DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Preliminary studies of the Raha Fault Zone and enclosing rocks in the Buqaya area, Jabal As Silsilah quadrangle, Kingdom of Saudi Arabia

by

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Open-File Report 86-29

Report prepared for Ministry of Petroleum and Mineral Resources,
Deputy Ministry for Mineral Resources, Saudi Arabia

1/ U.S. Geological Survey (retired)

1986

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PRELIMINARY STUDIES OF THE RAHA FAULT ZONE AND ENCLOSING ROCKS IN THE BUQAYA AREA JABAL AS SILSILAH QUADRANGLE KINGDOM OF SAUDI ARABIA

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ABSTRACT

The Raha fault zone in the Buqaya area is defined by a linear series of Proterozoic metagabbro plutons that intrude coarse, clastic Proterozoic metasediments. Conglomerates and graywackes of the Qarnayn formation on the north and east side of the fault zone are apparently older than similar rocks of the Maraghan formation that are south and west of the fault zone. The Maraghan is probably steeply overthrust over the Qarnayn.

The metagabbros are locally altered to form jasperoid and listwaenite lenses, but rock-chip sampling of these rocks found no anomalies in gold, silver, arsenic, or antimony. Rhyolite tuff overlies both metagabbro and metasedimentary rocks within the fault zone, contains disseminated pyrite, is cut by numerous quartz veins, and is anomalous in arsenic. One quartz vein is anomalous in gold.

A small diorite pluton intrudes metasedimentary rocks near the fault zone, and both the pluton and surrounding metasedimentary rocks are the site of ancient mining activity on gold-quartz veins. Sampling of quartz on dumps returned moderately high gold assays.

Near the south part of the map area, a small monzogranite boss is locally hydrothermally altered and cut by a small quartz vein bearing visible gold. Several rock chip samples from the monzogranite indicate a moderately high arsenic content. Quartz from dumps of a small, ancient working nearby contains moderate gold values.

1/ U.S. Geological Survey (retired)

INTRODUCTION

During mapping of the Jabal as Silsilah quadrangle, du Bray (in press) noted extensive jasperoid zones enclosed by mafic rocks in the Raha fault zone near the village of Buqaya. These he named Buqaya jasperoid (MODS 3155). His sampling of the jasperoids and quartz veins within the fault zone revealed anomalous values in chronium, nickel, arsenic, molybdenum, and antimony. He also located and sampled an ancient gold working near the Raha fault which he named Raha (MODS 3266).

Present studies were made with the intent of estimating the gold potential of the zone, and to obtain geochemical data of rocks within the Raha fault, especially jasperoids. Another objective of the study was to obtain more structural information concerning the fault zone. To this end, rocks enclosing the fault zone were mapped, and at the same time Zablocki and Hajnour (1985) ran several geophysical traverses across the zone using telluric-electric and audio-magnetotelluric methods. With the exception of du Bray's work, no recorded studies of the area have been made in recent times.

The author, assisted by Weiss Issa Assumali, carried out field work in the Buqaya area during November, 1984 (Safar and Rabi Awal, 1405 A.H.) that consisted of reconnaissance mapping and rock-chip-sampling. Work was coordinated with geophysical studies by Zablocki and Hajnour (1985).

The Buqaya area, including the Raha fault zone, is in the Jabal as Silsilah quadrangle at approximately lat $26^{\circ}18'00"$ N., long $42^{\circ}52'00"$ E., or 23 km northeast of the granite ring complex at Jabal as Silsilah (fig. 1). The small village of Buqaya is about 3 km northeast of the map area. Jabal Khaslah, a small, black jabal that rises up from relatively flat terrain, is a prominent landmark in the map area (plate 1). All of the map area is accessible by desert tracks.

These studies were made under sub-project 3.01.62 entitled "Mineral potential- Raha fault zone" in accordance with the work program of the Deputy Ministry for Mineral Resources for 1405.

Analytical data for all samples were provided by the laboratories of the Deputy Ministry for Mineral Resources in Jeddah under the direction of K. J. Curry, US Geological Survey. Thin sections and stained slabs were provided by the mineralogy laboratory of the U.S. Geological Survey in Jeddah under the direction of C. R. Thornber. All assistance is gratefully acknowledged.

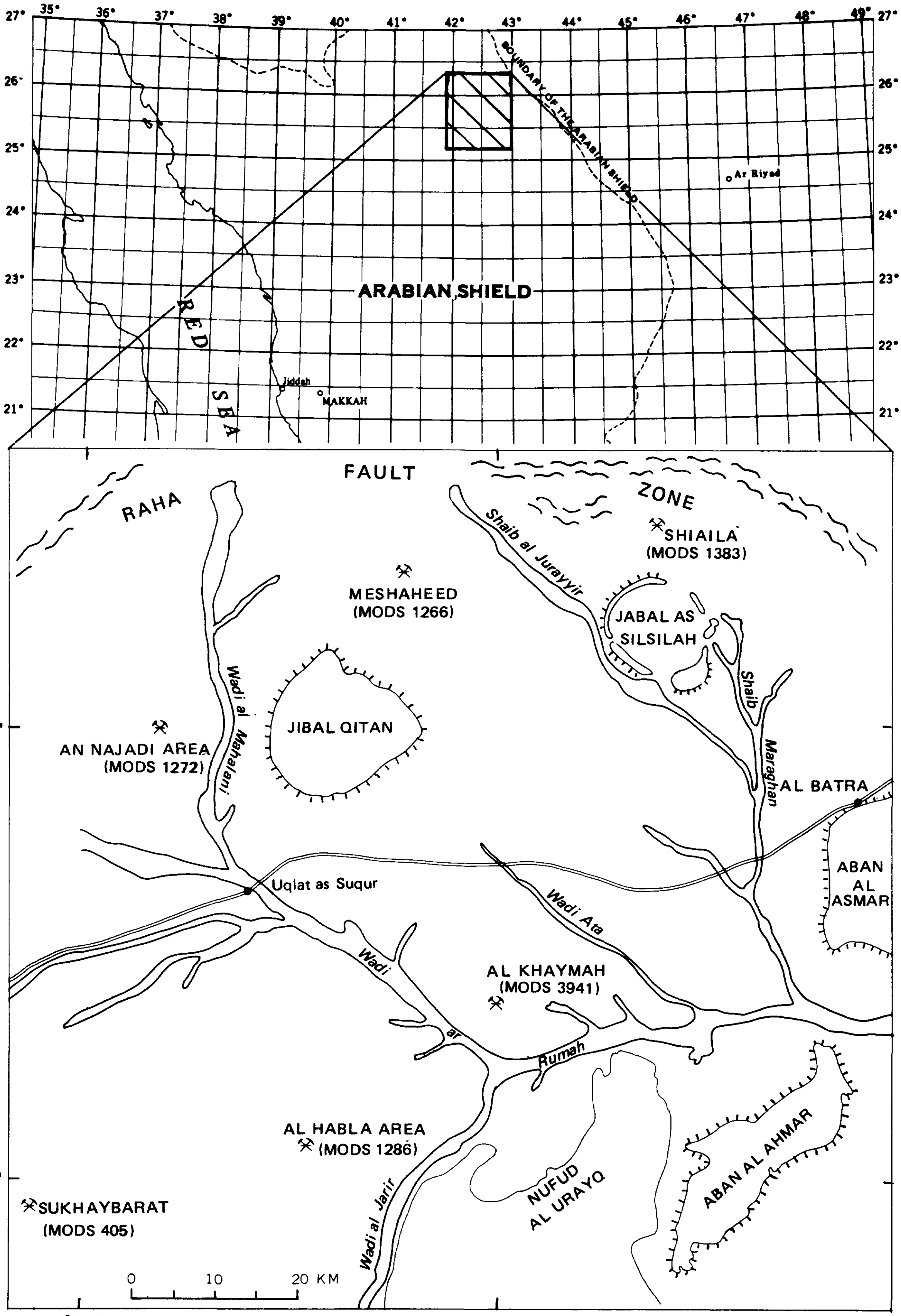

Figure 1.--*Index map showing location of the Raha fault zone, Buqaya area, regional geographic features, and surrounding mineral localities. Numbers in parentheses are identifiers used for mineral localities in the Mineral Occurrence Documentation System (MODS) of the Deputy Ministry for Mineral Resources.*

GEOLOGY

The Raha fault system as presently known is a major, complex structure extending west through the adjoining Samirah quadrangle (du Bray, in press ; Williams, 1983). As mapped by du Bray (in press), the fault zone in the Buqaya area is as much as 3 km wide with the south boundary passing through a prominent, black metagabbro forming Jabal Khaslah (plate 1). North and east of the fault zone, metamorphosed sandstones and conglomerates are designated the Buqaya sandstone, Qarnayn conglomerate, and Qarnayn lithic graywacke. Metasedimentary rocks within the fault zone consist of the Qarnayn lithic graywacke. Similar clastic metasediments south and west of the fault zone are designated the Maraghan lithic graywacke. The Qarnayn and Buqaya formations are thought to be older than the Maraghan formation because of their higher degree of metamorphism, and although metasedimentary rocks on either side of the fault zone are very similar in general outcrop appearance and composition, they are distinguishable by different aeromagnetic patterns. Metasediments north of the fault exibit a high-frequency anomalous pattern (BRGM, 1967), whereas the pattern of those to the south is subdued and homogeneous. In addition, metasediments north of the fault zone weather less recessively than those to the south and can be further distinguished by differing hues on LANDSAT false color images.

A somewhat different interpretation of structural features and age relationships of metasedimentary rocks is made in the present study (plate 1). The main segment of the fault system is defined by a curving, linear zone of metagabbro outcrops. Metasedimentary rocks south and west of this zone are classified as Maraghan, or younger rocks. Metasedimentary rocks north and east of the fault zone are assigned to the Qarnayn, or older rocks. Although the two names are used in this report to define rock units according to their lithologies, and also to differentiate relative ages, these studies found no direct evidence bearing on age relationships of metasedimentary rocks on either side of the fault. Generally, the conglomerates of the Qarnayn and Maraghan are similar and only locally are there conspicuous variations in rock types. Although there appear to be subtle variations in color and general composition, the conglomerates in most areas are strikingly similar on either side of the Raha fault zone. Distinguishing features, such as identifiable stratigraphic marker beds, were not found on both sides of the fault zone. Furthermore, the grade of metamorphism of rocks on either side of the fault zone is not noticeably different. The difference in ages of the two conglomerate units is based mainly on structural considerations, but also on the geophysical findings of Zablocki and Hajnour, (1985).

METASEDIMENTARY ROCKS

Qarnayn formation

Conglomerate - These rocks (qcg) are distributed more or less uniformly throughout the map area north and east of the Buqaya area fault zone (plate 1). They are dark gray-green and the matrix is black on fresh surfaces. Clasts are mostly of cobble size, but the size range is from pebble to boulder. In most places in about 90 percent of the sedimentary section, both clasts and matrix are made up of angular, volcanic lithic fragments of intermediate composition, white quartz shards derived by metamorphism of volcanic glass shards, and opaque iron oxide. Other types of cobbles noted are brown limestone, fine grained, intermediate intrusive rock, and well sorted, clean sandstone. Cobbles are closely packed allowing for only a minor amount of matrix. Individual cobbles are rounded to subrounded and bladed, and rough layering is apparent in much of the section. The conglomerates have a tendency to form low ridges approximately parallel to layering and appear as dark gray on black and white aerial photographs.

At two localities northeast of Jabal Khaslah (plate 1), thin, subvertical layers of blue-gray limestone (m) on the north edge of the fault complex grade north within a distance of approximately 100 m into the following lithologies: finely layered siltstone; clean, well-sorted sandstone; graywacke; pebble conglomerate; and cobble to boulder conglomerate as described above. Regardless of these and other exposures of finely layered Qarnayn rocks, stratigraphic succession was not determined, although according to local sedimentary progression, it is suggested that the metasediments are facing west toward the fault zone.

Lithic graywacke - This unit (qlg) is adjacent to the Raha fault and in fault contact with the Qarnayn conglomerate in the north-central to southeast part of the map area (plate 1). It is composed mainly of lithic volcanic fragments intermediate in composition, and white quartz shards. The rock is nearly black on fresh surfaces and resembles matrix material of the Qarnayn conglomerate. Blue-gray and brown limestone lenses (m) are interlayered with the graywacke at several localities (plate 1). In one zone (sample points 213281, 213282, and 213284), brown limestone grades into finely interlayered siltstone and limestone and subsequently into coarse graywacke within the distance of a few meters. Similar brown calcareous rocks are also thinly interlayered with graywacke in metasediments north of Jabal al Hammah (plate 1), but individual calcareous lenses are vaguely defined and are not shown on plate 1. Several other dark blue to blue-gray limestone lenses, some of which are thinly bedded, are interlayered with graywacke locally. Compared to the Qarnayn conglomerate the Qarnayn graywacke weathers recessively to form topographic lows, and appears in lighter shades of gray on black and white aerial photographs.

Maraghan formation

Conglomerate - Rocks of the Maraghan conglomerate (mcg) are in contact south and west of the Raha fault zone in the north-central part of the map area (plate 1). In many respects these rocks resemble those of the Qarnayn conglomerate north of the fault zone (plate 1); both cobbles and matrix are composed of volcanic rock fragments, mainly of intermediate composition, and white quartz shards over wide areas. Most of the cobbles have a bladed, sub-angular to rounded shape. Sparse, brown limestone clasts are also present and are similar to those in the Qarnayn conglomerate. The Maraghan conglomerate weathers positively in the same manner as the Qarnayn conglomerate and forms low ridges and hills. There are some differences in rock characteristics, however: the Maraghan conglomerate contains a greater proportion of boulder-size clasts; locally there are layers of chert cobbles, clean sandstone, or graywacke; cobbles of intrusive rocks were not noted; fresh surfaces of matrix material have a maroon color, probably resulting from contained iron oxides, in contrast to the dark gray to black color of Qarnayn conglomerate matrix material; in some areas the Maraghan conglomerates are steel-gray in outcrop, in contrast to the dark gray-green of the Qarnayn-conglomerates; and the Maraghan conglomerates appear as off-white to light gray on black and white aerial photographs as opposed to the dark gray of the Qarnayn conglomerates.

Lithic graywacke - The Maraghan lithic graywacke (mlg) is in contact with the Raha fault zone on its south and west sides in the south-central part of the map area (plate 1). It is medium gray, massive, and exhibits no layering in outcrop. The graywacke may be in fault contact with Maraghan conglomerates to the north and is comprised of large areas of monotonously uniform rocks. The erosional pattern is variable and in some areas these rocks form low ridges and in others broad, smooth plains. Microscopically, the graywacke is seen to be composed mainly of angular-volcanic-rock fragments, quartz, and feldspar in a matrix of clay, chlorite, and sericite.

On black and white aerial photographs, these rocks appear in lighter gray shades than the Qarnayn lithic graywacke.

IGNEOUS ROCKS

Metagabbro

Metagabbro (mgb) marks the trend of the curving Raha fault system in the Buqaya area (plate 1). Jabal al Hammah makes up the southeastern end of a continuous belt of gabbroic rocks that extends north and west out of the map area. Jabal Khaslah is the largest of a group of metagabbro outcrops aligned in a northeast direction where these outcrops probably lie along a split of the Raha fault (plate 1). A small gabbro outcrop is in sheared Maraghan conglomerate between Jabal Khaslah and the main Raha fault.

These rocks are the result of several stages of mafic-ultramafic intrusion into the Raha fault zone and range from relatively fresh, dark-green metagabbro at Jabal al Hammah to sheared, dark-green-gray talcose shist, or locally pods of serpentinite along much of the remainder of the fault zone. Some outcrops are of sheared, talcose schist intruded by metagabbro and later basalt dikes. The metagabbro contains disseminated chrome spinels, pyrite, and rare chalcopyrite.

Metagabbro is locally altered to jasperoid (j) or listwaenite (lw) in many places along the fault zone (plate 1). The jasperoid is mostly red-brown from contained iron oxides, is moderately brecciated, and displays abundant cubic voids resulting from weathered, disseminated pyrite. It is in lenticular form nearly everywhere and forms ridges. The formation of jasperoids appears to be controlled by faults and shears (not shown on plate 1) in the gabbroic rocks. The shear zone in Maraghan graywacke between Jabal Khaslah and and the main Raha fault zone (plate 1) contains a number of jasperoid and listwaenite lenses and, although in most places gabbroic rocks were not noted in association with lenses of either rock type, these outcrops almost certainly represent small, altered gabbroic intrusions within the shear zone. Listwaenite lenses are sparsely scattered along the fault zone. These rocks are friable, tan with a faint violet cast, are cut by late quartz stringers and pods, and contain disseminated chrome spinel and pyrite. In places, thin lenses of listwaenite are formed on the periphery of jasperoids (not shown on plate 1), but throughout most of the zone they are found as isolated lenses. The formation of listwaenite also appears to be controlled by faults and shears.

Metabasalt

At the southeast corner of the map area near outcrops of metagabbro is an area of metabasalt (mb, plate 1). In outcrop these rocks appear much the same as the metagabbro and are sheared over large areas to form talcose chlorite schist. In less-altered zones the metabasalt shows some original textures, but here also, mafic minerals are mainly altered to chlorite. The rock, however, is finer grained than the metagabbro and at several localities forms dikes intruding the metagabbro. Very small jasperoid lenses (j), similar in every respect to those described above, are distributed along shears and faults in the basalt.

Diorite

A posttectonic diorite pluton (di) intrudes Maraghan graywacke in the south part of the map area (plate 1). The pluton, measuring approximately 1 by 1.5 kms, is eroded below the level of metasedimentary rocks and is similar to numerous other plutons in the northern Shield (Cole, 1985; Williams, 1983; Smith and Samater, 1984; Smith and others, 1984). The rock is a medium-to dark-gray, fine-grained, biotite-hornblende diorite. The center of the pluton is cut by pink, medium grained dikes that probably originated from the nearby Wagt monzogranite (plate 1).

An aureole of dark-gray to greenish hornfelsic graywacke surrounds the pluton and numerous, small ancient workings on quartz veins are in both the metamorphic aureole and the diorite itself.

Granite porphyry

A small plug of granite porphyry (gp) is intruded into metagabbro of the Raha fault zone near the northwest end of the map area (plate 1). The rock is brick red and contains porphyritic potassium-feldspar phenocrysts in a groundmass of quartz, plagioclase, and potassium feldspar. The granite is probably genetically related to the nearby Raha metarhyolite as mapped by du Bray (in press).

Wagt monzogranite

The Wagt monzogranite (wmg) is in contact with Maraghan and Qarnayn graywackes at the southeast end of the map area (plate 1). Outcrops within the map area are at the north end of a large pluton, mapped and described by du Bray (1983a), that covers much of the eastern half of the Jabal as Silsilah quadrangle. Two small outliers of the same rock are in the map area. One, at the extreme southern part of the map area (plate 1), is intruded into Maraghan graywacke where it forms a prominant hill in relatively flat terrain. The rock is a plagioclase-quartz-microcline monzogranite with a moderate dusting of the feldspars by sericite. The other is a small boss intruded into metagabbro at Jabal al Hammah (plate 1). The rock here is a pink monzogranite, similar in composition to that described above, that contains xenoliths of metagabbro as much as 30 cm in diameter, and that is intruded by granite and aplite dikes.

Rhyolite tuff

Several small areas of rhyolite tuff (ry) overlie metagabbro and Qarnayn lithic graywacke in the map area (plate 1). The rock is tan with shades of violet, and is moderately iron-stained by disseminated pyrite. It contains quartz shards as much as 2 mm in diameter in a finer matrix consisting mostly of feldspar with silica. In places, it is finely stratified.

The origin of the rhyolite tuff is questionable, but the rock could be related to small volcanic pipes in the fault zone. A noteworthy feature of the tuff is the presence of numerous quartz veins, at least one of which contains a moderate amount of gold. Furthermore, the tuff has a high arsenic content. This type of evidence indicates the presence of a hydrothermal system, perhaps associated with a felsic intrusive source at depth.

STRUCTURE

The Raha fault zone as interpreted by du Bray (in press,b) and Williams (1983) is a deeply penetrating, major discontinuity that transects the Murdama group and other metasedimentary rocks in the Jabal SaQ, Jabal as Silsilah and Samirah quadrangles. In the map area, the Raha fault zone is delineated by a curvilinear array of mafic intrusions (plate 1). A branch of the fault is indicated by a small gabbro pluton at Jabal Khaslah and a linear array of smaller gabbro plutons and listwaenite that trends southwest. A broad, curving shear zone is represented by listwaenite pods, a small gabbro pluton, and a long, curved jasperoid lens in the area between Jabal Khaslah and the main fault (plate 1).

Direct evidence of faulting such as fault gouges or breccias, slickensides, or obvious relative displacement was not observed in the map area. The best rock exposures in the area are in the Qarnayn conglomerates on the north and east sides of the fault zone. Although folded to subvertical attitudes, these rocks are relatively undisturbed. Stretched pebble conglomerates were mapped by du Bray (in press) in an area north of the fault zone and several kilometers west of the Buqaya area, but indications of intense folding such as cleavage, schistosity, mineral streaking, or stretched pebbles were not observed in the Qarnayn conglomerates of the map area. They appear as compact, relatively competent rocks that are nearly vertical with bedding parallel to the fault zone. Younger east and northeast-striking faults intersect the major fault zone and Qarnayn rocks, but lateral movement is apparent only on the east-striking fault. One of the northeast-striking faults was mapped as connecting with the subsidiary fault along which lies the metagabbro at Jabal Khaslah (plate 1). However, no lateral movement across the Raha fault zone was noted, and it is believed that most of this type of movement is taken up by the shear zone that bends into the main fault.

Bedding is also vertical to subvertical and parallel to the fault zone in relatively undisturbed rocks of the Qarnayn graywacke fault-block (plate 1), with the exception that some limestone pods near the contact with the fault zone are locally folded. Mapping revealed no evidence concerning the relative movement of the fault block with respect to the Qarnayn conglomerate to the north.

Layering in the Maraghan conglomerate is also subvertical, but strikes are nearly perpendicular to the main fault zone (plate 1), indicating greater deformation of the Maraghan rocks as compared to the relatively undisturbed Qarnayn rocks. Notwithstanding the structural complications caused by the subsidiary Jabal Khaslah fault and shear zone, it appears that the entire Maraghan fault block has been rotated.

A geophysical study by Zablocki and Hajnour (1985), contributes to understanding the structure of the Raha fault zone. Five telluric-electric (TE) profiles were run across the Raha fault zone over Qarnayn conglomerate, Qarnayn lithic graywacke, and Maraghan conglomerate (plate 1). This geophysical method measures electrical resistivity of rocks, which generally varies directly with the degree of metamorphism and inversely with clay content. Their findings were that the electrical resistivity of rocks of the Maraghan conglomerate is much less than that of either the Qarnayn graywacke or conglomerate, and also that the resistivity is greatest in the Qarnayn conglomerate. Numerous audio-magnetotelluric (AMT) soundings, also made during the study (not shown on plate 1), more or less duplicate results of the TE survey and indicate less resistive rocks on the south and west sides of the fault zone. Both the TE and AMT surveys also indicate that the Raha fault zone dips steeply south and southwest. From the above data, it is suggested that younger, less metamorphosed Maraghan formation is thrust steeply northeast over older Qarnayn formation, as shown on plate 1.

ECONOMIC GEOLOGY

GEOCHEMISTRY OF ROCKS IN THE RAHA FAULT ZONE

Rock-chip sampling, emphasized in the present study, was concentrated mainly on various rock types and quartz veins in the Raha fault zone. A total of 117 rock-chip samples were collected in the map area, and of These, 104 samples are from the main fault zone or subsidiary shears (plate 1). Samples within the fault zone are of four principal rock or vein categories: jasperoid, listwaenite, quartz veins, and metagabbro, but a few samples of limestone, monzogranite, and rhyolite tuff were also collected. The purpose of the rock-chip-sampling program was primarily to test their gold content, but also to obtain geochemical signatures for the various rocks and veins in the fault zone.

Rock-chip samples were assayed for gold in the DMMR-USGS laboratories by use of an analytical technique that employs a graphite furnace in conjunction with atomic absorption analytical procedures. Use of the graphite furnace increases the sensitivity of gold analyses to 4 parts per billion (ppb) compared to a detection limit of approximately 50 parts per billion using the atomic absorption technique without the furnace (where results are usually reported in parts per million (ppm)). The atomic absorption analytical method without the use of a furnace was employed for silver analyses, and spectrographic analytical techniques were used for the analyses of gold, silver, and twenty-nine other elements (table 1).

The average gold content for all samples collected in the Raha fault zone is 51 ppb which is approximately average for mafic rocks worldwide (Rose and others, 1979). The range of analytical gold values is 0 to 3400 ppb, with the high value resulting from a quartz vein sample (No. 213284, plate 1 and table 1); this sample also contains 1000 ppm bismuth and 150 ppm tungsten. Silver values for all sampling in the fault zone are very low with a range of 0 to 2.9 ppm. The high value is also from a quartz vein.

Spectrographic analyses show eight jasperoid samples with a range of 200 to 1500 ppm zinc, and two quartz-vein samples assaying 300 and 700 ppm zinc (table 1); otherwise, the zinc content of all other samples is below the detection limit of 200 ppm. Sampling of jasperoid, quartz veins, and monzogranite show a slight enrichment of molybdenum, and in more than half of these samples molybdenum is in the range of 5 to 70 ppm.

Sample No. 213282, chipped from rhyolite tuff (plate 1; table 1) gave an assay return of 500 ppm arsenic. Two samples of the same rock (213338 and 213339, plate 1) were subsequently assayed for arsenic using a small spectrometer at the USGS laboratories, and one of these (No. 213339) assayed 300 ppm of that metal.

Table 2 lists geometric means of cobalt, chromium, copper, molybdenum, and nickel for rock units grouped as jasperoid, listwaenite, metagabbro, and quartz veins. It is interesting to note that the geometric mean of chromium in metagabbro is less than half of those for jasperoid and listwaenite. Also, that the mean for nickel in metagabbro is three to four times smaller than those for jasperoid and listwaenite. The geometric mean for molybdenum in jasperoid and quartz veins is about 30 ppm, but both listwaenite and metagabbro are deficient in that metal. Metagabbro, with a geometric mean of 71 ppm for copper is two to three times greater than the mean for that metal in the other rock categories. Geometric means for other elements such as gold, silver, lead, zinc, arsenic, and antimony were not calculated because these elements are not present in significant amounts in most samples.

Table 1.--Atomic absorption and semi-quantitative spectrographic analytical data for all samples in the Raha fault zone, Buqaya area.

[Gold values for atomic absorption assays 213191-213290 inclusive, are in parts per billion (ppb), all remaining gold values are in parts per million (ppm); values for iron, magnesium, calcium, and titanium are in percent; analytical data for other elements are in parts per million (ppm). S preceding element indicates analysis by spectrographic methods; AA preceding element indicates analysis by atomic absorption methods; leaders indicate none detected; N succeeding quantity indicates none detected; L succeeding quantity indicates less than quantity given; G succeeding element indicates greater than quantity given.]

SAMPLE	S-PB	S-SB	S-SC	S-SN	S-SR	S-V	S-W	S-Y	S-ZN	S-ZR
213191	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	10.0000L	50.0000N	10.0000N	200.0000N	10.0000N
213192	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	10.0000L	50.0000N	10.0000N	200.0000N	10.0000N
213193	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	10.0000L	50.0000N	10.0000N	200.0000N	10.0000N
213194	10.0000L	100.0000N	20.0000	10.0000N	700.0000	30.0000	50.0000N	10.0000N	200.0000N	10.0000N
213195	10.0000L	100.0000N	20.0000	10.0000N	500.0000	50.0000	50.0000N	10.0000N	200.0000N	10.0000N
213196	10.0000N	100.0000N	5.0000L	10.0000N	150.0000	10.0000	50.0000N	10.0000N	200.0000N	10.0000N
213197	10.0000L	100.0000N	5.0000	10.0000N	300.0000	15.0000	50.0000N	10.0000N	200.0000N	10.0000N
213198	10.0000N	100.0000N	5.0000L	10.0000N	500.0000	15.0000	50.0000N	10.0000N	200.0000N	10.0000N
213199	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	10.0000L	50.0000N	10.0000N	200.0000N	10.0000N
213200	50.0000	100.0000N	5.0000	10.0000N	100.0000N	20.0000	50.0000N	10.0000N	200.0000L	10.0000N
213201	20.0000	100.0000N	5.0000L	10.0000N	100.0000N	10.0000L	50.0000N	50.0000	200.0000L	150.0000
213202	50.0000	100.0000N	5.0000N	10.0000N	100.0000N	10.0000L	50.0000N	15.0000	200.0000N	30.0000
213203	10.0000L	100.0000N	7.0000	10.0000N	100.0000L	50.0000	50.0000N	10.0000L	200.0000L	10.0000N
213204	10.0000L	100.0000N	100.0000	10.0000N	100.0000L	100.0000	50.0000N	10.0000N	200.0000L	10.0000N
213205	10.0000L	100.0000N	100.0000G	10.0000N	150.0000	500.0000	50.0000N	30.0000	200.0000N	150.0000
213206	10.0000L	100.0000N	7.0000	10.0000N	100.0000N	15.0000	50.0000N	10.0000N	200.0000L	10.0000N
213207	50.0000	100.0000N	50.0000	10.0000N	200.0000	150.0000	50.0000N	10.0000L	200.0000L	10.0000N
213208	10.0000N	100.0000N	100.0000G	10.0000N	100.0000N	150.0000	50.0000N	10.0000N	200.0000L	10.0000N
213209	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	20.0000	50.0000N	10.0000N	200.0000L	10.0000N
213210	10.0000N	100.0000N	5.0000L	10.0000N	100.0000L	10.0000L	50.0000N	10.0000N	200.0000L	10.0000N
213211	10.0000N	100.0000N	100.0000G	10.0000N	100.0000	200.0000	50.0000N	10.0000L	200.0000L	15.0000
213212	10.0000N	100.0000N	20.0000	10.0000N	100.0000L	100.0000	50.0000N	10.0000L	200.0000L	10.0000N
213213	15.0000	100.0000N	5.0000	10.0000N	100.0000L	70.0000	50.0000N	10.0000L	200.0000L	10.0000N
213214	10.0000L	100.0000N	5.0000L	10.0000N	100.0000N	100.0000	50.0000N	10.0000N	200.0000L	10.0000N
213215	10.0000N	100.0000N	5.0000L	10.0000N	100.0000N	100.0000	50.0000N	10.0000N	200.0000L	10.0000N
213216	10.0000L	100.0000N	50.0000	10.0000N	100.0000N	300.0000	50.0000N	30.0000	200.0000N	50.0000
213217	10.0000N	100.0000N	5.0000L	10.0000N	100.0000L	150.0000	50.0000N	10.0000N	200.0000N	10.0000N
213218	10.0000N	100.0000N	5.0000	10.0000N	100.0000N	100.0000	50.0000N	10.0000N	200.0000L	10.0000N
213219	10.0000N	100.0000N	5.0000	10.0000N	300.0000	200.0000	50.0000N	10.0000N	200.0000L	10.0000N
213220	10.0000L	100.0000N	5.0000	10.0000N	200.0000	300.0000	50.0000N	10.0000N	300.0000N	10.0000N
213221	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	15.0000	50.0000N	10.0000N	200.0000N	15.0000
213222	10.0000N	100.0000N	5.0000N	10.0000N	100.0000N	30.0000	50.0000N	10.0000N	200.0000N	10.0000
213223	10.0000L	100.0000N	5.0000L	10.0000N	100.0000N	150.0000	50.0000N	10.0000N	200.0000L	10.0000N
213224	10.0000L	100.0000N	20.0000	10.0000N	100.0000	300.0000	50.0000N	10.0000L	200.0000L	10.0000L
213225	10.0000L	100.0000N	5.0000L	10.0000N	100.0000N	30.0000	50.0000N	10.0000N	200.0000L	10.0000N
213226	10.0000L	100.0000N	5.0000L	10.0000N	100.0000L	30.0000	50.0000N	10.0000N	200.0000L	10.0000N
213227	10.0000L	100.0000N	7.0000	10.0000N	500.0000	100.0000	50.0000N	10.0000N	200.0000L	10.0000
213228	10.0000	100.0000N	20.0000	10.0000N	200.0000	100.0000	50.0000N	10.0000N	200.0000	10.0000N
213229	10.0000L	100.0000N	15.0000	10.0000N	100.0000L	100.0000	50.0000N	10.0000N	200.0000L	15.0000
213230	10.0000L	100.0000N	15.0000	10.0000N	100.0000N	100.0000	50.0000N	10.0000N	200.0000L	10.0000N
213231	10.0000	100.0000N	5.0000	10.0000N	100.0000N	70.0000	50.0000N	10.0000N	300.0000	10.0000N
213232	10.0000N	100.0000N	5.0000	10.0000N	100.0000N	150.0000	50.0000N	10.0000N	200.0000L	10.0000N
213233	10.0000N	100.0000N	7.0000	10.0000N	100.0000L	150.0000	50.0000N	30.0000	200.0000N	150.0000
213234	10.0000N	100.0000N	5.0000N	10.0000N	1000.0000	10.0000L	50.0000N	10.0000N	200.0000N	10.0000N
213235	10.0000	100.0000N	5.0000	10.0000N	500.0000	100.0000	50.0000N	30.0000	200.0000N	200.0000
213236	10.0000L	100.0000N	70.0000	10.0000N	100.0000	300.0000	50.0000N	30.0000	200.0000N	100.0000
213237	10.0000L	100.0000N	7.0000	10.0000N	150.0000	100.0000	50.0000N	10.0000L	200.0000N	10.0000N
213238	10.0000L	100.0000N	5.0000L	10.0000N	150.0000	100.0000	50.0000N	10.0000L	200.0000	10.0000N
213239	10.0000L	100.0000N	5.0000N	10.0000N	700.0000	15.0000	50.0000N	15.0000	200.0000N	30.0000
213240	10.0000L	100.0000N	5.0000L	10.0000N	150.0000	30.0000	50.0000N	20.0000	200.0000N	50.0000

Table 1.--Atomic absorption and semi-quantitative spectrographic analytical data--Continued.

SAMPLE	S-BE	S-BI	S-CD	S-CO	S-CR	S-CU	S-LA	S-MO	S-NB	S-NI
213191	1.0000N	10.0000N	20.0000N	5.0000L	100.0000	5.0000	20.0000N	20.0000	20.0000N	15.0000
213192	1.0000N	10.0000N	20.0000N	5.0000L	150.0000	5.0000	20.0000N	5.0000N	20.0000N	30.0000
213193	1.0000N	10.0000N	20.0000N	5.0000L	100.0000	7.0000	20.0000N	30.0000	20.0000N	20.0000
213194	1.0000N	10.0000N	20.0000N	50.0000	1500.0000	70.0000	20.0000N	10.0000	20.0000N	700.0000
213195	1.0000N	10.0000N	20.0000N	30.0000	1000.0000	20.0000	20.0000N	5.0000N	20.0000N	300.0000
213196	1.0000N	10.0000N	20.0000N	50.0000	1500.0000	20.0000	20.0000N	5.0000N	20.0000N	700.0000
213197	1.0000N	10.0000N	20.0000N	50.0000	1500.0000	5.0000L	20.0000N	30.0000	20.0000N	500.0000
213198	1.0000N	10.0000N	20.0000N	5.0000L	500.0000	7.0000	20.0000N	50.0000	20.0000N	30.0000
213199	1.0000N	10.0000N	20.0000N	5.0000L	300.0000	5.0000L	20.0000N	5.0000L	20.0000N	30.0000
213200	2.0000	10.0000N	20.0000N	20.0000	1500.0000	15.0000	20.0000N	5.0000L	20.0000N	150.0000
213201	2.0000	10.0000N	20.0000N	5.0000N	300.0000	5.0000	20.0000N	5.0000N	20.0000N	15.0000
213202	1.0000	10.0000N	20.0000N	5.0000N	200.0000	5.0000L	20.0000N	30.0000	20.0000N	7.0000
213203	1.0000L	10.0000N	20.0000N	50.0000	1000.0000	15.0000	20.0000N	5.0000N	20.0000N	300.0000
213204	1.0000	10.0000N	20.0000N	20.0000	1500.0000	20.0000	20.0000N	5.0000N	20.0000N	100.0000
213205	2.0000	10.0000N	20.0000N	30.0000	200.0000	30.0000	20.0000N	5.0000N	20.0000N	100.0000
213206	2.0000	10.0000N	20.0000N	30.0000	1500.0000	15.0000	20.0000N	5.0000N	20.0000N	200.0000
213207	2.0000	10.0000N	20.0000N	70.0000	3000.0000	70.0000	20.0000N	5.0000N	20.0000N	500.0000
213208	1.0000N	10.0000N	20.0000N	30.0000	2000.0000	5.0000L	20.0000N	5.0000N	20.0000N	70.0000
213209	1.0000N	10.0000N	20.0000N	5.0000L	700.0000	7.0000	20.0000N	50.0000	20.0000N	50.0000
213210	1.0000N	10.0000N	20.0000N	30.0000	1500.0000	7.0000	20.0000N	5.0000N	20.0000N	1000.0000
213211	2.0000	10.0000N	20.0000N	200.0000	1000.0000	20.0000	20.0000N	30.0000	20.0000N	500.0000
213212	2.0000	10.0000N	20.0000N	100.0000	700.0000	30.0000	20.0000N	5.0000N	20.0000N	500.0000
213213	1.0000L	10.0000N	20.0000N	30.0000	1500.0000	70.0000	20.0000N	5.0000L	20.0000N	700.0000
213214	1.0000L	10.0000N	20.0000N	30.0000	2000.0000	20.0000	20.0000N	50.0000	20.0000N	700.0000
213215	1.0000N	10.0000N	20.0000N	15.0000	2000.0000	30.0000	20.0000N	30.0000	20.0000N	700.0000
213216	1.0000N	10.0000N	20.0000N	30.0000	500.0000	100.0000	20.0000N	5.0000N	20.0000N	70.0000
213217	1.0000N	10.0000N	20.0000N	30.0000	5000.0000G	10.0000	20.0000N	5.0000N	20.0000N	1000.0000
213218	1.0000	10.0000N	20.0000N	30.0000	2000.0000	50.0000	20.0000N	5.0000N	20.0000N	700.0000
213219	1.0000	10.0000N	20.0000N	50.0000	5000.0000	100.0000	20.0000N	5.0000L	20.0000N	700.0000
213220	1.0000N	10.0000N	20.0000N	30.0000	3000.0000	100.0000	20.0000N	7.0000	20.0000N	500.0000
213221	1.0000N	10.0000N	20.0000N	5.0000N	300.0000	50.0000	20.0000N	50.0000	20.0000N	15.0000
213222	1.0000N	10.0000N	20.0000N	5.0000L	500.0000	20.0000	20.0000N	70.0000	20.0000N	20.0000
213223	1.0000N	10.0000N	20.0000N	20.0000	1500.0000	70.0000	20.0000N	10.0000	20.0000N	700.0000
213224	1.0000L	10.0000N	20.0000N	30.0000	5000.0000G	100.0000	20.0000N	30.0000	20.0000N	700.0000
213225	1.0000L	10.0000N	20.0000N	30.0000	700.0000	50.0000	20.0000N	5.0000N	20.0000N	200.0000
213226	1.0000N	10.0000N	20.0000N	15.0000	1000.0000	50.0000	20.0000N	5.0000L	20.0000N	500.0000
213227	2.0000	10.0000N	20.0000N	70.0000	3000.0000	70.0000	20.0000N	5.0000N	20.0000N	1500.0000
213228	2.0000	10.0000N	20.0000N	50.0000	5000.0000	100.0000	20.0000N	30.0000	20.0000N	700.0000
213229	1.0000	10.0000N	20.0000N	30.0000	2000.0000	70.0000	20.0000N	20.0000	20.0000N	500.0000
213230	1.0000L	10.0000N	20.0000N	30.0000	1500.0000	70.0000	20.0000N	5.0000L	20.0000N	500.0000
213231	7.0000	10.0000N	20.0000N	20.0000	5000.0000G	20.0000	20.0000N	5.0000N	20.0000N	150.0000
213232	1.0000N	10.0000N	20.0000N	30.0000	3000.0000	30.0000	20.0000N	30.0000	20.0000N	100.0000
213233	1.0000L	10.0000N	20.0000N	5.0000L	200.0000	50.0000	20.0000L	5.0000L	20.0000N	20.0000
213234	1.0000N	10.0000N	20.0000N	5.0000N	50.0000	5.0000L	20.0000N	5.0000N	20.0000N	5.0000L
213235	1.0000L	10.0000N	20.0000N	10.0000	150.0000	70.0000	30.0000	5.0000N	20.0000N	20.0000
213236	1.0000N	10.0000N	20.0000N	50.0000	700.0000	100.0000	20.0000N	5.0000N	20.0000N	100.0000
213237	1.0000L	10.0000N	20.0000N	30.0000	1000.0000	50.0000	20.0000N	30.0000	20.0000N	1500.0000
213238	1.0000L	10.0000N	20.0000N	30.0000	3000.0000	30.0000	20.0000N	10.0000	20.0000N	1500.0000
213239	1.0000N	10.0000N	20.0000N	5.0000N	70.0000	5.0000L	20.0000N	5.0000N	20.0000N	5.0000L
213240	1.0000L	10.0000N	20.0000N	5.0000L	300.0000	20.0000	20.0000N	30.0000	20.0000N	15.0000

Table 1.--Atomic absorption and semi-quantitative spectrographic analytical data--Continued.

SAMPLE	S-FE	S-MG	S-CA	S-TI	S-MN	S-AG	S-AS	S-AU	S-B	S-BA
213191	0.2000	0.0300	0.0500	0.0020	70.0000	0.5000N	200.0000N	10.0000N	10.0000L	20.0000N
213192	0.5000	0.1000	0.1500	0.0070	100.0000	0.5000N	200.0000N	10.0000N	10.0000L	50.0000
213193	0.3000	0.0300	0.1000	0.0020L	70.0000	0.5000N	200.0000N	10.0000N	10.0000L	20.0000L
213194	3.0000	3.0000	5.0000	0.0050	1000.0000	0.5000N	200.0000N	10.0000N	10.0000N	50.0000
213195	3.0000	3.0000	5.0000	0.0500	1500.0000	0.5000N	200.0000N	10.0000N	10.0000N	200.0000
213196	3.0000	5.0000	3.0000	0.0020L	700.0000	0.5000N	200.0000N	10.0000N	10.0000N	50.0000
213197	5.0000	5.0000	7.0000	0.0150	2000.0000	0.5000N	200.0000N	10.0000N	10.0000N	100.0000
213198	1.0000	1.5000	3.0000	0.0030	1000.0000	0.5000N	200.0000N	10.0000N	10.0000L	30.0000
213199	0.5000	0.2000	0.3000	0.0030	150.0000	0.5000N	200.0000N	10.0000N	10.0000L	20.0000
213200	2.0000	0.3000	0.2000	0.0100	1000.0000	0.5000N	200.0000N	10.0000N	10.0000L	100.0000
213201	0.5000	0.1000	0.1500	0.0070	1500.0000	0.5000N	200.0000N	10.0000N	10.0000L	200.0000
213202	0.5000	0.0700	0.2000	0.0200	200.0000	0.5000N	200.0000N	10.0000N	10.0000L	30.0000
213203	10.0000	0.3000	0.5000	0.0020L	3000.0000	0.5000N	200.0000N	10.0000N	10.0000N	100.0000
213204	7.0000	0.1500	2.0000	0.0150	1500.0000	0.5000N	200.0000N	10.0000N	10.0000N	50.0000
213205	20.0000	0.5000	0.7000	1.0000G	3000.0000	0.5000N	200.0000N	10.0000N	20.0000	20.0000L
213206	15.0000	0.3000	0.7000	0.0030	2000.0000	0.5000N	200.0000N	10.0000N	10.0000N	150.0000
213207	15.0000	0.5000	10.0000	0.0300	2000.0000	0.5000N	200.0000N	10.0000N	10.0000N	500.0000
213208	7.0000	10.0000	7.0000	0.0500	3000.0000	0.5000N	200.0000N	10.0000N	10.0000N	30.0000
213209	0.7000	0.5000	1.0000	0.0020L	700.0000	0.5000N	200.0000N	10.0000N	15.0000	20.0000L
213210	3.0000	7.0000	2.0000	0.0020L	700.0000	0.5000N	200.0000N	10.0000N	10.0000N	20.0000L
213211	20.0000	0.2000	2.0000	0.0500	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000N	300.0000
213212	20.0000G	0.2000	2.0000	0.0070	3000.0000	0.5000N	200.0000N	10.0000N	10.0000N	150.0000
213213	3.0000	0.3000	3.0000	0.0100	5000.0000	0.5000N	200.0000N	10.0000N	10.0000N	700.0000
213214	3.0000	0.3000	1.0000	0.0030	3000.0000	0.5000N	200.0000N	10.0000N	10.0000N	200.0000
213215	5.0000	0.3000	0.7000	0.0020	300.0000	0.5000N	200.0000N	10.0000N	10.0000N	70.0000
213216	15.0000	3.0000	3.0000	1.0000G	2000.0000	0.5000N	200.0000N	10.0000N	10.0000N	100.0000
213217	20.0000	10.0000	10.0000	0.0020L	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000N	70.0000
213218	15.0000	0.3000	3.0000	0.0020L	3000.0000	0.5000N	200.0000N	10.0000N	10.0000L	70.0000
213219	15.0000	0.5000	3.0000	0.0020L	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000L	1500.0000
213220	15.0000	0.5000	5.0000	0.0020	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000L	700.0000
213221	0.3000	0.0200L	0.0500	0.0020L	100.0000	0.5000N	200.0000N	10.0000N	20.0000	20.0000N
213222	0.7000	0.3000	0.7000	0.2000	200.0000	0.5000N	200.0000N	10.0000N	15.0000	20.0000N
213223	5.0000	1.0000	0.2000	0.0150	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000L	150.0000
213224	20.0000G	0.7000	5.0000	0.0100	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000N	300.0000
213225	5.0000	0.2000	1.0000	0.0020L	1500.0000	0.5000N	200.0000N	10.0000N	10.0000L	150.0000
213226	3.0000	1.0000	0.3000	0.0020	1000.0000	0.5000N	200.0000N	10.0000N	10.0000L	70.0000
213227	15.0000	0.2000	3.0000	0.0100	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000N	1000.0000
213228	15.0000	0.5000	5.0000	0.0150	5000.0000G	0.5000N	200.0000N	10.0000N	10.0000L	150.0000
213229	5.0000	0.5000	2.0000	0.2000	1000.0000	0.5000N	200.0000N	10.0000N	10.0000L	150.0000
213230	7.0000	0.3000	1.0000	0.0150	1500.0000	0.5000N	200.0000N	10.0000N	10.0000L	150.0000
213231	10.0000	0.1500	0.7000	0.0020L	1000.0000	0.5000N	200.0000N	10.0000N	10.0000L	100.0000
213232	3.0000	0.2000	2.0000	0.0500	700.0000	0.5000N	200.0000N	10.0000N	10.0000L	100.0000
213233	1.0000	0.2000	0.5000	0.5000	150.0000	0.5000N	200.0000N	10.0000N	1000.0000	300.0000
213234	0.0500L	0.1000	20.0000G	0.0020L	100.0000	0.5000N	200.0000N	10.0000N	10.0000N	20.0000N
213235	1.5000	0.7000	0.7000	0.5000	150.0000	0.5000N	200.0000N	10.0000N	300.0000	500.0000
213236	15.0000	3.0000	5.0000	1.0000G	1500.0000	0.5000N	200.0000N	10.0000N	10.0000N	200.0000
213237	15.0000	0.2000	3.0000	0.0070	700.0000	0.5000N	200.0000N	10.0000N	10.0000N	200.0000
213238	20.0000G	0.3000	7.0000	0.0020L	1500.0000	0.5000N	200.0000N	10.0000N	10.0000N	200.0000
213239	0.5000	0.3000	20.0000	0.0700	200.0000	0.5000N	200.0000N	10.0000N	100.0000	30.0000
213240	2.0000	0.1500	10.0000	0.0500	5000.0000G	0.5000N	200.0000N	10.0000N	15.0000	300.0000

Table 1.--Atomic absorption and semi-quantitative spectrographic analytical data--Continued.

Sample	AA-Au	AA-Ag	Sample	AA-Au	AA-Ag
213191	4 L	-	213241	4	-
213192	4	0.1	213242	4 L	-
213193	4	0.1	213243	4 L	-
213194	4	-	213244	58	-
213195	4 L	-	213245	32	0.1
213196	4	-	213246	4 L	-
213197	4 L	-	213247	70	-
213198	4 L	-	213248	4	0.1
213199	4 L	-	213249	10	-
213200	8	-	213250	4	-
213201	24	-	213251	4	-
213202	4 L	-	213252	4	-
213203	180	-	213253	4 L	-
213204	4	-	213254	4	-
213205	4	-	213255	280	0.3
213206	28	-	213256	58	0.4
213207	4	-	213257	4 L	-
213208	-	-	213258	4 L	-
213209	4 L	-	213259	8	-
213210	4 L	-	213260	-	-
213211	6	-	213261	4 L	2.4
213212	8	-	213262	4 L	-
213213	110	-	213263	-	-
213214	40	-	213264	-	-
213215	22	-	213265	4 L	-
213216	6	-	213266	4	-
213217	8	-	213267	4	-
213218	118	-	213268	4 L	-
213219	22	-	213269	4 L	-
213220	4 L	-	213270	4 L	-
213221	4	-	213271	4 L	-
213222	-	-	213272	-	-
213223	4 L	-	213273	-	-
213224	6	-	213274	-	-
213225	4	-	213275	16	-
213226	4	-	213276	4	-
213227	6	-	213277	4 L	-
213228	16	0.1	213278	4 L	-
213229	12	0.1	213279	80	-
213230	4	-	213280	20	2.9
213231	14	-	213281	24	-
213232	6	-	213282	6	-
213233	4	-	213283	104	-
213234	4 L	-	213284	3400	1.7
213235	6	-	213285	20	-
213236	4 L	-	213286	6	-
213237	6	-	213287	4 L	-
213238	4	-	213288	8	-
213239	4 L	0.2	213289	56	-
213240	10	0.1	213290	34000	5.1

Table 2.--*Geometric means of cobalt, chromium, copper, molybdenum, and nickel for rock chip samples in the Raha fault zone, Buqaya area.*

[Analyses by spectographic methods. Leaders indicate that in most samples values are below detection limits.]

	Jasperoid	Listwaenite	Metagabbro	Quartz veins
No. of samples	44	14	9	22
Cobalt	42	37	55	-
Chromium	1950	1966	888	325
Copper	43	31	71	22
Molybdenum	30	-	-	33
Nickel	600	887	165	27

ANCIENT MINE SITES

During geologic mapping of the Jabal as Silsilah quadrangle du Bray (in press) located and sampled an ancient working which he named Raha (MODS 3266). The same mining site was visited during these studies and a general reconnaissance of the area indicated the presence of scattered ancient workings over a fairly large area. They are in both Maraghan lithic graywacke and diorite in the southern part of the map area (plate 1). Most of the workings are linear in form and probably resulted from underhand stoping on quartz veins. None of the veins are exposed, but judging from the size of quartz fragments remaining on dumps, they are narrow and probably average much less than 1 m thick. Most of the ancient dumps are composed of waste rock with only minor quartz, and in some zones quartz is absent from dumps, indicating that in these places, ancient miners probably recovered all of the quartz for milling purposes. Workings extend N 20 E intermittently for 520 m in hornfelsic graywacke in the southern part of the zone and two short workings trend northwest in metasediments on the west flank of the diorite pluton, otherwise all of the mining appears to have been carried out within the pluton, mostly on northwest-striking quartz veins (plate 1). Commonly, ancient villages with quartz crushing areas are located near ancient mine sites in this part of the Arabian Shield, but none were found at this locality.

Contact metamorphism of the Maraghan graywacke by intrusions of both the diorite and monzogranite plutons in the area (plate 1), formed dark gray to greenish, siliceous, indurated hornfels containing appreciable biotite and disseminated pyrite. These rocks, being more resistant to erosion, form a topographic high around the more easily eroded diorite. As a result, much of the intrusive rock is covered by a thin layer of alluvium and colluvium, but rare outcrops near ancient workings reveal hydrothermal alteration of the diorite to form potassium feldspar locally. Otherwise, the diorite is unaltered in areas removed from quartz veins. One ancient working in the intrusive has exposed a coarse-grained, pink, granitic dike bearing large biotite crystals where a quartz vein had evidently formed between the contact of the dike and diorite wallrock, but most ancient workings in diorite indicate that quartz veins were formed along fractures with no dikes present.

Sparse quartz on dumps ranges in texture from fine grained to vuggy, coarsely crystalline, and in places the vein material is composed of quartz with minor calcite. Some of the quartz is moderately iron-stained and contains cubic, limonitic pseudomorphs after pyrite. Evidence of other types of sulfide minerals in the quartz was not noted, nor was free gold observed during dump sampling, but the veins were undoubtedly mined for their gold content. Both metasedimentary and diorite wall rocks on dumps are moderately iron-stained by the oxidation of disseminated pyrite, and some of the dump rock is moderately hydrothermally altered to kaolin and sericite, but hydrothermal alteration is by no means pervasive and probably extends no more than a meter or two into vein walls.

Analysis of gold and silver was done by the use of the atomic absorption method. These metals and 29 other elements were also assayed by the use of the semi-quantitative spectrographic method. Dumps were sampled by collecting representative quartz along their entire length, and each dump constituted one sample. Twenty of such samples were collected.

Analytical data for gold in quartz (table 3) range from 0.2 to 60.0 ppm and the average gold value for the twenty samples is 11.8 ppm. The range of silver values for the quartz is trace to 11.0 ppm and the average is 2.5 ppm. Spectrographic analyses give a range of nil to 5000 ppm arsenic and one-half of the quartz samples contain no detectable amounts of the metal (the detection limit of arsenic using the spectrographic analytical method is 200 ppm). Molybdenum, the only remaining element to show significant values in quartz, has a range of nil to 50 ppm.

Three wall-rock dump samples were collected for assay (table 3). One sample of slightly iron-stained diorite assayed 18.2 ppm gold, 2.5 ppm silver and 3000 ppm arsenic. Two samples of pyritized metasediments assayed 1.3 and 5.2 ppm gold; 0.6 and 0.8 ppm silver; and 500 and 5000 ppm arsenic.

Three kilometers southwest of the diorite pluton near a small outlier of monzogranite (plate 1) is a small ancient trench with white to gray pyritized quartz on dumps. One sample of the quartz assayed 12.6 ppm gold, 2.5 ppm silver, and 700 ppm arsenic.

GEOCHEMISTRY OF AN UNNAMED MONZOGRANITE PLUTON

A satellitic monzogranite pluton measuring approximately 100 by 300 m is intruded into Maraghan graywacke near the southern extremity of the map area (plate 1). The monzogranite forms a small hill and is pink to brown in outcrop. The intrusive is variously hydrothermally altered over much of its outcrop area with the degree and type of alteration ranging from moderate to intense kaolinization with accompanying sericite, quartz, and disseminated pyrite. The northern part of the pluton is essentially unaltered. An iron-stained quartz vein near the center of the pluton is about 5 m long and bears visible gold associated with limonite. A chip sample across the vein assayed 9.0 ppm gold, nil silver, and 5000 ppm arsenic.

Nine rock-chip samples of the monzogranite were collected along north- and east-oriented lines (plate 1; table 1). In addition, two samples were chipped from the north end of the pluton. Three of the samples contain detectable gold with the highest value being 0.7 ppm, however, none of the samples contain silver. Arsenic is present in all but two of the samples in the range 300 to 1000 ppm, and about half of the samples contain as much as 30 ppm molybdenum.

In another area south of the diorite pluton (plate 1), two chip samples (213308 and 213332), one across a white quartz vein and the other across an aplite dike, do not contain metals of significance.

Table 3.--Analytical data for dump samples in the Buqaya area.

[Values in parts per million (ppm). Tr indicates trace amounts detected.]

Sample Number	Description	Atomic Absorption Analyses Au	Ag	Spectrographic Analyses Notable Elements
	Ancient workings in the diorite pluton and surrounding metasediments			
213290	Quartz, nearly sulfide-free. Several workings along 110 m. Sample from north end dumps	34.0	5.1	As-5000
213291	As above. Sample from south end dumps	11.4	1.5	As-1000
213307	Quartz, white and gray, with pyrite. Working 7 m long	12.6	2.5	As-700
213310	Quartz, white, working 90 m long	17.2	5.5	Pb-200
213311	Quartz, white, working 80 m long	60.0	11.0	As-200, Pb-200
213312	Quartz, white, working 110 m long	2.0	0.8	As-1000
213313	Wall rock from above dumps.	1.3	0.6	As-500
213314	Quartz, white. Small pit in fresh diorite	16.2	8.3	
213315	Quartz, white. Pit on granite dikes in diorite.	1.3	Tr	
213316	Quartz, white. Working 70 m long	1.5	1.2	As-200, Pb-100
213317	Wall rock, diorite with lesser metasediments; slightly iron-stained. From above working	18.2	2.5	As-3000
213318	Quartz, white. Pit in diorite.	6.0	Tr	
213319	Quartz, white. Working 15 m long	3.5	Tr	Mo-50
213320	Quartz, iron-stained. South end of five pits along 50 m trend	2.4	Tr	As-1000
213321	Quartz, as above, from north end of above group of workings	7.6	Tr	
213322	Quartz, iron-stained. From south end of working 73 m long in diorite	16.6	2.0	As-700
213323	Quartz, as above. From north end of above dumps	5.4	0.9	As-1000
213324	Quartz with pyrite. From two workings along 30 m trend.	2.2	Tr	As-1000, Mo-50
213325	Wall rock, altered metasediments. From same site as above	5.2	0.8	As-5000
213326	Quartz, iron-stained. From dumps 40 m long	1.7	0.7	As-500
213327	Quartz, slightly iron-stained. From working 10 m long	14.0	5.0	
213328	Quartz, white. From working 20 m long in hornfelsic metasediments	0.2	Tr	
213329	Quartz with calcite. From dumps 40 m long	31.6	6.1	
213330	Quartz. Thin stringers in hornfelsic metasediments	0.2	1.3	
	Ancient working near the satellitic monzogranite pluton			
213307	Quartz, milky white to gray, with pyrite.	12.6	2.5	As-700

CONCLUSIONS AND RECOMMENDATIONS

Rock chip sampling in the Raha fault zone found that jasperoid and listwaenite lenses, quartz veins, and metagabbro are deficient in gold, silver, arsenic, lead, and antimony. The survey found no more than background values in copper and a few spurious high zinc values for all of the rock categories. Jasperoid lenses and quartz veins are slightly enriched in molybdenum. They are also enriched in chromium and nickel compared to original metagabbro, from which these metals were apparently leached by hydrothermal solutions and redeposited during formation of jasperoid and listwaenite.

One quartz vein of twenty-two samples was found to contain significant gold (3.4 ppm). The vein is in rhyolite tuff containing disseminated pyrite and three chip samples of the tuff contain nil, 300, and 500 ppm arsenic. Several small tuff outcrops, some cut by numerous quartz veins, are distributed along the fault zone (plate 1). The source of the volcanic activity is not known, but it seems possible that the rock may be associated with small buried felsic volcanic plugs. Such a possibility, and the presence of gold and arsenic in the rock and veins, warrant a further, detailed examination. Otherwise, further investigation of the fault zone in the study area is not recommended in view of the poor sampling results. Development of listwaenite and jasperoid by the hydrothermal alteration of mafic rocks has taken place only locally in the study area, in contrast to the Raha fault zone in the Shiaila area (Smith and Samater, 1985; fig. 1) where large volumes of mafic rock have been replaced by carbonate and silica. At Shiaila, rock-chip sampling of the long listwaenite and jasperoid lens in the Raha fault zone found erratic, but high arsenic values over much of its length, and a few quartz veins in the listwaenite that contain gold. However, it is probable that because much less metasomatism has taken place at Buqaya fault zone, there is less probability of deposition of gold or other metals in these rocks.

It is now well established that a direct correlation exists between major faults in the Arabian Shield and gold deposits (Boyle and others, 1984; Stoeser and others, 1985; Worl, 1979; Smith and Samater, 1985). The gold deposits are generally in the form of gold-quartz veins adjacent to the faults. Correlation of gold deposits in the northern Arabian Shield with small, posttectonic dioritic-granodioritic plutons geochronically dated at 620 to 615 Ma ago (Cole and Hedge, 1985 unpub. data; Cole, 1985; Smith and Samater, 1984; Smith and others, 1984) is also well established. In most places the gold-quartz veins are in metasedimentary or volcanic rocks near contacts with diorite to granodiorite plutons, and in a few places in the plutons themselves. Most gold deposits in this part of the Shield have undergone only preliminary mapping and sampling, so it is not known whether gold is confined only to quartz veins, or if in places, it may also occur in disseminated form in adjacent rocks.

The gold-quartz veins in the southern part of the map area (plate 1) are in a small diorite pluton and enclosing metasediments near the Raha fault zone, thus satisfying the two genetic models as outlined above. Three AMT soundings by Zablocki and Hajnour (1985), two in metasedimentary rocks near the diorite pluton and one in the pluton itself, encountered highly resistive rocks, which indicates that the diorite and surrounding metasediments are not argillically altered over large areas. The diorite is poorly exposed, but in outcrops the rock in most places is fresh and unaffected by hydrothermal alteration, although potassic alteration is evident locally. As a consequence, it is likely that gold is confined to quartz veins and selvages in the pluton, and this may also be the case for veins in metasediments, although, here again, the veins and adjacent wall rocks are not exposed. Nevertheless, both veins and wall rock are known to contain appreciable gold, and vein outcrops and selvages have not been examined. It is therefore recommended that further trenching and sampling studies be made to established the distribution of gold.

Zablocki and Hajnour (1985) also ran one AMT sounding at the center of the small monzogranite outlier (plate 1, AMT sounding station not shown). They found that resistivity in this rock is much lower than that of the diorite pluton, and, therefore, must have undergone argillic alteration. Studies by the author confirm that the pluton is at least locally altered, and sampling has shown that the rock contains moderately high arsenic values. One quartz vein with visible gold cuts the pluton and a small ancient working on a gold-quartz vein is nearby. The small stock may represent a late, mineralized phase of the large, adjoining Wagt monzogranite and it is recommended that more detailed mapping and sampling be carried out to include the small stock and the nearby quartz vein. Further studies in the area should include the diorite pluton and all of the intervening area south including the monzogranite boss.

DATA STORAGE

Petrographic descriptions, sample locations, and results of chemical analyses are stored in Data-File USGS-DF-05-7 (Smith, 1985) in the Jeddah office of the U. S. Geological Survey Saudi Arabian Mission.

Data on mineral occurrences in the Buqaya region have been entered for the following MODS numbers:

3155	Buqaya jasperoid	Cr, Mo, Ni, Sb	prospect	updated 5/85
3266	Raha	Au	prospect	updated 5/85

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