contact and is converted to quartz-biotite schist. Dikes of pink aplitic granite in the gabbro represent offshoots of the granite body.

The southern part of Aban al Amar has a core of young, gray to pink, medium- to coarse-grained biotite granite, flanked by graywacke. Small roof pendants of graywacke are in the stock. At one locality on the eastern flank of Aban al Ahmar a sequence of dirty siltstone to wacke, interbedded with purple silty argillite and conglomerate, is intruded by the young granite which also contains inclusions of the graywacke unit in the granite stock to the west. To the east, the graywacke unit is in contact with the large granite batholith. The basal unit is dark-green wacke that overlies dark-gray, medium-grained, mafic granite containing much biotite and pink feldspar. To the east the feldspar becomes white, and gray biotite granite has a lighter color. Near the contact there is much epidotization. Though no apophyses of this granite were observed in the overlying graywacke, alteration of the granite at the contact, shearing of the granite, and a lack of basal conglomerate in the graywacke unit suggest that the granite is younger than the graywacke. No baking or shearing of the basal wacke unit was observed. A few kilometers southeast of the village of Jarrar there is an excellent view of the contact between the same granite batholith and the graywacke on the west side of Jabal Amudon. The granite unquestionably intrudes the graywacke and cuts through the bedding. Numerous easterly trending dikes of rhyolite cut both the graywacke and the granite.

The graywacke sequence overlying the gray biotite granite just south of Jarrar includes alternating argillite, siltstone, and wacke, with massive conglomerate units containing clasts ranging in size from pebbles up to cobbles. These units dip to the south as far south as Jabal Kutayfah, where they are again in contact with the gray, medium-grained, biotite granite. Dark reddish-brown rhyolite porphyry cuts the graywacke and conglomerate at Jabal Kutayfah. At the southeast end of Jabal Kutayfah dark, finely crystalline, bedded limestone makes up two prominent hills. The attitude of the bedding varies considerably because of local folding. The limestone appears to be overlain by the sequence of graywacke and conglomerate. The sequence of graywacke and conglomerate southeast of Al Jurdhawiyah is associated with bodies of andesite grading to gabbro. Small bodies of gabbroic rock are at the Jarrar mine southwest of the village of Jarrar and are sporadically present south to Jabal Shawfan, and in the low-lying area of graywacke as far south as Jabal Shaba. These mafic igneous rocks commonly form more or less conical-shaped bodies. Green andesite porphyry is the most common type of rock exposed in these bodies between Al Jurdhawiyah and the southern end of Jabal Shawfan.

Jabal Shaba is a complex of a variety of rock types, including granite, graywacke, and mafic igneous rocks. The northern part of the jabal consists primarily of a dark, brownish-gray biotite granite which at its northern tip is in contact with a pink feldspathic granite that is probably younger than the gray granite. Both granites are coarse grained. To the east of Jabal Shaba a large area in which the village of Dariyah is located is underlain by a variety of granit_. The principal variety is gray, medium-grained, porphyritic biotite granite. No attempt was made to differentiate between the granites of Jabal Shaba and those underlying the extensive area to the east and southeast.

The southern part of Jabal Shaba is mostly graywacke and conglomerate with a regional dip to the west. This sequence of graywacke and conglomerate is intruded by what appears to be sills of rhyolite and felsite. The central part of the jabal is most complex. Here siltstone and graywacke are associated with dark mafic igneous rocks that are probably gabbro and fine-grained basic diorite, which have been intruded and altered by granite. The fine-grained basic diorite may be more properly referred to as an amphibolite and may represent that part of the gabbro that was altered by emplacement of the granite and related felsic rocks. Similar diorite is to the west at Jabal al Koom (Mytton, 1967, 1970).

The Jabal Qunnah area east of Dariyah is a complex of graywacke associated with mafic igneous rocks and intruded by the large granite batholith to the southwest. Jabal Kabshan is made up of a normal graywacke sequence, though rocks are slightly hornfelsic near their contact with the granite. The graywacke of Jabal Kuff and Jabal Shir is associated with mafic igneous rocks as are the graywackes of the Akliyah area (Hummel and Ankary, unpublished data.).

Gabbro and diorite:-- A body of gabbro and diorite extends southeast from Jabal Suwaj to the boundary of the quadrangle. The body consists of a gabbroic core which is altered to diorite along its flanks near the granite. The diorite may be more properly termed an amphibolite. The gabbro and diorite body is severed by a large zone of major wrench-faults that trend about 20° - 30° W., from the southern boundary of the quadrangle to a point just south of Ash Shubayrimah, then makes a rather sharp bend to the west and trend about N.50°W. The fault zone is shown terminating at Jabal Laym on the 1:500,000 geologic map of the Wadi ar Rimah quadrangle (Bramkamp and others, 1963); however, it is here believed to extend well beyond that point, as shown on plate 1. By extending the line of the fault zone along the same strike beyond the western boundary of the quadrangle, it will coincide with a large wrench-fault mapped by Hummel, Ankary, and Hakim (19~~66~~70). They ~~(1966)~~ map the rocks of the gabbro and diorite unit as Halaban diorite north of the fault zone and Halaban andeiste south of the fault zone. It is evident from either the 1:500,000-scale geologic map of the Wadi ar Rimah quadrangle or the 1:2,000,000-scale geologic map of the Arabian Peninsula (Anon., 1963) the Halaban diorite part is offset several kilometers to the northwest from the Halaban andesite part, indicating left lateral movement of some magnitude. All northwesterly trending faults in the general region have left lateral movement and the northeast ones have right lateral movement (Mytton, 1967, 19~~65~~70; Hummel, Ankary and Hakim, 19~~66~~70). The direction of the principal stress in the region was east-west (Hummel, Ankary, and Hakim, 19~~66~~70).

<u>Granite</u>:-- A large granite batholith extends south of Wadi ar Rimah along the eastern margin of the Precambrian Shield to the southern boundary of the quadrangle. It is a complex of several varieties of granite cut by numerous dike swarms. It is of interest because the ore

deposits of the Ad Dawadami area are in it. South of Ad Dawadami the granite is intimately associated with a complex of both mafic and felsic rocks (Theobald, 1966). To the southwest the granite intrudes a northerly trending belt of chlorite-sericite-biotite schist that make up Jabal al Urd and vicinity (Mytton, 1965).

GEOCHEMICAL RECONNAISSANCE

Samples of wadi sediment, detrital magnetite, and heavy-mineral concentrates were collected from widely separated areas in the Wadi ar Rimah quadrangle. The wadi sediment was screened and the -30 +80 fraction was analyzed in Jiddah by semi-quantitative spectrographic methods for 27 elements; C.E. Thompson and J. Goldsmith, U.S. Geological Survey, and Mohammed Said, Directorate General of Mineral Resources. Detrital magnetite was collected with a small horseshoe magnet, cleaned magnetically, and analyzed by L. Al Dugaither and E. Brady of the Directorate, by means of wet chemical methods for copper, zinc, and molybdenum. Heavy-mineral concentrates panned from samples of wadi sediment were analyzed by L. Al Dugaither by wet chemical methods for copper, zinc, molybdenum, and tungsten. The concentrates were examined under ultra-violet light for scheelite and other fluorescent minerals.

Sampling was mostly in areas of relatively high relief, such as jabals, because the drainage systems of these areas are better developed, contain a greater amount of wadi sediment in the -30 +80 range, and are more protected from windblown sand than the drainage of intervening areas of low relief. The drainage of the low-lying regions are larger wadis, including Wadi ar Rimah, the major wadi in the quadrangle. These large wadis contain very little -30 /80 mesh sediment. The most abundant material is in the silt and clay fractions. The floors of these wadis are commonly underlain by hard-packed clay which supports sparse vegètation. Locally, channels containing abundant -30 /80 mesh sediment are along some reaches of the wadis. Windblown sand is commonly in many of these wadis, especially those near areas of dune sand, notably near the Nafud al Urayk. In these areas the lower reaches of wadis draining jabals also contain appreciable windblown sand. Though the drainage of the jabals is generally better integrated than that of the wide expanses separating them, some wadis draining jabals are better developed than others, especially those draining the more gentle flanks of a jabal. Those draining the steeper flanks are smaller and mostly contain only /10 mesh sediment. Samples of wadi sediment and detrital magnetite were collected at closely spaced intervals (1 to 2 km) to provide more geochemical background data and better detection of possible mineral occurrences.

The sample sites, plotted on the 1:500,000-scale map of the Wadi ar Rimah quadrangle (pl.1), are concentrated in at least nine major localities which are listed in table 1 along with a general description of their major lithologies. Included with the samples from Jabal al Habla are a few widely spaced samples collected between Al Fawwarah and

Jabal al Habla, all of which represent the major grawacke unit that underlies the region between these localities. Samples collected at four widely separated localities between Jabal Suwaj and Al Hamjah, all of which are underlain by diorite and unrelated rocks, have been placed in an additional group, also included in table 1, and referred to as the Halaban Formation. The major areas listed in table 1 are shown on plate 1.

Wadi sediment

Histograms (fig.2) have been constructed for barium, chromium, copper, nickel, lead, and vanadium that were determined spectrographically in samples of wadi sediment collected from the nine major sample areas. These elements were selected because they were detected in all samples analyzed, and among the elements detected they show the widest variation among localities. Such elements as beryllium, zinc, and molybdenum are not included because they are present in most of the samples in amounts below the limits detection.

Barium:-- In general, there is no significant variation in barium in samples collected from the nine areas listed on table 1. The norm is 500 parts per million (ppm) at six of the major sample localities. The norm is 300 ppm in the area underlain by the Halaban Formation and 700 ppm in the Jabal al Urd region. The highest value for barium in wadi sediment is 1000 ppm in two samples from Jabal al Habla and vicinity and in one sample from Aban al Ahmar and vicinity. These

Table 1 - Major localities from which samples of wadi sediment and detrital magnetite were collected, and the dominant rocks underlying them.

	Area		Major rock units
1.	Jabal Salma	--	Mostly red feldspathic granite; minor biotite granite.
2.	Jabal Hibshi and vicinity (includes Jabal Musawda'ah and Jabal at Tin	--	Graywacke and conglomerate.
3.	Aban al Asmar	--	Red rhyolite porphyry grading to granite porphyry and pink biotite granite grading to hornblende granite
4.	Jabal al Habla and vicinity including random samples collected north of Wadi ar Rimah.	--	Chiefly graywacke and conglomerate; siltstone, argillaceous shale, limestone, and minor tuffaceous wacke.
5.	Aban al Ahmar and vicinity (includes Jabal Magawgi, Jabal Shawfan and Jabal Kutayfah)	--	Mostly graywacke and conglomerate associated with plugs and sills of diorite, and andesite, and plutons of different granites.
6.	Jabal Shaba	--	A complex of graywacke, conglomerate, amphibolite, diorite, andesite, and granite; granite is common in the north and graywacke conglomerate in the south.
7.	Jabal Kabshan	--	Graywacke and conglomerate intruded in places by gray biotite granite.
8.	Halaban Formation	--	Mostly mafic igneous rocks, and gabbro and diorite associated with minor graywacke and granite.
9.	Jabal al Urd	--	Chlorite-sericite-biotite schist with veins of segregated quartz parallel to schistosity.

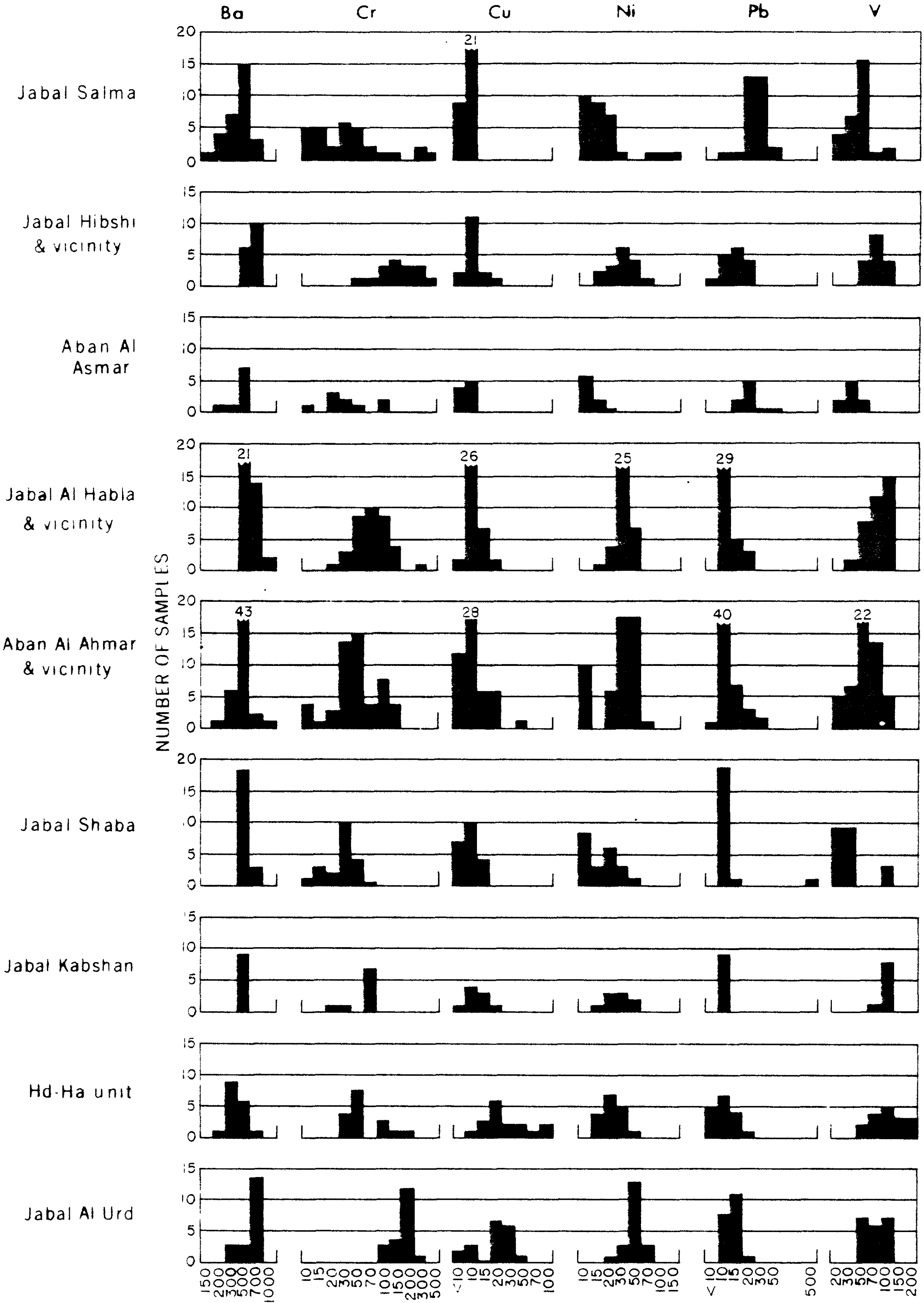

Figure 2. Histograms showing distribution of barium, chromium, copper, nickel, lead, and vanadium in wadi sediment

samples were collected from wadis located some distance from the main jabals in which sampling was concentrated and which drain relatively low-lying areas. The schistose rocks of Jabal al Urd have the highest background values in barium, whereas the mafic igneous rocks of the Halaban Formation apparently have the lowest. The high barium background at Jabal al Urd appears to be anomalous in itself. The barium content of samples collected at Jabal al Urd has the greatest spread of values ranging between 150 ppm and 700 ppm.

Chromium:-- There is notable variation in the chromium content in samples collected from the nine major localities, and of any of the six selected elements, chromium has the greatest spread in values, ranging between 10 ppm and 500 ppm at Jabal Salma. Value of 300 and 500 ppm chromium at Jabal Salma is considered anomalous. The norms for chromium in samples collected at both Jabal Salma and Jabal Shaba are 30 ppm, though chromium values at Jabal Salma are somewhat biomodal. Aban al Asmar has a norm of 20 ppm, and in general it appears that the granitic rocks in the Wadi ar Rimah quadrangle have a lower background in chromium than the other rock types. The isolated peak of 10 ppm chromium in the histogram for Aban al Ahmar represents samples collected from wadis containing chiefly granite wash.

Mafic igneous rocks as represented by the Halaban apparently have the relatively low chromium background of only 50 ppm. Graywacke has a slightly higher background in chromium in the Wadi ar Rimah quadrangle than gabbro and diorite. At Jabal al Habla and vicinity, the norm for chromium is 70 ppm and at Jabal Hibshi and vicinity it is as much as 150 ppm. The schistose rocks of Jabal al Urd, however, have the highest background in chromium, which is as much as 200 ppm. These data suggests that the finer-grained sedimentary units, such as siltstones and shales and their metamorphic derivatives, are richer in chromium than either the felsic or mafic igneous rocks.

Copper:-- The norm for copper is 10 ppm for all but two of the major localities. These exceptions are the Halaban Formation and Jabal al Urd both of which have norms of 20 ppm. There is not much spread in copper values in samples of wadi sediment from the other localities either. The highest value for copper, which is 100 ppm, is in two samples from the Halaban. In general, the gabbroic and dioritic rocks are richer in copper in the Wadi ar Rimah quadrangle, and the granitic rocks are perhaps the leanest.

Nickel:-- The nickel content of wadi sediment shows a definite variation between that in sediment derived from granitic terrain and that in sediment derived from areas underlain by graywacke, mica schist, and mafic igneous rocks. The norms for nickel in the Jabal Salma and Aban al Asmar areas is only 10 ppm. The bimodal distribution of nickel at Jabal Shaba is related to the presence of two major rock types, granite and graywacke. All values of 10 ppm are from samples of granitic debris. The isolated peak of the histogram for Aban al Ahmar and vicinity, which also is 10 ppm, similarly represents granitic material.

The norm for samples of wadi sediment collected from Jabal Hibshi and vicinity, Jabal Habla and vicinity, and Aban al Ahmar and vicinity is 30 to 50 ppm. The norm for nickel in wadi samples presenting the Halaban from Jabal al Urd is 50 ppm. Three samples containing 70 ppm nickel were also collected from Jabal al Urd.

The granitic rocks, as a whole, appear to be deficient in nickel; the schistose rocks as typified by the chlorite-sericite-biotite schists of Jabal al Urd are relatively rich in nickel and the graywacke are slightly less so. The dioritic types fall between the granites and graywackes. The fact that the graywackes and schistose rocks are higher in both chromium and nickel than the gabbroic and dioritic types, which would normally be expected to contain higher amounts of these elements, indicates enrichment of chromium and nickel in the graywackes and schists, probably through normal sedimentation.

Though nickel is notably low in the granites, the highest values for nickel are from Jabal Salma. Two samples collected from wadis within this prominent granite jabal has 100 ppm and 150 ppm nickel respectively, both of which are definitely anomalous quantities.

Lead:-- Histograms for lead show five of the major sample areas to have norms of 10 ppm. Jabal Hibshi and vicinity and Jabal al Urd both show norms of 15 ppm lead, Jabal Aban al Asmar has a norm of 20 ppm, and Jabal Salma has a norm of 20 to 30 ppm. The areas which are only granitic, such as Jabal Salma and Jabal Aban al Asmar, have higher backgrounds in lead. The only samples with 50 ppm lead are from wadis in these two areas. The gabbro and diorite appear to be leaner with respect to their lead content than the other rocks as indicated by the number of samples from the Halaban that have values of less than 10 ppm lead.

One sample collected from Jabal Shaba contained 500 ppm lead, the highest anomalous value of any sample of wadi sediment in the quadrangle. The wadi that was sampled contained a variety of detritus representing granite, rhyolite, diorite and/or amphibolite, and schistose argillite. The high value for lead may be related to the granite or rhyolite. Red granite and rhyolite crop out in the vicinity of the sample site. The sample site is located just south of the Shaba um Satih mine, but the wadi from which it was collected does not drain the area of the mine.

<u>Vanadium</u>:-- The graywackes and related rocks are generally richer in vanadium than the granites in the Wadi ar Rimah quadrangle, and the mafic igneous rocks appear to be the richest (fig.2). The norms for vanadium in samples from Aban al Asmar and Jabal Salma are 30 ppm and 50 ppm respectively. The norms for samples from Jabal Hibshi and vicinity and Jabal al Habla and vicinity are 70 ppm and 100 ppm

respectively, and Jabal Kabshan has a norm of 100 ppm vanadium.

The vanadium content of all but three of the samples from Jabal Shaba is between 20 and 30 ppm. The nongranitic rocks appear to be lower in vanadium at this locality. The highest vanadium values, 150 ppm and 200 ppm, are in samples from the Halaban.

Other elements:-- In addition to the six elements discussed above, anomalous beryllium in the amount of 30 ppm was detected in one sample from the Jabal al Habla area (pl.1). Beryllium in other samples is less than 3 ppm. Lanthanum is in anomalous amounts in a few samples from Jabal Salma, Aban al Asmar, and Aban al Ahmar. The background for lanthanum at Jabal Salma and Aban al Asmar is 30 ppm, and the highest values for lanthanum are 100 and 150 ppm. At Aban al Ahmar one sample with 100 ppm lanthanum is from a wadi that drains a granite stock. The background for lanthanum in samples from the Aban al Ahmar area is less than 20 ppm. The higher lanthanum values in the Wadi ar Rimah quadrangle are definitely related to granitic rocks. Yttrium also is in slightly higher amounts in the granites.

Detrital magnetite and heavy-mineral concentrates

Histograms showing the distribution of copper, zinc, and molybdenum in samples of detrital magnetite and heavy-mineral concentrates are presented in figure 3.

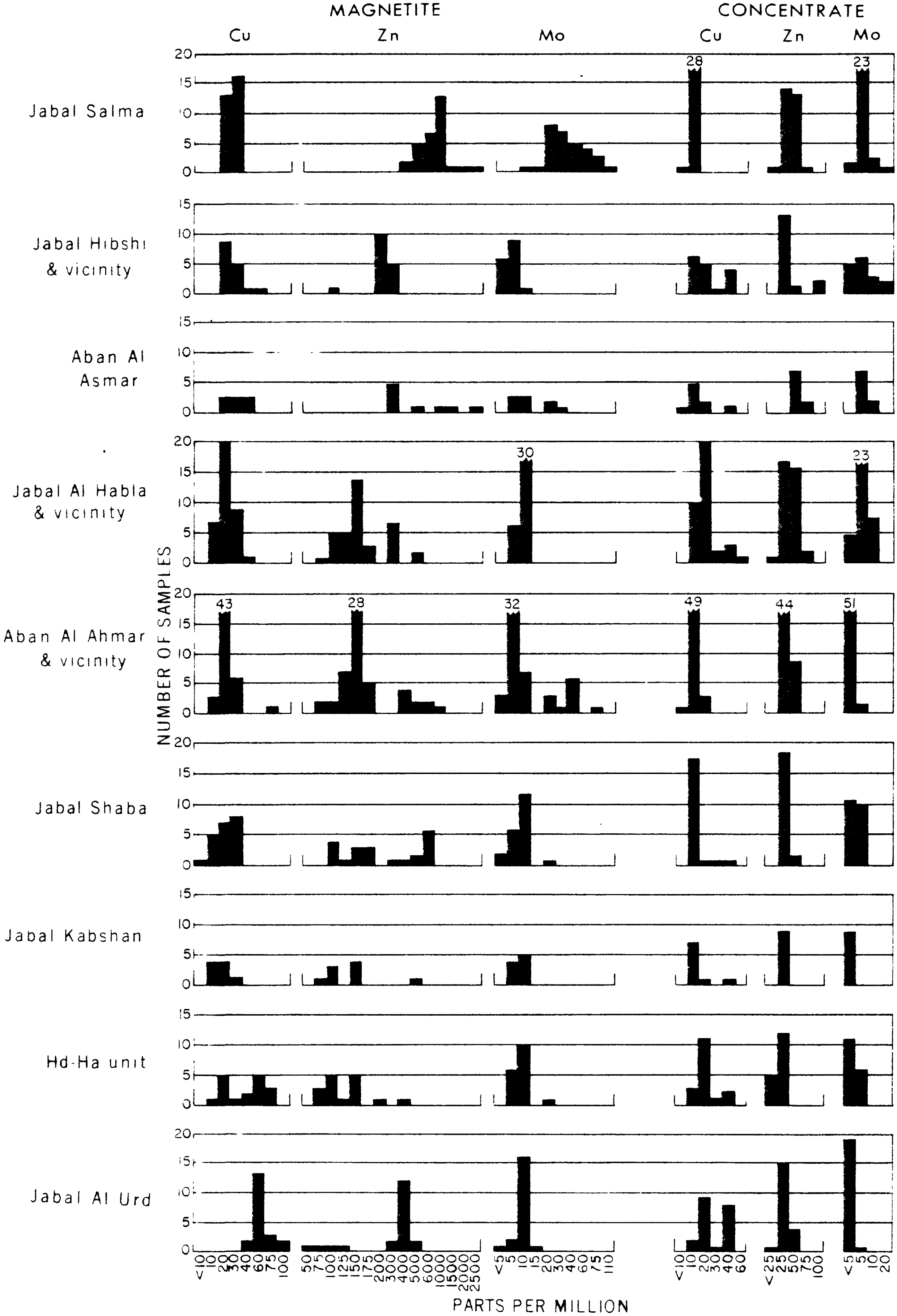

Figure 3. Histograms showing distribution of copper, zinc, and molybdenum in samples of detrital magnetite and heavy-mineral concentrates

Copper:-- Copper in detrital magnetite is slightly higher than copper in heavy-mineral concentrates throughout the area. The norm for copper in magnetite is between 20 and 30 ppm for most major sample localities, and in heavy-mineral concentrates it is between 10 and 20 ppm. Values for copper may be slightly lower in granitic rocks than in the graywackes or their associated rocks. Values for copper in magnetite in the mafic igneous rocks, as seen in the histogram for the Halaban, are clearly higher, though the distribution of determinations for copper is bimodal. The schistose rocks of Jabal al Urd have the highest norm for copper in detrital magnetite, 60 ppm, and the highest copper content, 100 ppm. Copper in the heavy-mineral concentrates from this locality shows a bimodal distribution, the second peak representing values of 40 ppm copper.

Zinc:-- There is a much greater spread in values for zinc in detrital magnetite than in values for zinc in heavy-mineral concentrates. The norm for zinc in magnetite ranges from 150 ppm to as much as 1000 ppm, whereas in heavy-mineral concentrates, it is 25 ppm in all major sample areas except Aban al Asmar, where the norm for zinc in heavy-mineral concentrates is 50 ppm. The zinc content of the heavy-mineral concentrates, therefore, varies only slightly throughout the quadrangle and appears to be of little significance. Two samples of concentrate from Jabal Hibshi and vicinity contain 100 ppm zinc.

The zinc content of detrital magnetite is of much more significance because of the wider distribution of values in samples from most of the area. The distribution of zinc determinations is bimodal or nearly so at a few localities such as that of the Halaban Formation. The wider spread in values for zinc at localities such as Aban al Ahmar and Jabal Shaba probably reflect in part the heterogeneity of the rock units underlying these areas. The zinc values for Jabal Salma and Jabal Hibshi and vicinity, two localities which are underlain by homogenous rock units, have a relatively smaller distribution. The separate grouping of higher values at both Aban al Ahmar and Jabal Shaba represent samples of detrital magnetite collected from wadis draining granitic areas.

In general, it can be stated that detrital magnetite derived from the granitic rocks is higher in zinc than that derived from other rocks. Samples of detrital magnetite from Jabal Salma and Aban al Asmar have the highest zinc content of any collected in the quadrangle, namely 2500 ppm, which is considered to be an anomalous amount, especially at Aban al Asmar where the background for zinc in detrital magnetite is 300 ppm. The schistose rocks of Jabal al Urd, as a whole, have a relatively high background for zinc, the norm for samples collected from this area being 400 ppm.

Molybdenum:-- Molybdenum likewise is better represented in the detrital magnetite than in the heavy-mineral concentrate, and its distribution somewhat parallels that of zinc. Values for molybdenum in heavy-mineral concentrates show virtually no spread, the norm for at least five of the major sample localities is less than 5 ppm. The norm for the other areas is only 5 ppm molybdenum. The values for samples of concentrate representing wadi sediment from Jabal Hibshi and vicinity show a slightly better distribution than the values of samples from the other areas, and two of these samples contain 20 ppm molybdenum in the heavy-mineral concentrate, the highest value in the quadrangle. Concentrates from Jabal al Urd appear to be most deficient in molybdenum, and concentrates from Jabal al Habla and vicinity appear to be richest in molybdenum with at least eight samples containing 10 ppm. On the other hand, detrital magnetite from Jabal al Habla and vicinity is poorer in molybdenum.

The norms for molybdenum in detrital magnetite from all major sample localities except Jabal Salma are between 5 and 10 ppm. The norm for Jabal Salma is 20 ppm molybdenum. As in the case of zinc, detrital magnetite collected from granitic areas, especially younger granites, has the highest molybdenum content. The isolated grouping of higher molybdenum values in the histogram for Aban al Ahmar for instance, represents samples of detrital magnetite collected from wadis draining granite bodies. The highest amounts of molybdenum (110 ppm) are in samples from Jabal Salma.

Tungsten:-- Tungsten was determined only in the heavy-mineral concentrates from wadi sediment. In all but a few samples, tungsten was less than the minimum detectable amount. Values of 10 ppm or greater are plotted on plate 1. Of the samples plotted, nine contain 10 ppm tungsten, two contain 20 ppm, one has 40 ppm, two have 80 ppm, one has 160 ppm, and one contain 240 ppm tungsten. The sample with 240 ppm tungsten is from the northern part of Jabal Salma. The sample with 160 ppm is from a wadi in Halaban rocks near Jabal Minya that drains the area containing the Minya South mine (lat 24°59'N.; long 43° 24'E.). This mine was rather insignificant and is not included in the section on mineral deposits. Numerous barren veins of milky white quartz are on the slopes of Jabal Minya. Scheelite was not observed on any pieces of quartz examined under ultra-violet light. It is interesting to note that the molybdenum content of the concentrate is no higher than 5 ppm, which is the amount contained by at least one third of the samples collected in the Halaban rocks. Both the absence of scheelite in the samples of vein material examined and the relatively low molybdenum content of the concentrate suggests that the tungsten may be contained in wolframite. The high values for tungsten in the other samples of concentrate were likewise accompanied by values of 5 ppm or less molybdenum, except for two samples containing 20 to 80 ppm tungsten for which the molybdenum content was 10 ppm.

The only place in the Wadi ar Rimah quadrangle where tungsten-bearing minerals have been identified is in the El Koom-Ashumta district (Ankary, 1965a; 1965b). One sample of heavy-mineral concentrate from a wadi close to one of the tungsten-bearing veins contained as much as 1200 ppm tungsten and 30 ppm molybdenum. Scheelite as well as wolframite is in this vein. Concentrates of other samples of wadi sediment in the vicinity of the veins have a tungsten content ranging between 80 ppm and 800 ppm, with the majority having 240 ppm tungsten. The molybdenum content ranged between 10 and 30 ppm. In these samples there was no direct relation between the molybdenum and tungsten contents. As a matter of fact, the sample containing 800 ppm tungsten had only 15 ppm molybdenum, whereas one of the samples having 240 ppm tungsten had as much as 30 ppm molybdenum.

MINERAL DEPOSITS

The known mineral occurrences in the Wadi ar Rimah quadrangle are restricted to ancient mines and prospects. With the exception of the Ad Dawadami area and a few other localities, most of these mines are in the western one third of the quadrangle between lat 24°N. and 26°30'N. and long 42°E. and 43°E. Ancient mines were accurately located on 1:60,000 aerial photographs, and their locations transferred to 1:100,000-scale photo mosaics, and subsequently plotted on the 1:500,000-scale map of the quadrangle (pl.1). These mines and their locations are listed in alphabetical order in table 2. Locations of mines in the

Ad Dawadami area are from Theobald (19~~66~~70b) and unpublished report by Quinn. Locations of mines south of Jabal al Habla and west of the Nafud al Urayk are from ~~an~~ unpublished ~~report~~ data by Hummel and Ankary.

The mines discussed in this report are referred to districts, named after either a major village in the area or a prominent landmark or physiographic feature (pl.1). In addition to the districts of this report, mines located in the south-western corner of the quadrangle are referred to the Akliyah district and the Al Hasan district (C. L. Hummel, oral commun., 1966). The Akliyah district includes the Arahiyah and Derahn mines as well as the Akliyah mine.

Table 2. Mines in the Wadi ar Rimah quadrangle.

Name of mine	Location	
	North latitude	East longitude
Abdt	$24^{\circ}20'$	$42^{\circ}10'$
Abrack Sawfan	$25^{\circ}01'$ - $25^{\circ}03'$	$42^{\circ}03'$
Afra	$25^{\circ}51'$	$42^{\circ}10'$
Agob	$26^{\circ}01'$	$42^{\circ}06'$
Akliyah	$24^{\circ}11'$	$42^{\circ}37'$
Amayir al Madan	$25^{\circ}59'$ - $26^{\circ}00'$	$42^{\circ}05'$
Arahiyah North	$24^{\circ}18'$	$42^{\circ}32'$
Arahiyah South	$24^{\circ}17'$	$42^{\circ}33'$
Ardoniyah North	$24^{\circ}23'$	$44^{\circ}40'$
Ardoniyah South	$24^{\circ}22'$	$44^{\circ}39'$

Table 2. Mines in the Wadi ar Rimah quadrangle (cont'd).

Name of mine	Location	
	North latitude	East latitude
Ashumta	24°49'	42°18'
Bede El Gemala	25°09'	42°12'
Bejadi North	24°18'	43°45'
Bejadi South	24°17'	43°46'
Boharah	24°33'	42°15'
Derahn	24°14'	42°34'
Gerthemi	26°30'	42°49'
Ghinaymawat North	26°14'	42°40'
Ghinaymawat South	26°12'	42°40'
Habla North	25°33'	42°15'
Habla South	25°32'	42°15'
Habla East	25°33'	42°20'
Halee	24°47'	43°29'
Hamrurah	24°22'	44°23'
Hasan North	24°17'	42°55'-42°56'
Hasan South	24°16'	42°55'
Hebairiah	26°18'	42°28'
Jarrar	25°23'	42°48'
Jerayer	26°07'	42°50'

Table 2. Mines in the Wadi ar Rimah quadrangle (cont'd).

Neme of mine	Location	
	North latitude	East longitude
Jurayyir North	26°09'	42°32'
Jurayyir South	26°02'	42°35'
Khidar	26°16'	42°10'
Koom	24°49'	42°03'-42°07'
	24°50'	42°04'-42°09'
Kowaifer	25°50'	43°02'
Laym	24°56'	42°59'
	24°55'	42°58'
Magawgi	25°16'	42°39'
Meshaheed	26°11'	42°23'
Minya North	25°01'	43°22'
Minya South	24°59'	43°24'
Qunnah North	24°46'	43°05'
Qunnah South	24°44'	43°05'
Rudahat	24°22'	44°19'
Samirah	26°31'	42°09'
Samrah	24°21'	44°20'
Samrah East	24°22'	44°22'
Samrah Thorayh North	24°15'	43°46'

Table 2. Mines in the Wadi ar Rimah quadrangle (cont'd).

Name of mine	Location	
	North latitude	East longitude
Samrah Thorayh South	24°14'	43°45'
Shaba um Safih	24°49'	42°41'
Shaib al Jurayyir	25°49'	42°45'
Shiaila	26°14'	42°42'
Sidriyah	24°31'	44°19'
Umjerfan	25°35'	42°46'
Um Urgabah	24°21'	44°20'
Wagt	26°05'	42°50'

The mines of the Ad Dawadami district, namely those south of the village of Ad Dawadami, are discussed in detail by Quinn (unpublished ~~report~~ data) and by Theobald (19~~66~~70b). The mines and mineral occurrences south of Jabal al Habla to lat 24°00'N. and west of the Nafud al Urayk are discussed by Hummel, Ankary, and Hakim (19~~66~~70c) ~~and in an unpublished report by Hummel and~~ Ankary.

Samples of various types, though chiefly vein quartz, are from several of the ancient mines and a few of the more promising mineralized veins. The fire assay for gold and silver, and chemical analysis for copper, zinc, and lead for the samples are given in table 3. Only one vein that was sampled proved to be of even remote significance and it

Table 3. Fire assay and analyses for gold, silver, copper, zinc, and lead in selected samples from mineral districts in the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia. Analyses by Sayyad Matoug Sahijri, Ministry of Petroleum and Mineral Resources.

District, name and reference[1]	Type of mine	Sample Kind	Sample Number	Oz/ton Gold	Oz/ton Silver	Percent Copper	Percent Zinc	Percent Lead	Remarks
Ad Dawadami									
Samrah	Ag	-	-	-	-	-	-	-	
Bogue[2]	-	Tailings		-	12.31	-	-	-	
		Veins		-	3.45	-	-	-	
Quinn[3]		Tailings	-	trace	9.63	0.10	2.02	1.57	Average of 14 samples
U.S.G.S.		Core, vein	29111-C	0.1	37.69	0.2	9.6	5.1	
			29111-C	0.04	42.75	0.4	3.45	7.55	
			29112-C	trace	4.00	trace	2.9	2.85	
			29112-C	trace	2.30	0.10	2.95	4.05	
			29113-C	0.5	139.49	0.4	8.25	38.4	
			29113-C	0.34	120.05	1.0	8.35	51.35	
Umm Urgabah	Ag	Tailings	-	-	5.18	-	-	-	Weighted average of 16 samples
Samrah-Umm Urgabah area	Ag	Slag	-	trace	1.42	0.16	8.49	7.26	
Ar Rudahat	Ag	Tailings	-	-	3.24	-	-	-	Weighted average of 15 samples
Humrurah	Ag	Tailings	-	trace	1.12	-	-	-	
Sidriyah	Ag	Tailings	-	trace	3.41	-	-	-	Average of 7 samples
Bogue[2]		Veins	-	trace	7.59	-	-	-	Average of 5 samples
Ardoniyah South	?	Quartz w/hematite	21194	trace	nil	0.03	0.015	0.03	
Al Hamjah									
Bejadi 24°18'N.X 43°45'E.	?	Milky quartz w/ hematite	21133	0.02	0.04	0.1	0.02	0.1	Northwest vein
24°16'N.X 43°49'E.		Smoky quartz	21135	0.11	nil	0.5	0.02	0.1	
Dariyah									
Qunnah N.	Au	Quartz	21033	0.43	0.10	0.03	0.02	0.2	With pyrite
Qunnah S.	Au	Quartz	21032	1.60	0.78	0.35	0.15	0.9	With hematite
Koom-Ashumta									
El Koom Quinn[3]	Au	Quartz	P1498-1541	0.14	-	-	-	-	Average of 8 samples
Ashumta Quinn[3]	Au	Quartz	P1743-1745	0.40	-	-	-	-	Average of 3 grab samples mill pile
			P1746	0.10	-	-	-	-	Grab of vein material
			1747	0.05	-	-	-	-	Grab of slag pile
Al Jurdhawiya									
Abrak Shawfan	Au	Milky quartz	21041	0.11	nil	0.02	0.015	0.1	Grab sample from dump
Bede El Gamala	Au, Ag	Quartz	6976A	0.10	5.84	0.1	0.2	1.6	Grab from dump
		Slag	6976B	0.06	0.53	0.45	0.2	1.5	Grab from dump
Maqawqi'	Au	Pink quartz	6959A	0.11	0.09	0.2	0.01	0.1	Grab from area of vein No.1
	Au	Pink quartz	6959B	0.14	1.17	0.15	0.005	0.1	Grab from area of veins No.2 and 3
Jarrar	Au	Gray quartz	6896A	2.32	2.11	0.1	0.01	0.25	Grab from dump with pyrite
		Gray quartz	6896B	0.12	0.09	0.1	0.005	0.25	Grab from dump with pyrite
		Quartz	6896C	0.02	0.26	0.1	0.015	0.1	Pink to gray w/hematite and pyrite
		Gray quartz	6896D	0.63	nil	0.2	0.01	0.1	With pyrite
Umjerfan	Au	Gray quartz	6880B	0.09	0.29	trace	0.005	0.2	
		Milky quartz	6880C	0.6	0.58	0.1	0.005	0.2	With pyrite
		Mixture	6880D	0.33	0.49	trace	0.005	0.25	Quartz, stibnite, limonite and hematite
		Smoky quartz	6880E	0.88	0.36	trace	0.005	0.25	

Footnote at end of table

Table 3. Fire assay and analyses for gold, silver, copper, zinc, and lead in selected samples from mineral districts in the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia. Analyses by Sayyad Matoug Bahijri Ministry of Petroleum and Mineral Resources. (Cont'd).

District, name and reference[1]	Type of mine	Sample		Oz/ton		Percent			Remarks
		Kind	Number	Gold	Silver	Copper	Zinc	Lead	
Al Habla	Au								
Dirom[4]		Quartz	-	0.312	-	-	-	-	Grab from dumps; Av.59 samples
Shaffner[5]		Quartz	-	0.176	-	-	-	-	Grab from dumps; Av.26 samples
Al Habla E. 25°33'N.X 42°20'E.	Au	Quartz w/ pyrite	6837	1.43	0.06	0.1	0.01	-	Grab from dump
25°30'N.X 42°04'E.		Quartz w/ pyrite	6805	nil	0.16	trace	0.005	0.1	Grab from vein
Al Fawwarah									
Sha'ib al	Au	Quartz	6716A	0.06	0.24	0.1	0.005	0.1	Grab from dump
Jurayyir		Slag	6716B	nil	0.24	0.25	0.005	0.45	Grab from dump
Waqt	Au	Stibnite/ quartz	6084	2.79	0.08	trace	0.01	0.2	Grab from dump
Ghinaymawat South	Au	Quartz	6671A	0.06	0.62	0.1	0.01	0.15	
Meshaheed	Au	Quartz	6096	0.04	0.43	1.0?	0.02	0.1	Grab from dump
Hebairiah	Au	Pk.Quartz	6667A	0.02	0.64	0.1	0.005	0.1	Grab from dump
		Slag(?)	6667B	0.16	0.93	0.25	0.02	1.15	Grab from dump
Khidar	Au?	Slag	6672	trace	0.39	trace	0.005	0.1	Grab from dump
Agob-Amayer al Madan	Au	Quartz	-	0.09	-	-	-	-	Av. of 17 samples from dumps
Schaffner[5]		Tailings	-	0.07	-	-	-	-	Av. of 11 Test hole samples
		Vein	-	0.04	-	-	-	-	Av. of 12 cut samples of veins
Samirah	Au	Gray quartz	6572	0.24	nil	0.1	0.03	0.1	Grab from dumps

1, All samples were collected by U.S.G.S. unless otherwise indicated.

2. Unpub. data, R. G. Bogue, 1954
3. Unpub. data, H. A. Quinn, 1963
4. Unpub. data, D. F. Schaffner, 1956
5. Unpub. data, D. F. Schaffner, 1956

is in the Al Hamjah district. Assay data for the other veins sampled are not included because the results were mostly negative with respect to the elements for which the samples were analyzed. Of all the districts visited by either this writer or other workers, the Ad Dawadami district is by far the most important and perhaps the only one which mertis an intensive and extensive mapping and drilling program. Core drilling in one of the mines (Samrah) has shown there is the possibility of a high lead-silver potential in the district (Kiilsgaard, 19~~68~~70). Moreover, the district is the most accessible of any of those of any consequence in the quadrangle because it is crossed by the Darb al Hijaz which is the major artery linking Jiddah with Ar Riyad.

No visible mineral occurrences of any significance were seen during the reconnaissance of the Wadi ar Rimah quadrangle, other than a few flakes of gold and pieces of stibnite on some of the mine dumps. Scheelite and wolframite were reported by Abdulla Ankary (1965a; 1965b) of the Ministry of Petroleum and Mineral Resources in the El Koom-Ashumta district and localities south of there. Geochemical data show that a few of the samples of wadi sediment, magnetite, and heavy-mineral concentrate contain anomalous amounts of some elements, such as beryllium, lead, zinc, and tungsten (pl.1).

Ad Dawadami district

The mineral occurrences in the Ad Dawadami mining district are discribed by Bogue and by Quinn (unpub. data) ~~unpublished reports by Bogue and by Quinn,~~ and in a published report by Theobald (19~~65~~70a, 19~~66~~70b). Quinn reports 40 mines in the district. Most mines are in easterly and northeasterly trending silicified and brecciated fault zones that are locally mineralized. The rocks underlying the area range in composition from gabbro to pegmatite and dacite (Theobald, 19~~66~~70b). The mafic plutonic rocks are generally older, and the more felsic dike types are younger. Ore in the district is chiefly white to gray quartz containing pyrite, chalcopyrite, sphalerite, galena, hematite, magnetite, tetrahedrite, and possibly argentite. The quartz is confined to parts of the silicified fault zones that were fractured and brecciated following the introduction of an earlier, relatively barren quartz (Bogue, unpublished data report). The main ore shoots, however, appear at terminations, bends, or intersections of the fault zones (Theobald, 19~~65~~70a), and the principal control for mineralization along preferred fracture sets appears to have been 'structural knots' produced at the intersection of several divergent fractures (Theobald, 19~~66~~70b). The ore minerals were deposited in open fractures to which the mineralizing solutions had access, adjacent to sealed fractures which restricted the movement of these solutions. Alteration products, such as chlorite and especially serpentine, which are easily recognizable and are intimately associated with metallization, commonly are in or near veins in the Ad Dawadami district (Bogue, unpublished data ~~report~~; Theobald, 19~~66~~70b).

The mines were probably worked mostly for silver. Samples taken from tailings at the Samrah mine contain as much as 13.36 oz silver per ton (Quinn, unpublished ~~report~~ data) and a core sample, representing the principal vein, assayed as high as 139.49 oz silver per ton. High values in silver are commonly accompanied by high values in lead and zinc. The same core sample that gave the rich assay for silver, contained as much as 51.35 per cent lead and 8.35 percent zinc. The lowest silver content of samples of this core was 2.80 oz per ton which is not much less than the silver content of the tailings and veins exposed in the workings. Bogue (unpublished ~~report~~ data) states that the samples from the workings do not truly represent the ore mined by the ancients, because such samples probably are collected from parts of the veins apparently considered by the ancients to be of too low grade to be mined. It is also generally believed (Bogue, unpublished ~~report~~ data; Theobald, 19~~66~~70b) that the ancients confined their operations only to the oxidized parts of veins where the ore was enriched and could be recovered more easily, and that the primary ore at lower depths was virtually untouched.

Samrah mine:-- The Samrah mine, lat 24°21'N; long 44°20'E., has been described in detail by Bogue (unpublished ~~report~~ data), Quinn (unpublished ~~report~~ data), Theobald (19~~65~~70a; 19~~66~~70b), and Kiilsgaard (19~~68~~70). Work by Kiilsgaard (ibid) summarized most earlier work and thorough economic evaluation of the mine. The workings are aligned N.70°E. and extend for 425 meters on a silicified and mineralized fault zone (Bogue, unpublished ~~report~~ data). They include two large open cuts up to 15 meters deep, numerous stopes, some 20 to 30 meters deep, and raises, trenches, and pits. The workings have been partly filled with debris and their original depths are not known.

The faults that are occupied by the ore-bearing veins of silicified breccia and quartz strike between N.60°E. and S.80°E. and generally dip steeply to the south, though some are vertical (Quinn, unpublished rep~~ort)~~. The ore minerals are confined to the faults and adjacent fractures, and there is no widespread dissemination of ore minerals in the rocks away from the fault zone (Bogue, unpublished ~~report~~ data). The country rock in the immediate vicinity of the vein is chiefly grano-diorite and granite.

The ore of the workings is mostly white to gray quartz containing pyrite, chalcopyrite, sphalerite, galena, hematite, magnetite, and possibly argentite, and is confined to the parts of the silicified fault zone that were brecciated following the introduction of an earlier, relatively barren quartz (Bogue unpublished ~~repo~~rt). A suite of minerals, including magnetite, pyrite, sphalerite, galena, tetrahedrite, and chalcopyrite, has been identified by Louis Gonzalez (oral commun., 1966) in a core from one of the holes drilled in the Samrah mine. The rocks penetrated by the drill were identified as diorite, granodiorite, and red granite (H.D. Horn, written commun., 1965). The major zone of mineralization is mostly breccia. Four mineralized vein systems were encountered in this hole before the principal vein was intersected; however, these were too thin or too lean to be of economic interest (P.K. Theobald, Jr., written commun., 1966). The main vein, except for a 1.5 meter interval of serpentine and serpentinized mylonite, is continuously mineralized for some 15 meters. Within the 15 meters of mineralized vein there is an interval of 4.5 meters which is of economic significance. The 4.5 meters interval contains a 1.5 meters section of massive sulfide of commercial grade. Assay data samples collected from the 1.5 meters section of massive sulfide along with the data of Bogue and Quinn is given in table 3. Subsequent drill holes have intersected the same mineralized fault zone, and the mineralization was found to range from the suite including abundant sphalerite and galena to that including only pyrite.

The tailings of the Samrah mine are estimated by Quinn to be in axcess of 30,000 tons and are themselves rich in lead, zinc, and silver.

Mines in the vicinity of Samrah mine:-- Several mines are located in the vicinity of Samrah mine. They are only briefly mentioned here because their descriptions have been adequately covered in unpublished reports by Bogue and a published report by Theobald 20a (1965). Among these mines are Umm Urgabah and Ar Rudahat. They also have deep workings and extensive piles of waste rock.

The geology and ore deposits at Umm Urgabah (lat $24^{\circ}21'$N; long $44^{\circ}20'$E.) located about 1.5 kilometer southwest of the Samrah mine, are similar to the Samrah deposit. The workings at Umm Urgabah are in a silicified and locally mineralized fault zone striking N.70° to 80°E. and dipping 60° to 70° to the north. The workings extend along the strike for about 750 meters.

The workings at Ar Rudahat (lat $24^{\circ}22'$N; long $44^{\circ}19'$E.) located about 3 kilometers northwest of the Samrah mine, include pits and trenches that are distributed along a mineralized fault zone for about 600 meters. The fault zone which is silicified and locally mineralized, strikes N.80° to 85°W., and dips 70° to 85° north. According to Bogue (unpublished ~~report~~ data) the ore at Ar Rudahat contains more copper minerals than the other mines in the area.

The Ar Rudahat mines are near the basic ring complex described in detail by Theobald (19~~66~~70), which may explain the high copper.

<u>Sidriyah mine</u>:-- The Sidriyah mine (lat $24^{\circ}21'$N; long $44^{\circ}19'$E.) is about 2 kilometers northwest of Ad Dawadami. The workings are located along a silicified and brecciated fault zone which, in general, strikes N.55°E. and is partially mineralized. Bogue states that the major silicification in the fault zone was caused by introduction of white quartz containing sparse hematite and pyrite. The ore minerals, which were introduced later, along with a gray quartz, include chalcopyrite, sphalerite, galena, and hematite. The ore-bearing quartz was

introduced only in the parts of the fault zone that were fractured and brecciated following silicification.

Small amounts of chlorite and serpentine are with the ore minerals, and minute crystals of argentite, magnetite, and molybdenite are associated with the chlorite. In the weathered parts of the veins and outcrops, the sulphides are altered and small amounts of chrysocolla, malachite, chalcocite, and smithsonite are present along with appreciable limonite. The metal content of the weathered parts of the veins is probably greater than that of the unweathered parts because of oxidization and supergene enrichment shown by the slight increase in the amount of copper in the form of secondary chalcocite. The ancient miners probably confined their operations to this part only.

Assay data is listed in table 3 for the gold and silver in samples collected by Bogue from tailing dumps and exposed veins.

Ardoniyah mines:-- The mines at Jabal Ardoniyah (lat 24°23'N; long 44°40E.) are over 20 kilometers to the east of the mines in the Ad Dawadami district; however, for the purpose of this report they are included in the same mining district.

The Ardoniyah mines are in fine-grained biotite schist that appears to have been assimilated by granite along its foliation which strikes N.15°E. and dips 60°SE. (Mytton, 1967,70). The schist is partly silicified and in places is intruded by lenses of gneissic or schistose granite containing irregular, paper-thin layers of biotite. Many prominent sills of aplite or fine-grained aplitic granite are along the strike of the foliation. The mines are located in the areas where the greatest number of sills are present.

One mine at lat 24°22'N; long 44°39'E., about 2 kilometers south of the other mines, cuts across a series of small quartz veins. The veins are in a hard, silicified, quartz-biotite schist striking N.15°E. and dipping 60°SE. The veins range in width from 5 to 30 centimeters and have the same attitude as the foliation of the schist. The quartz is stained with hematite but is otherwise apparently unmineralized. Assay data for samples of quartz from the veins is given in table 3. No silver is present and there is only a trace of gold, showing that the unmined parts of the veins are barren and confirming the supposition that the ancient workers took as little barren vein material as possible.

The mine extends for 71 meters with only one third of its length exposed. An open cut in the western third of the workings is 33 meters long and contains four stopes that are about 6 meters deep. The stopes are in parts of the cut where veins are most numerous. The width of the open cut ranges from about 60 centimeters to 1 meter along most of its length, but it is as much as 3 meters wide at its western end. Areas of the country rock have been assimilated by granite along the foliation where the schist consists of alternating layers of quartz and biotite penetrated by lenses of granite porphyry containing large crystals of white feldspar in a dark-brown groundmass of fine-grained quartz, feldspar, and biotite. The granite, in turn, is cut by small dikes of apatite.

Al Hamjah district

Several mine workings and prospects are located in an area underlain largely by dioritic rocks just west of the village of Al Hamjah which is on the old section of the Ar Riyad-Jiddah road or Darb al Hijaz. The new highway is located north of Al Hamjah and skirts the mines on the north. The Al Hamjah district is bounded on the east and west by two major faults which belong to the principal fault zone of the Wadi ar Rimah quadrangle and which more or less parallel the longer Najd fault zone located to the south of the quadrangle. The fault to the east trends about N.35°W., and the one to the west trends about N.20°W. The workings are located about midway between the two faults. About kilometers north of Al Hamjah the two faults bend to the west and strike N.50° to 60°W. This bend is even more apparent on the 1:2,000,000-scale geologic map of the Arabian Peninsula.

No previous reports describe the mines in the Al Hamjah district. Workings located on and near the old road at lat 24°14'N; long 42° 54'E. just east of the prominent granite knobs known locally as Samrah Thorayh, are referred to here by that name. Openings located 4 kilometers north of the Samrah Thorayh mine are referred to here as the Bejadi mine.

Samrah Thorayh mine:-- Just off the old section of the Darb al Hijaz about 60 meters to the south there are four or five small workings completely filled with debris (lat 24°14'N; long 43°45'E.). Vein quartz on the dumps is fractured and coated with hematite. Malachite and pyrite in small amounts are also present. The dominant rock type in the area is diorite; however, it is locally intruded by fine-grained granite grading to felsite which may represent the wall rock because pieces of this granite commonly are in the dumps.

North of the road, at lat 24°15'N; long 43°46'E., a few workings are on a quartz vein about 90 meters long and 60 centimeters wide that strikes N.10°E. The quartz is stained with hematite, but is essentially barren. Felsite dikes are common in the area. Other small prospects in hematite-stained quartz are in the area, but base-metal sulfide minerals and gold were not seen in the veins.

Bejadi mine:-- The workings of the Bejadi mine are in two veins about 1 kilometer apart. One is located at lat 24°17'N; long 43°46'E. and trends north; the other is located at lat 24°18'N; long 43°45'E. and trends northwest. The veins are well exposed and consist of milky fractured quartz with some hematite staining, and sparse malachi and pyrite. The veins are essentially unmineralized as shown by the analyses of samples from the northwesterly trending vein (table 3). The outcrops in the vicinity of the veins represent a complex of diorite, granodiorite, and, possibly, graywacke.

Mineralized vein:-- Due north of Al Hamjah at lat 24°16'N; long 43°49'E. is a vein of fractured milky and smoky quartz which is 75 to 100 meters long, 60 centimeters to 1 meter wide, and strikes N.67°W. The vein is in slightly sheared chloritic aplitic granite(?) in which the foliation strikes N.30°E. The quartz contains fracture planes that are parallel to the strike of the vein.

The vein contains, in addition to hematite stains, malachite, pyrite and possibly chalcocite. Mineralization is associated with parts of the smoky quartz vein. Assays of samples from this vein (table 3) show higher values of gold and copper than those of the samples from the Bejadi mine.

Dariyah district

The mineral deposits of the Dariyah district have been discussed briefly in unpublished reports by A. Fakhry. Deposits investigated during the present mineral reconnaissance are located at Jabal Shaba, Jabal Qunnah, and Jabal Laym. The workings are partly to completely filled with sand and debris; however, dump material suggests the workings are in quartz veins which, according to the alignment of the pits, commonly strike northwest. The vein material in the dumps is mostly ribbon-type quartz in which the fractures are filled with hematite. This quartz may not contain gold, but is often associated with it.

The fractures filled with vein material at Jabal Qunnah are probably subsidiary fractures of the principal fault zone of the quadrangle which is just northeast of the mines. Jabal Laym is located on the fault zone. The trend of the fault is about N.60°W. The rocks in and near the fault zone are noticeably sheared. Most mines in the district are in the vicinity of the major fault zone. Only one mine was found at Jabal Shaba, some distance from the fault zone. The workings at Jabal Laym are nearly buried by windblown sand and little information could be obtained from them.

<u>Qunnah mines</u>:-- The mines at Jabal Qunnah, referred to previously in unpublished reports by A. Fakhry, as Ginnaina and Ginna, are called Qunnah North and Qunnah South in this report.

Qunnah North, located at lat 24°46'N; long 42°35'E., has at least 30 workings distributed over a distance of about 450 meters in a northerly direction. Most workings, especially the largest ones, are clustered together. The workings have a general alignment of about N.40°W. All workings are completely filled and are outlined only by dump material. The largest pit is at least 12 meters across.

Little, if any, vein material is at the mine site. Some fractured, milky quartz with pyrite and specular hematite was found and submitted for fire assay (table 3). The country rock is a dark diorite, some of which is gabbroic to andesitic in composition and texture. Several veins were apparently mined. The mine site is traversed by a road which joins the road between Dariyah and Al Mishash to the north.

Foundations of buildings east of the mine workings indicate the presence of an ancient mine camp. Grinding stones of granite were found nearby.

Qunnah South, lat 24°44'N; long 42°35'E. is about 3.5 kilometers to the south of Qunnah North and is situated on the slopes of Jabal Qunnah. As reflected in the alignment of six workings, the Qunnah South mine apparently consists of one vein about 180 meters long which strikes N.40°W. The mine site is crossed by a road which joins the road between Dariyah and Al Mishah to the north.

The vein material is milky to pink ribbon quartz in which the fractures are filled with hematite. Pyrite in minor amounts is also present. Some pieces of quartz from the dumps are stained with malachite. An assay of this quartz disclosed as much as 1.6 oz/ton gold.

The country rock is green to dark-gray siltstone grading to wacke. Some of the rock is finely laminated, and at the site of the workings it displays a crude schistosity striking N.70°W. One pit strikes N.70°W. and may represent a small subsidiary vein striking in that direction. A prominent easterly trending dike of fine-grained granite is south of the mine. Gray, medium-grained biotite granite intrudes the graywacke and siltstone sequence to the southwest, and some of the sediments have been converted to hornfels. A major dike of rhyolite strikes N.55°W. and extends for several kilometers across both the granite and graywacke.

<u>Shaba um Safih mine</u>:-- The mine referred to as Shab um Safih (lat 24°49'N; long 42°41'E.) is on the northeast flank of Jabal Shaba. The mine has three workings which are partly filled with debris and are aligned N.60°W. Foundations of buildings and fragments of grinding stones are near the mine. The workings are probably on one vein consisting of fractured, milky quartz with hematite and some malachite and associated with pink, fine- to medium-grained granite that shows slickensides on some blocks. The country rock is mostly granite which is gray to red in color, medium- to coarse-grained, and contains biotite and scattered inclusions of black argillite or siltstone (and perhaps fine-grained diorite), possibly representative of rocks intruded by granite, which display abundant malachite and some pyrite. Other rocks in the general area include gabbro, diorite, amphibolite, and graywacke which have been intruded and altered by the granitic rocks. Argillite is highly sheared and changed to phyllite containing lenticular bodies of granite porphyry. Locally the gabbro is converted to diorite or amphibolite adjacent to contacts with the intrusive granite.

A sample of wadi sediment collected about 2 kilometers south of the mine contained as much as 500 ppm lead, the highest amount in any sample collected in the quadrangle. Though the wadi in question does not drain the area of the mine, the presence of this anomalous lead may be of considerable importance with respect to the possible occurrence of other mineral deposits in the immediate area.

El Koom - Ashumta district

The mines of the El Koom-Ashumta district are described by Ankary (1965a; 1965b), Hummel and others (19~~68~~ 70), and in unpublished reports by Quinn. I briefly examined the area south of the village of Al Bajah and west of the Nafud al Urayk as far south as Hadbat Akliyah in a period of 10 days. Geologic mapping and geochemical sampling at a scale of 1:50,000 was performed by Abdullah Ankary of the Ministry of Petroleum and Mineral Resources in the area bounded by lat 24°25'N. and 25°00'N; long 42°00'E. and 42°30'E., and a mineralogical reconnaissance of the area bounded by lat 24°00'N. and 26°30'N. and long 42°00'E. and 42°30'E. was subsequently conducted by C.L. Hummel and A.O. Ankary ~~(unpublished report).~~

<u>El Koom mine</u>:-- The principal mine of the El Koom group, was rediscovered by K.S. Twitchell (unpublished ~~report~~ data) and is located on the southwest side of Jabal El Koom (lat 24°49'N; long 42°03'E.). An open cut 480 meters long follows the trace of a quartz vein 30 to 50 centimeters wide which strikes N.17°E. and dips 10° to the

northwest. The ore supposedly pinches out at both ends of the open cut. Samples collected by D.F. Schaffner and G.L. McGarry, (unpublished ~~report~~ data) from dumps along the southern 400 meters of the open cut averaged 0.14 oz gold per ton. In a plain about 150 meters east of the northern part of the open cut are ruins of buildings and scattered pieces of grinding stones of granite.

The country rock is described by Twtichell ~~in an unpublished report~~ letter as "basic fine-grained diorite". The complex of diorite and andesite at Jabal el Koom and vicinity consists of a variety of rocks including fine-grained basic diorite or amphibolite and andesite which are intruded by a series of monzonites, monzonite porphyries, latites, and adamellites (Mytton, 19~~65b~~70c). Some of the monzonites between El Koom and Jabal Ablan to the north have slightly mineralized veins of quartz and calcite with traces of malachite and pyrite. In the El Koom area a circular body of gray biotite granite contains xenoliths of diorite similar to the diorite-andesite complex that makes up the surrounding hills.

Tungsten-bearing quartz was discovered by Abdullah Ankary in old mine workings (lat 24°50'N; long 42°07'E.) located near the southeast end of the circular body. The veins which contain the tungsten trend about N.70°W. and occupy fractures in dikes as well as in granite (Ankary, 1965a; 1965b). They are 120 to 900 meters long and 30 centimeters to 1 meter wide. The quartz is milky to translucent and stained with hematite.

The tungsten minerals which were identified by Charles E. Thompson of the U.S. Geological Survey as wolframite (ferberite-huebnerite) and scheelite are in the parts of the veins where there are well-developed crystals of quartz. Quartz veins containing scheelite were also found about 100 kilometers south of El Koom at about lat $24^{\circ}07'$N; long $42^{\circ}10'$E.

The concentrate of one sample of wadi sediment collected close to one of the tungsten-bearing quartz veins contained as much as 1200 ppm tungsten. The concentrate of another sample has as much as 800 ppm tungsten, whereas concentrates of samples of wadi sediment collected away from the veins all contained 240 ppm, and one was as low as 160 ppm.

Ashumta mine:-- On the western slope of the northeast ridge of Jabal Ashumta (lat $24^{\circ}51'$N; long $42^{\circ}19'$E.) there is a series of fan-shaped waste-dumps. The alignment of the dumps is N.23°E. and inclined at a gentle angle to the south (Quinn, unpublished ~~report~~ data). From a distance the alignment of dumps appears as a prominent scar on the side of the mountain. The dumps are probably at the entrance to adits that intersect the vein. The line of workings therefore represents the trace of the vein on the west side of the ridge. The strike (N.16°W) and dip (18°SW) of the vein, however, was determined from its trace on the north and east slopes of the ridge near its crest. ~~(Twitchell, unpublished report)~~.

The vein material, as seen in float and on the major dumps at the base of Jabal Ashumta, is essentially a fractured hematitic and limonitic quartz containing mostly pyrite. Some slag is on the dumps. Assay data for grab samples of vein quartz and slag collected by Schaffner and McGarry is given in table 3. Quinn reports that the best gold values are in quartz containing galena.

Graywacke and associated conglomerate, siltstone, and argillite are the dominant rocks at Jabal Ashumta and vicinity (Mytton, 19~~65b~~70). Where the mine is located the graywacke has been converted to hornfels by the intrusion of gray biotite granite. Dikes of porphyritic rhyolite are in the area. Quinn believes the gold may be in quartz veins or stringers in or associated with the rhyolite, because of the abundance of the rhyolite on the waste dumps.

Al Jurdhawiyah district

~~Some of the mines of Al Jurdhawiyah district examined during this investigation were briefly mentioned by A. Fakhry (1941a; 1941b), but~~ no previous reports relate to the mines here referred to as Maqawqi, Jarrar, and Umjerfan. The mineral deposits of the district are the gold-quartz type with gray to milky, hematite-stained quartz associated with malachite and pyrite common in all the veins. Stibnite was found on the dumps of the Umjerfan mine. It is at only one other mining locality in the Wadi ar Rimah quadrangle, and has not been recorded elsewhere in the Arabian Shield.

The rocks underlying the district are chiefly graywacke and conglomerate associated in places with mafic igneous rocks such as andesite porphyry, diorite, or amphibolite, and possibly gabbro which have all been intruded by plutons of granite of different ages. The mining district is bordered on the west by the northerly trending body of dune sand called the Nafud al Urayk. The large wrench-fault which is shown to terminate at Jabal Laym on the 1:500,000-scale geologic map of the Wadi ar Rimah quadrangle (Bramkamp and others, 1963) very likely continues northwestward and beyond the western boundary of the quadrangle. It would therefore bound the district on the south. An extensive body of granite borders the district on the east and Wadi ar Rimah acts as a boundary on the north.

The quartz veins trend generally east to northwest, but a few strike toward the northeast. The veins appear to have filled fractures in granite, or related rocks such as rhyolite and felsite, which have intruded older rock units including graywacke, conglomerate diorite (or amphibolite), and andesite. The diorite seen here and elsewhere in much of the area may actually be amphibolite, similar to that described by Theobald (19~~68~~70b), and may be a product of the alteration of darker, more basic rocks, like gabbro and pyroxenite by the introduction of more felsic rocks of the granitic series.

Abrak Shawfan mine:-- The mines and prospects referred to as Abrak Shawfan are about 7 kilometers south-southwest of Jabal Shawfan, within a kilometer or two of the eastern boundary of the Nafud al Urayk. The mines are scattered over an area of very low relief at least 2 kilometers wide and 3 kilometers long oriented with the long dimension trending north. The major workings are restricted to approximately 4 or 5 alignments trending N.60°W. A sketch map on plate 1 shows the northernmost workings (lat 25°03'N; long 42°03'E.). Assay data for samples of dumps near the workings are given in table 3.

All the workings are filled with silt and sand, but the openings appear to have been in quartz veins, probably to shallow depths of not more than 6 meters, to judge from exposed workings seen elsewhere in the region as at Shaba um Safih previously mentioned. The veins, only 30 to 60 centimeters in thickness, probably have the same strike as the alignments of the buried pits. All the veins appear to be in granite that intruded graywacke; wall rocks are altered, gray, biotite granite and minor graywacke. The vein quartz is milky with hematite- and malachite-filled fractures.

Bede el Gemala mine:-- Bede el Gemala consists of a series of workings located at lat 25°09'N; long 42°12'E. in low-lying hills just east of the main road between the villages of Al Jurdhawiya and Dariyah. The hills are made up of graywacke intruded by gray biotite granite which cuts the graywacke series. Quartz veins occupy fractures in the granite and strike about N.70° to 80°W. Much altered wallrock and breccia is in these fracture zones. Very little mineralization other than limonite and hematite was observed.

Numerous slag piles as well as the remains of old foundations for buildings attest to a fairly large milling operation. This may have been the site for the processing of ore from other mines in the district.

All the veins observed were short, being only a meter or so in length and a few centimeters in width. Assay data for material from Bede el Gemala mine is given in table 3.

<u>Maqawqi mine</u>:-- The Maqawqi mine, lat 25°16'N; long 42°29'E., is located about 7 kilometers northeast of Jabal Maqawqi in a relatively flat area just off the main road between Al Jurdhawiya and Dariyah. The mine consists of one major series of workings and 43 minor ones, the alignment of which are assumed to follow the trend of veins (pl.1). The no 1. vein strikes about N.75°W; veins no.2, 3, and 4 strike about N.80E.; and vein no.5 strikes about N.75°W. The no.1 vein, represented by the major series of workings, is close to 260 meters long. All workings are completely filled.

The vein material is fractured quartz which is pink in color with hematite filling the fractures. Pyrite and malachite are present. The wall rock is gray biotite granite which has been only slightly altered. The country rock is mostly dark graywacke and siltstone much of which has been converted to hornfels. A large body of granite underlies the area northwest of the mine.

A mill site is located between veins no. 1 and no. 2. It included ruined foundations of buildings and grinding stones of granite. Assay data for samples of vein material from the dumps of veins nos. 1, 2, 3 are presented in table 3.

Jarrar mine:-- The Jarrar mine (lat 25°23'N; long 42°48'E.) is located 4 kilometers southwest of the village of Jarrar and 2 kilometers south of the road between Jarrar and Al Jurdhawiyah. The mine consists of workings scattered over an area about 760 meters north-south by 600 meters east-west. The workings are along what appear to be 4 or 5 fairly extensive veins trending about N.20°W. and ranging in length between 150 and 300 meters (pl.1).

In only one or two workings can any veins actually be seen, and these range in width from about 5 to 15 centimeters.

The vein material is a bluish-gray to milky quartz which is fractured and contains hematite in the fractures. In addition, malachite, pyrite, and sparse limonite are present, and traces of gold were seen as minute flakes. Gold in this form was observed in three pieces of quartz from three workings. There appears to have been very little wall rock alteration along any of the veins. Samples collected from four of the workings were submitted for fire assay (table 3). A sample of vein material from the dump by one working contained as much as 2.32 oz gold per ton along with 2.11 oz silver per ton. Visible gold was seen in one piece of quartz from the same dump. No evidence exists of the ancient processing of ore at the site of the workings.

The country rock, which appears to be fine-grained diorite grading to andesite and includes a variety of graywacke, is penetrated by small conical-shaped bodies of gabbro and dike-like bodies of granodiorite. The dike-like bodies of granodiorite also cut the conical-shaped hills of gabbro. Dikes of rhyolite are also present. The country rock is also intruded by small apophyses of granite, and there are patchwork-like areas in the andesite and graywacke that are granitized. From observations elsewhere in the district, the mafic rocks, such as gabbro and andesite porphyry have been interpreted as post-dating the sequence of graywacke and conglomerate which underlies most of the region, but that the mafic rocks are older than the felsic rocks. The relations at the Jarrar mine suggest the possibility that the unit called diorite grading to andesite is actually an alteration product of gabbro caused by the intrusion of granodiorite. The granodiorite itself may be a hybrid product incorporating components of the country rock in the granite.

Umjerfan mine:-- The mine referred to as Umjerfan (lat 25°35'N; long 41°46'E.) consists of over one half-dozen workings located on a flat, featureless plain approximately 3 kilometers northwest of Aban al Alhmar. The general alignment of the workings is about N.20°W. and may represent an extensive vein system (pl.1).

Shorter veins, striking about N.60°E., may cut across the longer one. The intersection of veins would be a likely place for mineral deposits. The workings are completely filled, the only material present being vein quartz and highly altered country rock found on the dumps.

The quartz is blue or smoky to milky in color, and contains limonite, hematite, calcite, and possibly ankerite in the fractures. Pyrite in minute particles is associated with the smoky quartz, and visible gold, also associated with smoky quartz, was observed on one piece where the gold is in very minute flakes. Stibnite, the antimony trisulfide, is commonly found in abundant quantities in fractures and cavities in the quartz. This is the only locality, other than the Waqt mine, where stibnite has been seen in the quadrangle. Stibnite in association with vein quartz and highly altered wall rock was observed in dump material at three workings.

The altered wall rock is purple to ochre in color and highly brecciated and silicified. It is composed of a mixture of limonitic clayey material and gray to milky quartz. Stibnite is also intermixed with the limonitic clayey material.

Fragments of grinding stones, chiefly of granite, were seen at one of the workings.

Assay data for samples from four of the workings is given in table 3. One sample contained 0.88 oz gold per ton.

Al Habla district

The mines of the Al Habla district are south of Jabal al Habla in a relatively flat area that is underlain by sedimentary rocks including graywacke, conglomerate, siltstone, and limestone which have been intruded and slightly altered by a major granite pluton and minor bodies of diorite and gabbro.

The Al Habla mines were investigated by G.A. Dirom of the Saudi Arabian Mining Syndicate in 1946 ~~(unpublished report by Schaffner)~~ and F.K. Kabbani and D.F. Schaffner of the Ministry of Petroleum and Mineral Resources in 1955. No previous reports relate to the mines referred to in this report as Al Habla East.

<u>Al Habla mine</u>:-- The Al Habla mines consists of three sets of workings aligned north-south and covering an area about 3.5 kilometers from north to south and about 0.6 kilometers from east to west. The northernmost of the three sets of workings is located just south of Jabal al Habla at lat 25°33'N; long 42°15'E.; the other two sets are located at lat 25°32'N; long 42°15'E. and are along the same alignment. Both of the mines to the south have nearly a dozen workings distributed over a distance of about 0.3 kilometer.

The workings of all the mines are in quartz veins filling more or less northerly trending fractures in gray biotite granite. The dumps along the workings are small which indicates the workings are shallow.

Schaffner states that they contain no more than 2 tons per linear foot and the proportion of the quartz in the dumps is no more than 10 to 20 percent of the dump material. Quartz observed on the dumps appears to be essentially barren except for minor amounts of pyrite. Assay data for grab samples collected from dumps by both Dirom and Schaffner is given in table 3. Only one quartz vein was found in place by Kabbani and Schaffner after trenching in 12 workings and this assayed only 0.07 oz gold per ton. However, because of the great extent of the workings, Schaffner recommended that nine drill holes be located to intersect the projection of the vein 30 meters below the surface.

Al Habla East mine:-- A series of workings aligned about N.70°W. is located in an area of low relief at lat 25°33'N; long 42°20'E., some 8 kilometers east of the main workings of Al Habla mine and is here referred to as Al Habla East mine. About a half-dozen workings are present as indicated by dumps, and they are interpreted to be in a vein striking N.70°W.

Scattered fragments of vein quartz, highly fractured and filled with limonite, are on the dumps and elsewhere, along with fragments of wall rock. The quartz is milky, and contain sparse pyrite and malachite in addition to the limonite that fills the fractures. Traces of hematite, and possibly magnetite, are present. The wall rock consists of sheared and highly altered siliceous argillaceous material. The country rock is brecciated, dark, dense siltstone that appears to have been baked, probably by emplacement of the same granite that underlies the area of the main workings of Al Habla to the west.

Some hematitic vein quartz is present and it contains minute cubes of pyrite. Some fresh pyrite is in the country rock in the vicinity of the mine. Medium-gray silty to pelitic limestone, striking N.70°W. crops out nearby. The limestone is lenticular, has a blue cast, and has a fetid odor when broken. The outcrop shows weathering typical of carbonate rocks in arid regions.

Foundations of old buildings are present, as well as pieces of grinding stones of granite and one clay pot shard. The foundations are made of gabbro, diabase, and limestone blocks.

Another series of workings about 0.5 kilometer east of the workings described above strikes east. The west workings extend about 150 meters and the east workings reach about 100 meters in length.

Assay data for grab samples of quartz collected from the dumps is given in table 3, and the tenor reached 1.48 oz gold per ton. However, this is not surprising because selected parts of samples collected by Dirom at the main Al Habla workings assayed as high as 1.82 oz per ton (Schaffner, unpublished ~~report~~ data). The average gold content of Dirom's samples, however, was only 0.312 oz per ton, and of those collected by Schaffner, only 0.176 oz per ton.

Al Fawwarah district

The Al Fawwarah district includes a number of mines scattered over a fairly large area widely underlain by the extensive graywacke unit which is common in the district. The graywacke unit consists of a sequence of impure siltstone, wacke, conglomerate, tuffaceous wacke, argillite, and limestone. This unit is intruded by bodies of different types of granite and is cut by dikes of granite, rhyolite, felsite, diorite, and andesite.

The graywacke unit changes facies, and one or more of its representative types may be more common in one part of the district than another. For instance, tuffaceous wacke is commonly between Jabal Qutn and Wadi ar Rimah, whereas impure siltstone, graywacke, and conglomerate are in the vicinity of Jabal ar Raha.

Mineral occurrences are commonly in areas where the graywacke sequence is in close proximity to granite plutons or in areas where it is cut by felsic and mafic dikes.

Sha'ib al Jurayyir mine:-- The Sha'ib al Jurayyir mine (lat 25°19'N; long 42°15'E.) consists of two buried workings, both about 10 meters in length at a major bend in Sha'ib al Jurayyir just north of the road between the village of Aqlat as Suqur and Sobaih. It is about 5 kilometers northwest of the junction of Sha'ib al Jurayyir and Wadi Maraghan. The north working trends N.50°E. and the south working N.35°E. The workings are interpreted here to be in vein quartz in fracture zones in graywacke.

The quartz is the typical ribbon-type variety with limonite and hematite filling the fractures. Two sets of fractures are in the quartz normal to each other. The wall rock is silicified and limonitic. Some slag is at the site of the workings. Assays of both vein quartz and slag are given in table 3.

Waqt and Jerayer mines:-- The Waqt mine (lat 26°05'N; long 42°50'E.) and the Jerayer mine (lat 26°07'N; long 42°50'E.) are located about 6 kilometers northwest of Samra Waqt. The two mines are 4 kilometers apart and can be considered essentially one mining area.

The workings of both mines are completely filled and only a few scattered pieces of vein quartz on the ground give a clue as to the type of material mined. The alignment of workings at the Jerayer mine is about N.40°E.

The quartz is fractured and contains hematite along with some pyrite. At the Waqt mine one piece of quartz with abundant stibnite was found on the ground. An assay of this sample showed it to contain as much 2.79 oz per ton of gold (table 3).

The country rock is graywacke which is in close proximity to a large granitic area to the east. The graywacke is similar to that seen in the Al Fawwarah district, but is black, finer-grained, and denser, and appears to be approaching a hornfels.

Ruins of an ancient mine camp are located at Jerayer. Fragments of stone grinding wheels and a few pieces of slag are present.

Ghinaymawat mines:-- Two mines referred to as Ghinaymawat are located north of Jabal as Silsilah; one at lat 26°12'N; long 42°40'E., the other at lat 26°14;N; long 42°40'E. Both are in graywacke typical of the variety in the Al Fawwarah district, which is green to olive-gray, generally fine-grained with angular fragments of feldspar, quartz, and lithic particles in a chloritic matrix. The mines are in an area of low relief with a slightly undulating surface dissected by dendritic drainage.

The mine located at lat 26°12'N; long 42°40'E. has two alignments of buried workings, one at N.40°W., the other N.40°E. The alignments are interpreted to be mineralized veins that occupy intersecting fractures. A major northerly trending diorite(?) dike is located just west of the mine. The dike has a small unmineralized quartz vein adjacent to it.

The vein material, as seen on the dumps, is fractured quartz containing hematite and limonite. The results of the assay of one sample are given in table 3. The gangue appears to have been quartz and ankerite. A brown, highly altered rock found on the dumps may represent the wall rock.

The mine located at lat 26°14'N; long 42°40'E. has a series of workings aligned N.15°E. which is interpreted here to be the strike of a mineralized vein occupying a fault, as blocks of brown, fractured, tectonic limestone and breccia are on the dumps. The vein material was probably quartz and calcite.

Meshaheed mine:-- The Meshaheed mine (lat 26°11'N; long 42°23'E.) is located about 4 kilometers southwest of the bend in the road between the villages of An Nimriyah and Al Fawwara. The strike of the vein which was mined, estimated from the alignment of the workings, is about N.25°W. Vein material is fractured milky quartz with sparse pyrite. The fractures are filled with hematite and limonite.

The country rock is gray, coarse-grained biotite granite, friable and highly weathered; it is a small intrusive body in graywacke. An extensive area of this same granite is located to the north. A brown, siliceous granite, locally abundant, and which is almost rhyolitic, may be a dike enclosing the vein. A green to yellow soft argillaceous rock containing quartz veinlets may represent highly altered wall rock. This material was found beside one buried pit.

Assay data for the vein quartz is given in table 3.

Hebairiah mine:-- The mine workings referred to as Hebairiah are located just south of the southwest end of Jabal al Muwashsham at lat 26°18'N; long 42°28'E. The workings apparently were in a quartz vein striking about N.50°E. in a sequence of graywacke intruded by granite and diorite that form a prominent hill just north of the mine.

The vein material is fractured quartz with hematite. Heavy dark yellowish-brown slag, which is highly weathered, is present at the mine site. Assay data for both the quartz and slag are given in table 3.

The hill north of the mine is composed of gray biotite granite which is cut by a diorite dike that strikes about N.60°W. Near the contact, the granite has been converted to quartz diorite and granodiorite. The dike has an offshoot which forms a partly eroded sill capping the granite hill. A small diabase dike just north of the mine strikes N.70°E.

Amayer al Madan mines:-- The mines referred to as Amayer al Madan cover an area about 2 kilometers long from northeast to southwest by 1 kilometer long from northwest to southeast. The location of the area is about lat 26°00'N; long 42°05'E. Over 24 northerly trending alignments of workings are in the area and several of them are of considerable extent. All but a few of the workings are filled with sand and debris. A major wadi extends southward through the area of mines and bends to the southeast. The topography of the mine site has slightly more relief than the surrounding countryside which as a whole is flat or slightly undulating. The slightly greater relief may be explained by the presence of numerous veins which would be more resistant to erosion. The alignment of workings form prominent ridges in the area. If these alignments represent continuous veins, the strike of the veins is about due north. The country rock, interpreted to be a tuffaceous graywacke, appears to have the same strike as the veins.

One mine working, located on the west side of the wadi just about at its bend, has a partly exposed vein of fractured quartz which is about 45 centimeters wide. The vein strikes N.30°W. and dips 35°SW. Other than some hematite in fractures, the quartz appears to be essentially barren. Abundant hematite-stained quartz is in the general area. Assay data showing the gold in samples collected by D.F. Schaffner are presented in table 3. The samples represented dump material, test holes, and cut of veins. There is no appreciable difference in gold contents of the three types of sample.

Samirah district and mine

The Samirah district includes only the one mine north of the village of Samirah, but is designated a district because of its distance from Al Fawwarah and the difference in geology of the area from that of Al Fawwarah district. Nearly all of the Samirah district is granite of different varieties and perhaps of different ages, cut by numerous felsic and mafic dikes and dike-like masses.

The mineral deposits at Samirah are, however, similar to the gold-quartz type seen in the districts to the south. No other mines were found north of Samirah. Mineralized veins assayed in the area proved to be barren of precious or base metals.

The Samirah mine (lat 26°31'N; long 42°09'E.) is located just east of Darb Zubaydah in a flat area about 6 kilometers north of the village of Samirah. The workings which are completely filled, are in two parallel quartz veins that strike N.55°E. (pl.1). The veins are not readily distinguishable on the surface, their strike having been determined from the alignment of the pits. The veins do not appear to be continuous, but are probably lenticular and pinch and swell. The workings explore the swells. The veins are probably only a few centimeters to 60 centimeters or 1 meter wide at the most.

A diabase ddke striking N.40° cuts the southeast vein, and an andesite dike striking N.35°W. cuts the northwest vein. The continuation of the veins beyond the intersections of the dikes is uncertain. A vein of barren quartz striking N.55°W. is located northeast of the andesite dikes. The barren vein is estimated to be 300 meters long and is about 6 meters wide at its midpoint and pinches out at both ends.

Most mineralized vein material has been removed to the ancient and abandoned site of a large mine camp 1.5 kilometers south of the mine. The remains of the camp consists of about six foundations of buidlings. The vein material was stacked in about 24 small piles. These piles includ fragments of fractured and highly altered gray, brown, and red quartz. The quartz contains considerable hematite, sparse limonite, and abundant malachite as coatings and fracture fillings, together with some azurite and possibly some chalcocite. One specimen contained free gold in the form of a minute flake on the surface of the quartz adjacent to a patch of malachite and azurite. The gangue appears to be chiefly quartz with some calcite and ankerite. Fragments of grinding stones of granite, diorite, and diabase are common.

Wall rock at the workings is altered to a yellowish-red to purple mottled aphanitic felsitic(?) clay. The country rock is a gray to yellow fine- to medium-grained cataclastic gneissic granite.

Assay data for vein quartz collected at the milling site is given in table 3.

CONCLUSIONS AND RECOMMENDATIONS

A geochemical and mineralogical reconnaissance of the Precambrian rocks of the Wadi ar Rimah quadrangle shows the greatest mineral potential to be in the Ad Dawadami district, and the next greatest potential to be in the southwest part of the quadrangle. All ancient mines examined on the east side of the Nafud al Urayk, and those at Jabal al Habla and to the north, are probably related to the major wrench-fault south of Wadi ar Rimah. Most of the mines are in fractures which are interpreted as splays or subsidiary faults of the major fault zone.

Most ancient workings and mineralized veins examined are in graywacke terrain in or near small bodies of intrusive granite which are probably associated with the occurrence of the mineralized veins. The granite is a competent rock and is more susceptible to fracturing than the less competent metasediments; therefore, the granite provides openings for the movement of mineralizing fluids. These fluids may have contained elements derived from either the graywacke and associated mafic rocks, the intrusive granite, or both.

The small bodies of granite, probably offshoots of the granitic batholiths, in the graywacke terrain may be suitable areas for further mineralogical investigation, especially where there are veins. The veins that contain gray or smoky quartz appear to have a greater possibility of being gold-bearing than those of the ribbon variety in which the fractures are filled with hematite. Mineralization is commonly associated with areas of gray and smoky quartz as opposed to areas of milky quartz, which are generally barren.

Gold was the chief commodity at all the mineral districts except Ad Dawadami, whose mines were worked mainly for silver. No single mine in any of the districts is really significant, and probably the ore was milled from several mines.

The Ad Dawadami district is by far the most promising mineralized area in the Wadi ar Rimah quadrangle. It contains at least 40 mines located within easy access of the highway between Jiddah and Riyad, and recent core drilling at one of the mines indicates the area may contain numerous veins locally rich in lead and silver. Continued detailed geological mapping and diamond core drilling in this district is recommended. The tailings of some of the mines, such as Samrah, have been found in themselves to be fairly rich in silver and represent considerable tonnage.

Other metals in addition to gold and silver that are in slightly anomalous amounts in the quadrangle are beryllium, lead, zinc, molybdenum, and tungsten. However, only one beryllium and lead anomaly in wadi sediment was detected. Molybdenum and zinc are in anomalous quantities in detrital magnetite in a few localities, notably Jabal Salma, and tungsten is present in heavy-mineral concentrates in anomalous amounts at less than half a dozen sample sites throughout the quadrangle. The area in which the anomalies are located could be checked further, perhaps with more detailed sampling but a single anomaly in one area is not necessarily indicative of a mineral occurrence.

REFERENCES CITED

Ankary, A. O., 1965a, Short report on the El Koom-Ashumta area, Saudi Arabia: Saudi Arabian Project Tech. Letter 5, 2 p.

__________, 1966b, The occurrence of tungsten in the southwestern portion of the Wadi ar Rimah quadrangle, Saudi Arabia: Saudi Arabian Project Tech. Letter 11, 2 p.

Anon., 1963, Geologic map of the Arabian Peninsula (compiled by the U. S. Geol. Survey and the Arabian American Oil Co.): U. S. Geol. Survey Misc. Geol. Inv. Map I-270A.

Bramkamp, R. A., Ramirez, L. F., Brown, G. F., and Pockock, A. E., 1963, Geologic map of the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-206A.

Hummel, C. L., Ankary, A. O., and Hakim, Hashim, 1970, Preliminary report of mineral deposits and occurrences in quadrangles 205 and 206: U. S. Geol. Survey open file rept. (IR) SA-33, 45 p.

Kiilsgaard, T. H., 1970, Evaluation of a diamond drilling program at the Samrah mine near Ad Dawadami, Kingdom of Saudi Arabia: U. S. Geol. Survey open file rept. (IR) SA-106, 77 p.

Mytton, J. W., 1967, Geological and geochemical reconnaissance of the Jabal Al Urd quadrangle, Kingdom of Saudi Arabia: Saudi Arabia Ministry Petroleum and Min. Res. Map MI-4, scale 1:100,000.

__________, 1970, Geological reconnaissance of the western part of the Wadi ar Rimah quadrangle, Saudi Arabia: U. S. Geol. Survey open file rept. (IR) SA-3, 3 p.

Theobald, P. K., Jr., 1970a, Preliminary report on the Dawadami district, Saudi Arabia: U. S. Geol. Survey open file rept. (IR) SA-2, 3 p.

__________, 1970b, Geology of Samrah and vicinity, Kingdom of Saudi Arabia: U. S. Geol. Survey open file rept. (IR) SA-42, 24 p.

Theobald, P. K., Jr., Thompson, C. E., and Horn, H. D., 1970, Geologic log and chemical data, diamond drill hole 1, Samrah, Kingdom of Sadu Saudi Arabia: U. S. Geol. Survey open file rept. (IR) SA-86, 61 p.

2. Unpub

2. Unpub. data, R. G. Bogue, 1954
3. Unpub. data, H. A. Quinn, 1963
4. Unpub. data, D. F. Schaffner, 1956
5. Unpub. data, D. F. Schaffner, 1956