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Preliminary studies of gold deposits and a reconnaissance rock chip sampling program, Al Khaymah region, Aban al Ahmar quadrangle, Kingdom of Saudi Arabia, with a section on Geologic setting of the Al Khaymah region by James C. Cole

by

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AND

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AL KHAYMAH REGION, ABAN AL AHMAR QUADRANGLE,

KINGDOM OF SAUDI ARABIA

by

Charles W. Smith[1/] and Rashid M. Samater

with a section on

GEOLOGIC SETTING OF THE AL KHAYMAH REGION

by

James C. Cole

ABSTRACT

Quartz dumps of the Al Khaymah ancient workings display an unusual amount of free gold, as do some quartz veins in the surrounding 36 square km. The veins, however, are thin, of short strike length, and thinly scattered in the area. Repeated assays gave widely dissimilar results that preclude an estimate of the average gold grade.

The Al Khaymah region is within a fault-bounded block called the Ata-Shara block that is defined by the Ata fault on the north and the Shara fault on the south. Both faults have been active throughout much of the late Proterozoic history. Within the block, gold-quartz veins cut andesitic volcanic rocks of the Jurdhawiyah group and the older Dhiran meta-andesite. All structures within the region are cut by Idah-suite diorite-granodiorite plutons. Diorite dikes are associated with gold-quartz veins and aeromagnetic data indicate the probability of near surface plutonic rocks in the vicinity of the ancient mines.

A large chalcopyrite-bearing quartz stockwork in a granodiorite pluton extends about 3 km and is 250 m wide, and two small workings on copper-stained gossans on the south side of Wadi ar Rumah are on the same trend.

Regional rock-chip sampling along the Ata fault system found notable values in arsenic, antimony, lead, zinc, copper, and tin.

1/ U.S. Geological Survey Mission, Saudi Arabia

INTRODUCTION

The Al Khaymah ancient workings (MODS 3941) are at approximately lat 25°42' N., and long 42°30' E. in the northern Arabian Shield (fig. 1). The mines are in an area of low hills, easily accessable via the Gassim-Madinah asphalt highway that trends easterly immediately to the north.

Cole located the workings in 1981 while mapping the Uqlat as Suqur and Al Abanat quadrangles. He observed free gold in quartz on dumps, and collected several samples, some assaying high in gold content. The senior author later made two visits to the area, found that some unworked quartz veins also contain gold in appreciable amounts, and recommended that the region be studied in more detail. Studies by the authors, assisted by Waiss Issa Assumali and Ali Dualeh, were made during a two-week period in January, 1984, and more than 200 samples of quartz veins and rock were collected. Interesting geological features noted by Cole, such as major faults, or areas of hydrothermal alteration were given special attention in the sampling studies.

The Al Khaymah ancient mines are within a wide region of the northeastern Arabian Shield where gold deposits, mainly in quartz veins, are common (fig. 1). Although ancient miners concentrated on the more intensely mineralized zones, our studies found gold in unworked quartz veins over a broad area. In addition, examination and sampling of quartz on dumps revealed much visible gold.

Samples were assayed in the Deputy Ministry for Mineral Resources laboratories in Jeddah under the direction of K. J. Curry, U. S. Geological Survey (USGS). All samples were assayed for gold and silver by atomic absorption methods and for twenty-nine other elements by semiquantitative spectrographic methods. Atomic absorption methods were also used on forty-nine samples for arsenic, antimony, and zinc assays. Thin sections, polished thin sections, and stained slabs were made in the USGS laboratories under the direction of Carl Thornber. All assistance is gratefully acknowledged.

All quartz samples from the Al Khaymah region, whether from ancient mine dumps or from veins in outcrop, were subjected to three separate gold assays by atomic absorption methods. Samples were ground and split, and ten grams were used for gold analysis. Those samples with high gold content were reground and two additional ten-gram samples were analyzed.

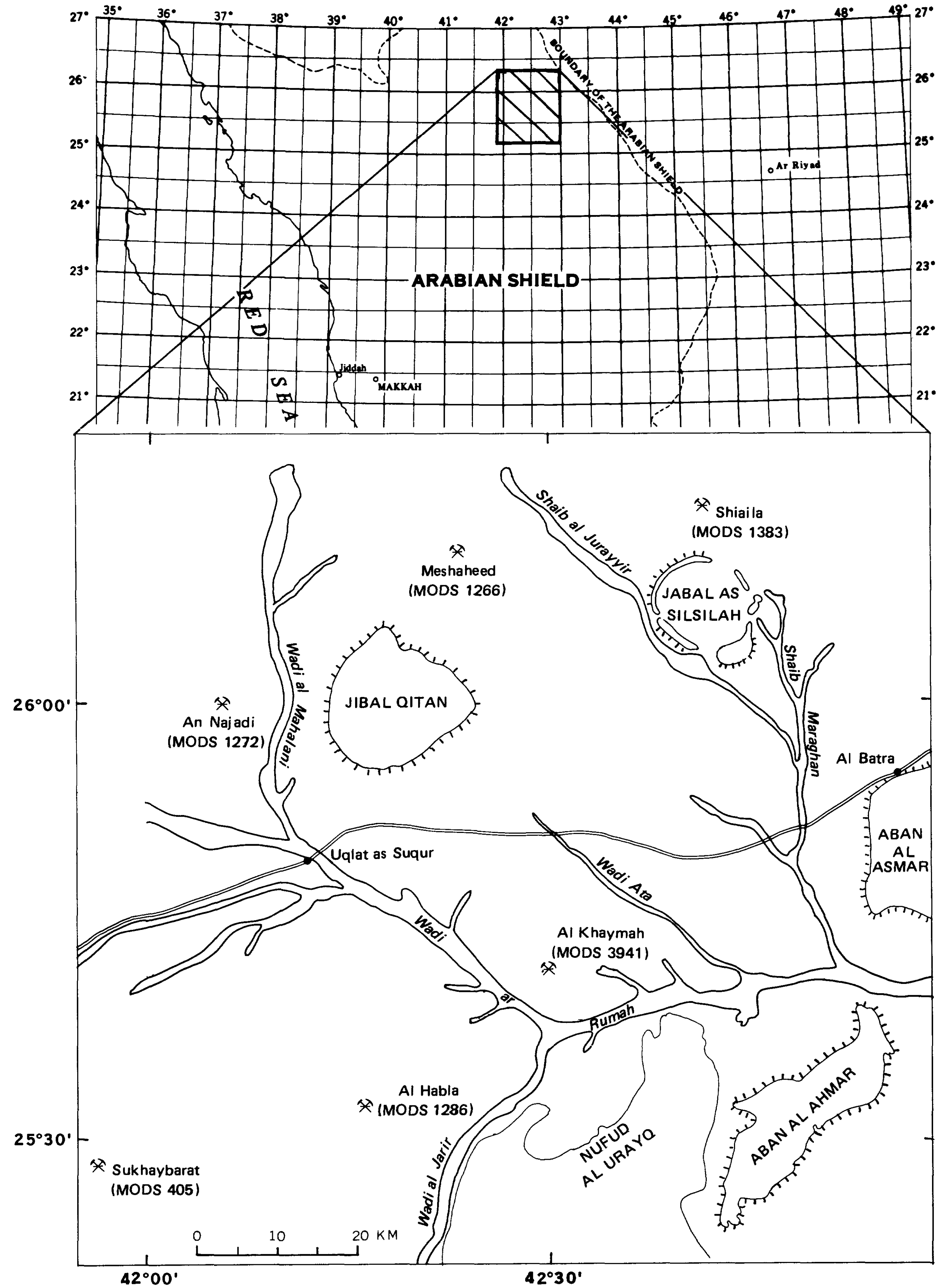

Figure 1.--Index map showing location of the Al Khaymah ancient mines and regional geographic features.

Tables 1 and 2 show a wide variation in the gold content for repeated assays of many samples. In fact, the variation is generally so great that average grade calculations cannot be made with any degree of confidence. These conditions are undoubtedly caused by the coarse particulate nature and erratic distribution of the gold in quartz.

These studies were made in accordance with sub-project 3.01.52 of the work program of the Deputy Ministry for Mineral Resources for 1403/04.

GEOLOGIC SETTING OF THE AL KHAYMAH REGION

by

James C. Cole

Al Khaymah is the local name for a geographic region that is characterized by low, rounded hills with a well-developed, dendritic drainage system and bounded on the south and west by the broad floodplain of Wadi ar Rumah. The northern and eastern boundaries of the region are marked by a distinct topographic break that coincides with the trace of the Ata fault and its subsidiary strands, beyond which a flat and poorly drained landscape is characteristic. The unusual topography and landforms of the Al Khaymah region are a reflection of the distinctive rock-types and structures that define it as a geologic entity.

The Al Khaymah region is the eastern part of a fault-bounded arch called the Ata-Shara block (Cole, 1985a, unpub. data) that extends at least 40 km west of Wadi ar Rumah in the Uqlat as Suqur quadrangle. This block is bounded by the Ata fault on the north and the Shara fault on the south, and both complex structures have been repeatedly active throughout much of the late Proterozoic history represented by the various rock units. The faults that coincide with the Wadi ar Rumah drainage channel (Rumah fault and Qunaynah fault) are relatively simple normal faults and appear to have had only one major period of displacement, which although Proterozoic, is younger than most other structures of the region (Cole, 1985a, unpub. data).

The oldest rocks of the region, defined as the Dhiran meta-andesite (Cole, 1985a, unpub. data) consist chiefly of weakly layered, fragmental and amygdaloidal meta-andesite, several prominent layers of gray-brown, schistose, porphyritic sodic metadacite, and minor metasedimentary schist and discontinuous marble pods. All rocks in the Dhiran are strongly altered, locally cataclastic, and metamorphosed to assemblages of sodic plagioclase, epidote, chlorite, actinolite, sphene, and calcite. These metamorphic rocks are intruded by altered, fine-grained diorite and by medium-grained granodiorite granophyre east of Jibal al Khusayyayn, and by similar rocks and cataclastically foliated hornblende quartz diorite south of Shaib Mibari and southeast across Wadi ar Rumah.

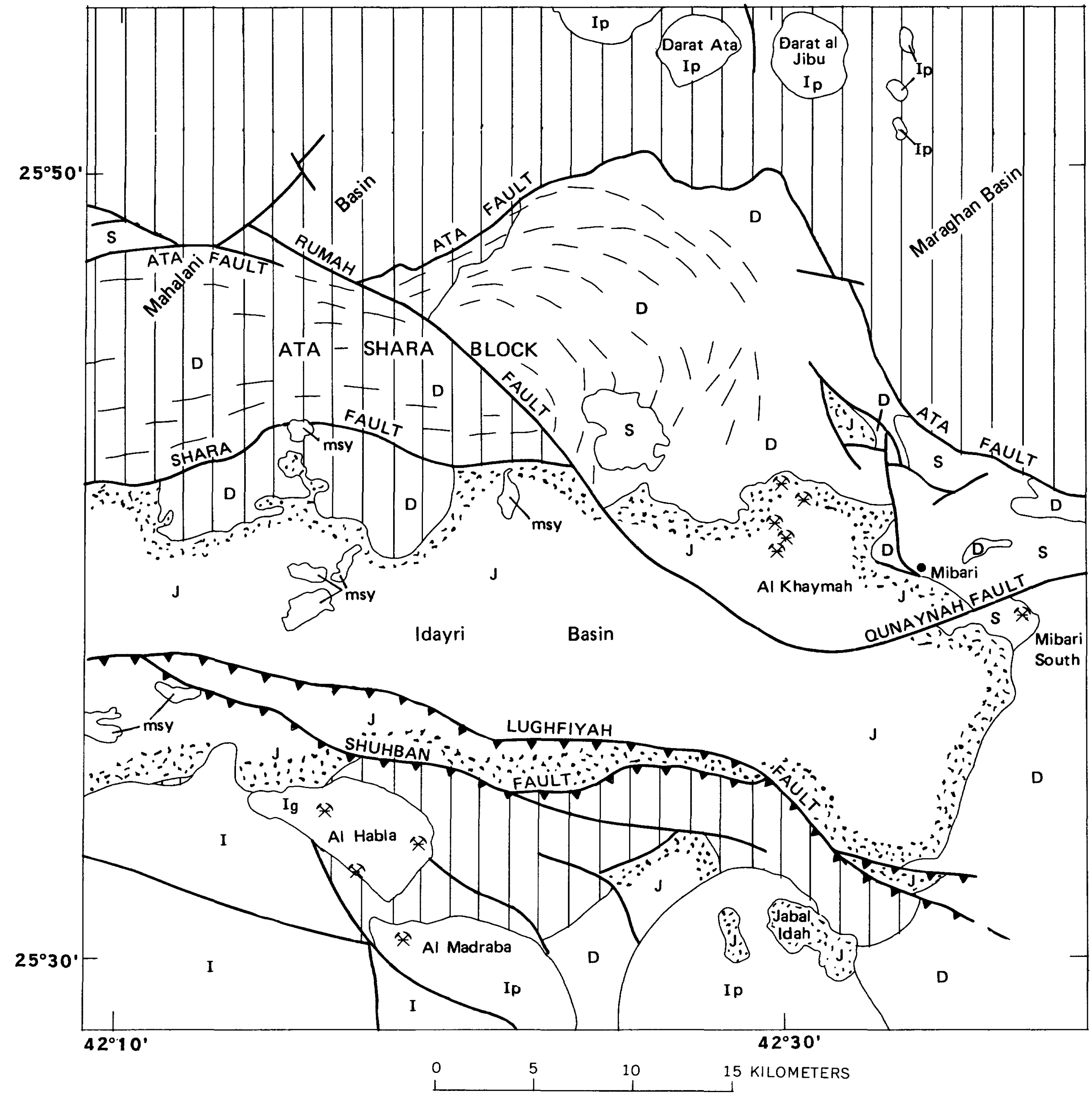

Figure 2.—Geologic sketch map of the Al Khaymah region showing structural elements and depositional basins (after Cole, 1985c). Explanation: Idah suite (I=undivided; Ig=syenogranite; Ip=granodiorite porphyry); sodic microsyenite (msy); Suwaj suite (S); Jurdhawiyah group (J; stipple pattern near base); Murdama group (vertical rule); Dhiran meta-andesite (D); faults (heavy line; teeth on upper plate of reverse fault); trend of penetrative schistosity in Ata-Shara block (short dash pattern.)

The metamorphic rocks of the Dhiran meta-andesite and the various rocks that intrude them (Suwaj suite of Cole, 1985a unpub. data) interpreted to be comagmatic and essentially coeval because they share textural and mineralogical characteristics, contain low amounts of potassium at all levels of silica content, and are similarly altered and metamorphosed. Radiometric ages for diorite and tonalite in adjoining parts of the northeastern Shield indicate the Suwaj suite was emplaced about 690 Ma to 680 Ma ago, although it may be younger in part because the age of the youngest unit (granodiorite granophyre) has not been determined (Cole and Hedge, 1984). Cole (1985a, unpub. data; c) interprets this volcanic-intrusive assemblage (Dhiran-Suwaj terrane) as the product of magma generation during subduction of chemically primitive (oceanic?) crust, and concludes that the Dhiran-Suwaj terrane formed the neo-continental crust of this part of the Shield.

The Dhiran-Suwaj terrane was metamorphosed and deformed during a regional orogenic event whose extent and cause have not yet been established (Cole, 1985c). The uplift and erosion of this deformed terrane, however, is recorded by the thick and widespread clastic deposits of the Murdama group. The Murdama was deposited in several marine basins bounded by uplifts of older rock, and the Al Khaymah region was one such uplift. The hinge line of the flanking Mahalani basin to the northwest and the Maraghan basin to the northeast is the trace of the Ata fault (fig. 2; Cole, 1985a, unpub. data).

An unusually thick wedge of basal Timiriyat conglomerate (Cole, 1985a, unpub. data) in the Jidhayib Marran area (plate 1) records the substantial uplift of the Dhiran-Suwaj terrane in the Al Khaymah region. The Timiriyat grades laterally and up-section into the dominant sandstone unit of the Murdama group and was deposited in a west-trending channel along the southern margin of the Mahalani depositional basin. Limestone is also common near the base of the Murdama, and it forms a thick, well-bedded unit at Jibal ash Shuhban on the northern margin of the separate Jarir depositional basin south of Jabal Bidan (plate 1). Carbonate deposition is also represented by limestone beds and abundant calcareous cement in Murdama sandstone north of Al Khaymah along the southern margin of the Mahalani basin (Cole, 1985a, unpub. data). The age of the Murdama is not precisely known, but it is inferred to be about 670 Ma to 650 Ma old (Cole and Hedge, 1984); deposition was terminated by broad regional folding while the sediments were still saturated with water (Cole, 1985a unpub. data).

The youngest layered-rock unit of the Al Khaymah region is the Jurdhawiyah group, inferred to have been deposited between about 640 Ma and 620 Ma ago, and it rests on the Murdama group and the Dhiran-Suwaj terrane above an irregular unconformity (Cole, 1985a unpub. data, Cole and Hedge, 1984). The Jurdhawiyah consists of calc-alkaline, andesitic volcanic rocks (lava and flow breccia), abundant volcaniclastic conglomerate and sandstone (derived from erosion of contemporaneous volcanic piles), and local layers of andesitic to rhyodacitic tuff. In this region, the Jurdhawiyah was deposited in the west-trending Idayri basin whose northern margin (unconformity) is exposed north of the Al Khaymah ancient workings and south of Wadi ar Rumah (offset by the Qunaynah fault, fig. 2). The southern margin of the basin is largely truncated by the Lughfiyah-Shuhban fault system (Cole, 1985a, unpub. data; b). Contemporaneous with Jurdhawiyah volcanic activity, dikes and plugs of porphyritic andesite and dacite were intruded within and near the margins of the depositional basin, and Cole, 1985a, unpub. data, b) concludes that these intrusions were the magma conduits for Jurdhawiyah volcanoes.

Final deposition of the Jurdhawiyah group in the Idayri basin was accompanied by a complex and protracted deformational event during which the basin was compressed toward the north, all of the major faults were active, and the rocks of the Ata-Shara block were intensely deformed and widely metamorphosed (Cole, 1985a, unpub. data). Structures formed during this event are truncated by simple elliptical plutons of calc-alkaline granodiorite, diorite, and minor syenogranite that define the Idah suite (Cole, 1985a, unpub. data). These bodies were emplaced during a short interval from about 620 Ma to 615 Ma ago (Cole and Hedge, 1984), but are extremely voluminous in this part of the northeastern Shield. In the Al Khaymah area, Idah-suite magmas were chiefly intruded peripheral to the Ata-Shara block, and are represented by the plutons at Darat al Jibu, Darat Ata, and Jabal Idah (fig. 2).

Plutons and small plugs of the Idah suite are regionally associated with quartz-vein gold deposits, particularly where they have intruded Murdama host rock (Kleinkopf and Cole, 1982); Boyle and Howes, 1983; Cole, 1985a, unpub. data). The extensive ancient workings at Sukhaybarat (MODS 406; Boyle and Howes, 1983; Cole 1985a, unpub. data) Al Habla-Al Madraba (MODS 1267, 1286, 3512, 3513; Smith and others, 1984a), and An Najadi (MODS 1272; Smith and others, 1984b) all share this common geologic setting, as do numerous smaller deposits in the region (Kleinkopf and Cole, 1982). As discussed below, the veins in the Al Khaymah ancient workings were probably also formed in the same type of setting, although the Idah-suite intrusion is not exposed, and the host rocks belong to the Jurdhawiyah group.

The structural setting of the Al Khaymah area is complicated by an abundance of faults and folds, but the structures are critical controls to the various types of mineralization, and the very complexity of the structural history may have been an important factor in preparing the ground for mineral deposition. Most of the deformation is interpreted to have occurred during three principal events that coincide with: 1) metamorphism of the Dhiran-Suwaj terrane; 2) termination of Murdama deposition; and 3) termination of Jurdhawiyah deposition (Cole, 1985a, unpub. data; c). The unconformities at the bases of the Murdama group, Jurdhawiyah group, and younger layered rocks (outside the Al Khaymah region) record the waning stages of these events (Cole, 1985a, unpub. data)

The Ata fault is a major crustal boundary and has been repeatedly active during the geologic history of the region. Along most of its trace, the Ata separates unmetamorphosed and gently deformed Murdama on the north from the Dhiran-Suwaj terrane and uncharacteristically deformed and metamorphosed Murdama on the south (Cole, 1985a, unpub. data). Exotic materials consisting of serpentinite, cataclastic breccia with serpentinite matrix, and carbonate-silica rock (listwaenite) derived from the replacement of serpentinite crop out within the Ata fault and suggest that it has great vertical extent (Cole, 1985a, unpub. data). The trace of the Ata fault south of Shaib Mibari is approximately parallel to the regional orientation of pervasive cataclastic foliation in Suwaj-suite quartz diorite (plate 1), and Cole (1985c) suggests that the two structures may have originally formed simultaneously during the earliest regional deformation, possibly about 680 Ma ago. The Ata fault was clearly active during initial deposition of the Murdama group because the unusually thick wedge of Timiriyat conglomerate was deposited in a long-lived channel bounded by the trace of the fault, and the Dhiran-Suwaj terrane of the Al Khaymah area was repeatedly uplifted to provide abundant, coarse clastic debris into that channel (Cole, 1985a, unpub. data).

The Ata fault and the parallel Shara fault west of Wadi ar Rumah were probably active normal faults during initial deposition of the Jurdhawiyah group in the Idayri basin, approximately 640 Ma ago (Cole, 1985a, unpub. data; Cole and Hedge, 1984). The Jurdhawiyah group laps onto the Dhiran-Suwaj terrane in the southern Al Khaymah area, and it laps onto the Murdama farther to the west. Conglomerate beds in the Jurdhawiyah contain locally abundant cobbles and boulders of plutonic and schistose rock from the Dhiran-Suwaj terrane, and clasts of Murdama sandstone are locally common (Cole, 1985a, unpub. data).

The most significant structural event in the Al Khaymah region coincides with the terminal deposition of Jurdhawiyah in the Idayri basin. On the basis of structural and stratigraphic evidence, Cole (1985a, unpub. data) concludes that the Ata-Shara block began moving upward along its bounding faults and, in the process, the Murdama group was metamorphosed, the Dhiran-Suwaj-terrane rocks were re-metamorphosed, and a sub-horizontal chlorite-muscovite schistosity was formed. The schistosity contains a strong north-northeast-trending lineation defined by elongated clasts in the Timiriyat conglomerate and by mineral-streaking in various units. The dip of the schistosity and the plunge of the contained lineation increase progressively toward the bounding Ata and Shara faults and merge with the fault planes. Schistosity follows the irregular trace of the Ata fault between Dulayat al Agharr and Dib Khulayf (plate 1) to define the eastern nose of a structural arch, but its intensity diminishes outward (structurally upward) and most of the Dhiran meta-andesite is non-schistose beneath the Jurdhawiyah unconformity.

The metamorphism that accompanied this intense deformation produced numerous barren quartz veins throughout the Ata-Shara block. These veins consist chiefly of coarse-grained and cockscomb, milky quartz, brown calcite, rare plates of specular hematite, and nebulous inclusions that contain very fine grained chlorite, calcite, and local tourmaline (Cole, 1985a, unpub. data). They are characteristically oriented perpendicular to the lineation and schistosity within the block, and are more common in mechanically competent host rocks. In the Al Khaymah region (fig. 2), these veins form an arcuate set that is roughly circumferential to a point near Jibal al Khusayyayn (plate 1).

These veins and the related metamorphic-deformational episode are known to pre-date the final deposition of the Jurdhawiyah sediments, because the youngest unit of the group, the Shara conglomerate, contains abundant recycled, elongated clasts derived from the Timiriyat conglomerate (Murdama group) in the Ata-Shara block, as well as clasts of schistose Murdama sandstone and quartz-calcite-chlorite-hematite vein material (Cole, 1985a, unpub. data). This event seems related to the northward movement on the Lughfiyah and Shuhban reverse faults that juxtaposed Murdama rocks with Jurdhawiyah rocks along the southern margin of the Idayri depositional basin and produced kilometer-scale chevron folds beneath the fault planes (Cole, 1985a, unpub. data).

The Shara conglomerate, the Shara fault, and the folded Jurdhawiyah group are intruded by irregular plugs and dikes of sodic microsyenite north of Dawbah and Al Ifayhid (plate 1). Cole (1985a, unpub. data) speculates that these unusual rocks (composed of 85 percent oligoclase, 15 per cent quartz, and trace amount of biotite and magnetite) may have been generated by partial melting of Dhiran-Suwaj-type rocks during this deformational episode. These small amounts of magma may have been produced by frictional heating along the major fault zones because, in the larger region (Cole, 1985, unpub. data, c), they are only present in proximity to these faults.

The elliptical plutons and stocks of the Idah suite, emplaced 620 Ma to 615 Ma ago, crosscut all of the structures formed during this last major deformational episode, as exemplified by the syenogranite porphyry pluton at Al Habla and the granodiorite porphyry pluton at Al Madraba (plate 1; Cole, 1985a, unpub. data; Smith and others, 1984a). Magmas of this suite are regionally associated with quartz-vein gold deposits, as noted above.

The gold-bearing veins in the Al Khaymah ancient workings are believed to have formed when the Idah suite was emplaced, even though there is no surface expression of an intrusion.

The trend of the Al Khaymah veins is uniformly north and northwest and is similar to the dominant orientation of gold-bearing veins associated with the Idah suite intrusions (Kleinkopf and Cole, 1982; Cole, 1985c). Although some of the older metamorphic quartz veins in the northern Al Khaymah region have a similar trend (especially east of Jibal al Khusayyayn), these barren veins are more variably oriented and their mineralogy and texture are different from the gold-bearing veins. Although only reconnaissance study has been made, Cole (1985b) suggests that the two types of veins may be further distinguished by outcrop-scale structural relationships: the barren veins are perpendicular to the local schistosity and lineation and are preferentially located in competent rocks (Suwaj-suite plutonic rocks and dense Dhiran meta-andesite), whereas the trend of gold-bearing veins is largely independent of host rock lithology and structure.

No plutonic body is exposed in the vicinity of the Al Khaymah ancient workings, and yet the deposit is very similar to others in the northeastern Shield where gold-bearing quartz-pyrite-chalcopyrite veins are localized near the hornfelsed contacts of Idah-suite intrusions. Smith and Samater (this report) note that diorite dikes, locally associated with some of the vein zones, may indicate a larger intrusion in the subsurface. Plate 2 shows skeletal, contoured magnetic-intensity data (ARGAS, 1967) for the area of the southern Al Khaymah workings that illustrates a circular magnetic high flanked by two discrete lows. These data are similar to the anomaly patterns produced by magnetic hornfelses near Idah-suite stocks in the region (Cole, 1985a, unpub. data, c), and suggest the possibility of a shallow, buried stock. To date, however, no definitive evidence of contact metamorphism has been detected in the Jurdhawiyah group rocks.

In summary, the rocks of the Dhiran-Suwaj terrane in the Al Khaymah region have behaved as a relatively rigid block throughout much of the geologic history of the area. Several periods of significant movement on the bounding Ata fault and on the Shara, Rumah, and Qunaynah faults have made the Al Khaymah region (the western Ata-Shara block) a source for Murdama sediments to the Mahalani and Maraghan basins, and a minor source for Jurdhawiyah sediments in the Idayri basin (fig. 2).

The Ata fault is most likely a major crustal structure along which sub-crustal ultramafic materials (serpentinite) were emplaced and altered to listwaenite. The timing and significance of the silicification, stockwork veining, and moderate copper mineralization at Mibari and Mibari South are not clear, although they seem to be localized in the Dhiran-Suwaj terrane and probably pre-date the Jurdhawiyah group.

Abundant quartz veins in the Ata-Shara block, including the quartz plugs at Jibal al Khusayyayn and vicinity, clearly formed during the localized deformation and low-grade metamorphism within the block, and appear to be completely barren. The local high values of boron in samples of these veins reflect the growth of tourmaline from boron-rich, connate, marine water in the Murdama (Cole, 1985a, unpub. data) and do not appear to suggest any mineralization process. Similarly, the small plugs of sodic microsyenite west of Wadi ar Rumah have been hydrothermally altered during emplacement (Cole, 1985a, unpub. data; Smith and Samater, this report), but sulfide minerals are absent and their associated mineral potential seems low. Some of the Shara conglomerate adjacent to these plugs has also been altered to assemblages of epidote, calcite, and andradite garnet, but no anomalous metal values have been detected (Cole, 1985a, unpub. data).

The gold-bearing quartz veins in the vicinity of the Al Khaymah ancient workings most probably formed during emplacement of an Idah-suite stock during the interval 620 Ma to 615 Ma ago. This stock is not exposed, but may be located about one kilometer southeast of the southern ancient workings (No.1), as suggested by the pattern of aeromagnetic anomalies. If this model is correct, the abundance of free gold and sulfide minerals and the variety of copper-bearing phases (chalcopyrite, covellite, and bornite(?)) at Al Khaymah, when compared with similar deposits that are exposed at the intrusion level, may be related to its cooler (structurally higher) environment of deposition.

The dominant northerly to northwesterly trend of gold-bearing veins associated with Idah-suite intrusions in this part of the Arabian Shield has been noted (Kleinkopf and Cole, 1982), but its significance is still uncertain. The Idah suite is known to have been emplaced during a time of relative structural quiescence, but immediately following the intense northward-directed compression that deformed the Idayri depositional basin (Cole 1985a, unpub. data, b, c; Cole and Hedge, 1984). Although it is difficult to generalize about stress conditions in large parts of the Shield, it does appear likely in the Al Khaymah region that residual compressive stress may have guided the general orientation of hydrothermal veins. They are dilational fractures and parallel to the direction of maximum compresseive stress inferred from displacements on the Lughfiyah-Shuhban reverse fault system.

THE AL KHAYMAH ANCIENT WORKINGS NO.'S 1 THROUGH 5

The small Al Khaymah ancient workings No.'s 1 through 5 (MODS 3941) are scattered over a distance of about 3.5 km (plates 1 and 2). All veins and dumps were sampled by Samater (table 1). The veins consist of milky quartz with minor ankerite and are generally stained by iron oxides and locally by secondary copper. They locally contain pyrite and chalcopyrite, and gold is ordinarily associated with either of the sulfides, or their limonitic pseudomorphs. In places gold may be found in microfractures near the sulfides. The veins generally trend northwest, dip near vertical, are generally less than 100 m long, and as much as one meter thick. They are hosted in dark-green volcaniclastics and pebble conglomerates of the Jurdhawiyah group that are largely unaffected by hydrothermal alteration. Brief descriptions and analytical results for each of the ancient workings follow.

Working No. 1

Working No. 1 consists of a nearly continuous series of trenches along a strike length of 75 m. A quartz vein about one meter thick, dips nearly vertical, and trends N 15 W along one section of the trench. This vein is milky white and free of sulfides, whereas quartz on dumps is generally iron stained and crudely banded. Chalcopyrite and pyrite, or their limonitic pseudomorphs, are distributed locally in minor amounts, and associated free gold in blebs as much as 0.5 mm diameter, or along microfractures, was observed in several places. The quartz on dumps is locally vuggy and coarsely crystalline.

Host rocks are dark-green volcaniclastics with individual clasts as much as 0.5 cm in diameter. An aplite dike intrudes volcanic rocks in one section adjacent to the workings.

Analytical data for six quartz samples collected along the dumps are shown in table 1. Repeat gold analyses for individual samples demonstrate the extremely erratic nature of gold distribution in quartz. Three 10-gram splits of sample 200743 assayed as high as 62.6 ppm gold and as low as 5.4 ppm. Silver values for the entire workings range from nil to 2.3 ppm.

Working No. 2

Working No. 2 is 20 m along strike N 15 W, and discloses no vein in outcrop. Quartz on dumps is milky white and contains few sulfides. Host rocks are dark-green pebble conglomerates unaffected by hydrothermal alteration.

Two quartz samples from the dumps give gold values for repeated assays of 54.2, 47.4, and 52.0 ppm, and 3.7, 3.0, and 2.4 ppm (table 1). Silver values are low. These assays are thought to reasonably represent the gold content of the samples.

Working No. 3

Working No. 3 consists of two small trenches separated by about 200 m. The 10-m-long northeast trench is presently filled with sand and mine rubble. Quartz on dumps displays minor iron and copper staining. The 10-m-long southwest trench contains part of a quartz vein that strikes about N 30 W and is approximately 50 m long. Quartz on dumps is slightly copper stained. Quartz veins are hosted by green to purple volcaniclastic rocks with clasts as much as 1 cm in diameter.

Two quartz samples from dumps of the northeast trench give 3.7, 3.4, and 9.2 ppm; and 3.4, 2.7, and 4.4 ppm gold for repeated assays (table 1). One sample from the southwest trench, that was not re-assayed, contained 0.4 ppm gold and 0.2 ppm silver.

These assay values are not greatly divergent and are considered to be reasonably representative of the true gold content of the samples.

Working No. 4

At working No. 4, the quartz vein is about 100 m long with 50 m worked extensively. The vein strikes N 5 W, and in the worked southern part quartz on dumps contains chalcopyrite, pyrite, and visible gold. The relatively unworked northern part of the vein is milky white and contains minor sulfides. The vein in outcrop averages less than one meter thick and dips gently. Host rocks are dark-green volcanics.

Seven samples collected from both dumps and vein give erratic results for gold values in repeated assaying (table 1). Differences in repeated assays are as great as 4.0 to 68.0 ppm gold. Silver values are low.

Working No. 5

Working No. 5 is approximately 50 m long and trends N 15 W. Quartz on dumps is slightly to moderately iron and copper stained. Host rocks are dark-green pebble conglomerates. These workings and adjacent quartz veins were mapped in detail (figure 3).

Repeated gold assays of five quartz samples from dumps also give highly erratic results (table 1). Variation in some samples are as great as 0.7 to 35.6 ppm gold. Silver values are low.

Conclusions

Quartz on dumps of the ancient workings at Al Khaymah is not typical of other gold deposits in quadrangles 25F and 26F when considering gold grades, gold/silver ratios, the amount of visible gold, and accessory elements or minerals. In fact, quartz on dumps of some of the ancient workings displays an inordinate amount of gold; an anomalous condition for the region, because the quartz was probably classed as waste by the ancient miners. These conditions are in direct contrast to those of An Najadi, (fig. 1; Smith and others, 1984) where quartz veins were mined over a very large area, and methodical sampling of the quartz on dumps gave very low gold values. Although gold/silver ratios for quartz veins at Al Khaymah were not calculated because of erratic repeated gold assays, they obviously are much higher than those at Al Habla (Smith and others, 1984), the An Najadi-Wuday region (Smith and others, 1984), or Meshaheed (Smith and Samater, 1984), but the only significance of the phenomenon that can be attached at this time is that gold and silver deposition was atypical for the region. Boyle (1979), after citing many studies of gold/silver ratios throughout the world, came to the conclusion that no universal trends can be observed concerning increase or decrease of ratios with depth, temperature, pressure, or zoning. Arsenic in trace amounts, and antimony, in places in the form of stibnite, are common accessory elements in this part of the Shield, but are not found in significant amounts in the Al Khaymah quartz veins. At nearby Al Habla (fig. 1) gold-bearing quartz veins contain minor amounts of chalcopyrite, sphalerite, and galena; and arsenic values as much as several hundred parts per million are found in the veins in the outlying parts of the mineral zone. But only chalcopyrite, and perhaps bornite, are the associate minerals of gold in quartz at Al Khaymah, and the region in general is decidedly a relatively copper-rich zone. Semi-quantitative spectrographic analyses show boron values ranging from 10 to 1000 ppm in samples from ancient workings No.'s 4 and 5, in the northern part of the study area, but boron is not an important element in other gold deposits in this part of the Arabian Shield.

QUARTZ VEINS NEAR AL KHAYMAH ANCIENT WORKING NO.5

Preliminary study of the Al Khaymah ancient workings disclosed a series of unworked quartz veins near working No. 5 (plate 2, fig. 3). Because these veins contain free gold and appeared to be compositionally similar to the veins that had been worked, it was decided that a detailed mapping and sampling study was warranted.

Geology

The quartz veins near Al Khaymah ancient working No. 5 (MODS 3941) strike northwest over a 250 by 250 m area of chloritized and epidotized pebble conglomerate (fig. 3). Medium-grained diorite dikes cut by quartz veins trend northeast across the vein system. One sample of dike material appearing unaltered in hand specimen, displays intense sericitic alteration, mainly of the feldspars, in thin section.

The saccharoidal to coarsely crystalline quartz veins are generally stained by iron, and locally by copper. They range from white to tan, but locally, quartz is clear and vugs contain terminated crystals. Veins range in thickness from a few centimeters to as much as 4 m and parts of veins have been sheared into pods. Medium brown ankerite is a major constituent in parts of the vein system, and locally the quartz contains irregular streaks of potassium feldspar. Limited amounts of pyrite and chalcopyrite are distributed erratically throughout the quartz. Although gold locally rims some sulfide minerals, or is in limonitic pseudomorphs, other gold is not associated with sulfides, because some samples with higher gold grade appear to

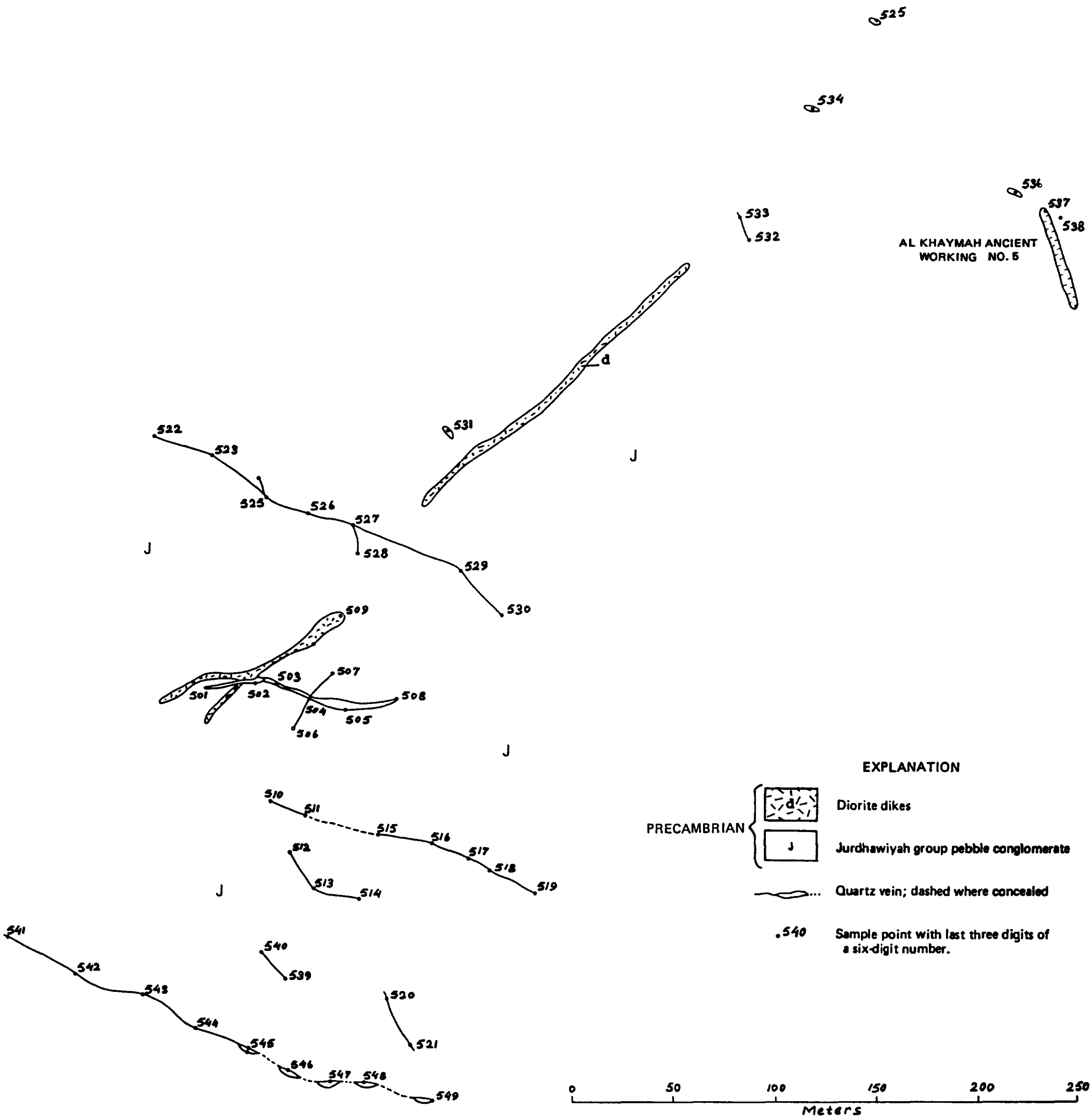

Figure 3.--Detailed geology and sample map of quartz veins near Al Khaymah ancient working No. 5.

be sulfide-free. Hydrothermal alteration of the wall rocks was not noted, although vein selvages are normally covered by vein rubble which makes observation difficult.

Summary of analytical data

Forty-four chip samples were collected across quartz veins, four samples were gathered from quartz dump material, and one sample was chipped from a diorite dike (table 3, fig. 3). Repeat assays give erratic results with differences of less than 0.05 to as much as 42.0 ppm gold. Gold was not detected in one vein (samples 200510 to 200519), although the vein in most respects appeared similar to others in the area. In general, the higher grade samples exhibit slightly more copper staining and more limonite. Streaks of potassium feldspar in veins do not correlate with areas of higher gold content. Some of the higher gold values were obtained in narrow splits of principal veins. The gold content is generally distributed very erratically. Silver values were consistently low throughout.

Spectrographic analyses indicate a paucity of accessory elements in the quartz veins, with copper generally no more than 100 ppm. One diorite dike sample assays 1000 ppm barium and 100 ppm copper. The high barium content may be reflect the amount of sericite present as an alteration product. Sericitic haloes around numerous ore deposits worldwide contain high barium values.

RECONNAISSANCE QUARTZ-VEIN SAMPLING

Preliminary reconnaissance studies of the Al Khaymah region disclosed numerous unworked quartz veins in a broad zone extending west and north of the group of ancient mine workings (MODS 3941; plate 2). Sampling of a few of the veins revealed that they contain visible gold, in places in appreciable amounts. Consequently, reconnaissance-type sampling was initiated to gain information relating to their size, distribution, description, and gold content. Numerous quartz vein samples were gathered over a wide area in a short time, but it must be emphasized that the reconnaissance sampling was by no means thorough. Many veins were not sampled, and large areas remain unexplored. The studies were made only to gain preliminary information concerning the gold potential of the region, and if encouraging, to recommend further, more detailed work.

Geology

Most of the veins strike northwest, and are less than 100 m long and less than 1 m thick. They contain small amounts of pyrite, and locally chalcopyrite. Brown ankerite in a curved crystalline habit, as well as calcite, and manganese oxide minerals are common. In places, the quartz contains a dark green unidentified mineral. Although generally thinly dispersed, the veins do form clusters in some areas. Free gold, commonly associated with sulfides, was noted in several places, but no definite criteria were established to differentiate gold-bearing from barren quartz veins.

Summary of analytical results

Sixty-six quartz vein samples were collected over a wide area in the Al Khaymah region. Plate 2 shows sample locations and designates those samples containing 3 ppm gold, or higher.

Analytical data (table 1) indicate that gold-bearing quartz veins, including those worked by ancient miners, are in a zone approximately 6 km in diameter. The data also show that repeated assay values for gold are erratic in much the same manner as those for dump or detailed quartz-vein sampling. For example, assay differences as much as 119.2 to nil ppm gold (table 1), indicate that the gold in quartz is distributed unevenly in a coarse, particulate form. Silver values are low in all of the samples, as are lead and zinc. Copper values reach 150 ppm, which is surprisingly low because chalcopyrite and copper staining, though not abundant, are prevalent in the veins. As much as 500 ppm boron is in some of the quartz veins north of the ancient workings.

RECONNAISSANCE ROCK-CHIP SAMPLING

Reconnaissance rock-chip sampling was carried out in the Al Khaymah region for the following purposes:

1. to investigate areas designated by wadi sediment sampling as anomalous in an element;

2. to study the geochemistry of various rocks in the Ata fault system;

3. to study rocks affected by hydrothermal alteration, especially those designated as microsyenite by Cole (1984a).

Areas designated as anomalous by wadi sediment sampling

Wadi sediment sampling in the Uqlat as Suqur quadrangle had identified a large area in the southwestern part of the study area as anomalous in silver (W. R. Miller, verbal communication). In addition, Miller asked the authors to examine and sample an area south of Wadi ar Rumah and adjacent to the east bank of Wadi al Jarir where anomalous amounts of chrome and nickel had been found in wadi sediment sampling (plate 2).

Reconnaissance rock chip sampling and observation of the rocks in the southwestern part of the area disclosed a thick succession of clastic rocks consisting of pebble to cobble conglomerate, graywacke, sandstone, and siltstone interlayered with volcaniclastic rocks of intermediate composition. All of the layered rocks are propylitically altered, and epidote is prevalent in the region. Twenty-five rock-chip samples (plate 2), analyzed by atomic absorption and spectrographic methods, indicate no anomalies (plate 2; table 2). Miller subsequently re-checked the wadi sediment samples, found no silver anomalies, and postulated an instrument error in the earlier findings.

The area east and adjacent to Wadi al Jarir where nearby chrome anomalies were found in sediments (plate 2) is underlain by brown to gray carbonate rocks locally intruded by diabase dikes. Three samples of the carbonates contained no anomalous metal values, but one sample of a diabase dike containing disseminated pyrite contained 1000 ppm chromium.

Geochemistry of rocks in the Ata fault system

The Ata fault system extends along the northern and eastern border of the Al Khaymah region (plate 2) and is a major structural component of the region (Cole, 1985a unpub. data). Faults along much of the system can be traced on aerial photographs since rocks in faults are comparatively more erosion resistant and form slight ridges in a generally flat, peneplained surface. Rocks along much of the system are silicified, but other zones contain brown carbonate lenses that are locally silicified and cut by quartz stockworks. The carbonate lenses (listwaenite) contain disseminated chrome and iron spinels, and in many places are stained by a secondary nickel mineral. These lenses resemble those along the Raha fault system in the Jabal as Silsilah quadrangle to the northeast (du Bray, in press, Smith and Samater, unpublished data) and probably result from the hydrothermal alteration of serpentine, an origin proposed for some of the carbonate rocks along the Al Amar-Idsas fault (Thekair, 1976). In such an environment, where great volumes of silica and iron are replaced by carbonates, conditions are probably optimal for the mobilization and concentration of precious metals and sulfide minerals; and indeed, Stoeser and others, in press), in their study of the tectonic evolution of the Arabian Shield, point up the close spatial relationship of large fault systems (suture zones) containing serpentine and listwaenite with deposits of this type. Thekair (1976), in a geochemical study of various rock types in the Al Amar-Idsas fault system, found that carbonatized rocks of the Al Amar area contain two to three times more gold than equivalent ultramafic rocks worldwide, and also, that the gold content increases concomitantly with the intensity of carbonatization. Furthermore, it is evident from a literature scan that a number of deposits, especially gold, are found in or near listwaenite lenses along suture zones in the Arabian Shield (Thekair, 1976; Labbe, 1984; du Bray, in press; Delfour, 1983), and that numerous gold-bearing quartz veins are spatially associated with suture zones bearing serpentinites (Worl, 1980; Wells, 1982). Consequently, reconnaissance-type sampling of the Ata fault system was initiated to determine its geochemical characteristics.

Twenty-four samples including listwaenite and silicified rock were collected along the fault system. Plate 2 shows notable amounts of elements detected in the samples, and as would be expected, all of the listwaenite samples contain chromium in the range 500-5000 ppm (table 2). Assay by atomic absorption methods detected no gold or silver in most of the samples from the fault system, but samples from listwaenite lenses along the northern part contain arsenic in the range 450-1200 ppm, and one sample contains 374 ppm antimony. One sample from a large carbonate lens south of Shaib Mibari (plate 2) contains 200 ppm lead. Six samples collected from the silicified rocks in faults contain no notable concentrations of metals, but two samples (200717 and 200718) from a south-trending split of the fault system near Shaib Jukhaydib contain 150 ppm zinc; and 2000 ppm lead, 300 ppm antimony, and 200 ppm tin, respectively.

Other hydrothermally altered rocks in the Al Khaymah region

Cole (1985a, unpub. data) mapped several bodies, particularly near Jabal al Idayri (plate 2), of a peculiar rock termed sodic microsyenite that consists of plagioclase with minor quartz and magnetite. All of these rocks are hydrothermally altered to quartz with lesser kaolin and minor carbonate and have a distinctive mottled white to cream color. In thin section they are finely crystalline rocks with relicts of feldspars and a large amount of late quartz introduced along fractures. The mafic minerals are largely altered to epidote and chlorite, and the feldspars are altered to kaolin.

A separate zone of intensely silicified rocks at Jabal al Khusayyayn (plate 2) contains minor tourmaline (Cole, 1985a, unpub. data). All of the hydrothermally altered rocks in both areas are essentially devoid of pyrite.

Rock-chip sampling in the altered area at Jabal al Khusayyayn found one sample with a value of 1000 ppm boron and two samples with values of 200 ppm molybdenum. Sampling of the altered rocks southwest of the wadi found boron in the 100-200 ppm range, and one sample contains 200 ppm lead.

THE MIBARI STOCKWORK ZONE

The Mibari stockwork zone (MODS 3944), found during our reconnaissance quartz-vein sampling in the region, is a large area of quartz stockworks and veins stained moderately with copper. Twenty-eight samples were collected for chemical analyses and petrographic work.

Geology

The south-trending split of the Ata fault system radically changes character south of Shaib al Jukhaydib (plate 2). Between sample numbers 200658 and 200721 the fault is a complex of small apophyses, or dikes of granodiorite, silicified and epidotized rock, and irregular quartz veins bearing secondary copper. A granodiorite (Sgg) pluton cut by a quartz stockwork system adjoins this zone and trends southeast at least as far as Wadi ar Rumah. The entire zone is about 3 km long and may represent another split of the Ata fault. In addition, two small ancient workings are south of the wadi on approximately the same trend. Apparently, the main branch of the fault bypasses the granodiorite on the west and joins a southeast-trending fault where pink rhyolitic dikes intrude the fault and delineate the trend in an area on the north bank of the wadi (plate 2).

Quartz stockwork veinlets in the granodiorite are as much as 1 cm thick, and are generally oriented N 70 W. The quartz is gray and contains tiny, thinly dispersed chalcopyrite and pyrite crystals. The granodiorite in outcrop is reddish-brown and displays abundant epidote as clots and patches. Mafic minerals are altered to chlorite and epidote. Several stained slabs of this material, however, indicate that margins along quartz veinlets are altered to potassium feldspar, and that the feldspar is disseminated throughout the rock. Thin sections indicate that the quartz has invaded much of the rock as tiny veinlets that are locally cut by calcite. At the southeast end of the outcropping granodiorite are a series of gray quartz veins that locally contain potassium feldspar and small chalcopyrite crystals, strike N 50 W, are 50 to 60 cm thick, and are no more than 100 m in length. They appear similar in character to the quartz in stockworks.

The two ancient workings south of Wadi ar Rumah, about 150 m apart, (Mibari South, MODS 3943) are in green-gray volcanic rocks. The northeast trench is 40 m long and trends N 65 W. A few fist-sized pieces of copper-stained gossan are strewn along the waste dumps, but the workings are generally covered by mine rubble and drifted sand. The southwest trench is 30 m long and trends N 85 W in the same volcanic rock. Lesser copper-stained gossan was observed here, but the workings are also mostly covered by sand and mine rubble. Examination of rock northwest of the workings and on the same trend as the stockwork zone (plate 2) revealed a fine- to medium-crystalline, light-gray intrusive rock with minor quartz. Evidently the stockwork does not extend southeast across Wadi ar Rumah.

Brief studies along the northwest extension of the southeast-trending fault (plate 2) disclosed a zone consisting mainly of silicified rocks, some of which show quartz crystal relicts. Pyrite is sparsely disseminated throughout the zone. A series of quartz veins and stockworks locally contain disseminated pyrite and moderate copper staining.

Summary of analytical data

Twenty-two quartz stockwork and vein samples were collected along the south extension of the Ata fault system (plate 2; table 1). Gold values for all samples are low and range from nil to 0.9 ppm; silver ranges from nil to 1.9 ppm. Copper values, which undoubtedly represent mostly oxidized minerals, are as much as 10,000 ppm, and the higher grade copper samples were obtained from quartz stockworks in granodiorite. Molybdenum values are erratic, ranging between nil and 100 ppm.

Six samples were collected west of Shaib Jukhaydib on the extension of the southeast-trending fault (plate 2). Five of the samples were devoid of any notable values, but one sample contained 3000 ppm copper and 300 ppm lead.

One copper-stained gossan sample each from Mibari South trenches assayed 0.8 and 2.1 ppm gold; 4.5 and 3.5 ppm silver; and 11,000 and 34,000 ppm copper. Molybdenum and antimony are also present in amounts of 300 and 500 ppm, respectively.

CONCLUSIONS AND RECOMMENDATIONS

These studies have delineated an area of gold-bearing quartz veins centering on the Al Khaymah group of ancient workings, and extending several kilometers west and north. Gold is generally associated with sulfides in the veins, and the area is unusual for the amount of visible gold, both in quartz on dumps of ancient workings, and in unworked quartz veins. Reconnaissance studies of the veins have indicated that they are narrow, of short strike length, and in many places thinly dispersed. However, in some zones there are clusters of veins, and the region needs more detailed sampling and mapping in an attempt to delineate zones of gold-quartz concentrations. Detailed mapping and sampling of quartz veins in one small area, quartz samples from ancient dumps, and reconnaissance quartz-vein sampling has shown that the veins locally contain gold in appreciable amounts, although repeated assaying of many samples give highly erratic results. Probably the gold is unevenly distributed in coarse particles, and as a result, average gold grades cannot be given with the present data. The best means of obtaining average gold grades would be to obtain large bulk samples of vein material.

Diorite dikes and small apophyses have been mapped in the region, and aeromagnetic maps indicate the possibility of a near surface pluton in the south Al Khaymah area. As the intrusive and subsequent hydrothermal activity may have caused gold-quartz deposition, ground magnetic studies might detect subsurface cupolas where a greater concentration of gold could be expected.

The few samples collected from the Ata fault system contained what were probably anomalous amounts in chromium, nickel, lead, copper, arsenic, antimony, zinc, and tin. A copper-bearing quartz stockwork zone in granodiorite appears also to be associated with the system. Large volumes of serpentine have been altered to carbonate within the fault system, silica has been remobilized to form stockworks, and undoubtedly, metals have been mobilized and concentrated during this process. Follow-up work should include much more detailed mapping and sampling.

DATA STORAGE

Petrographic descriptions, sample locations, and results of chemical analyses are stored in Data-File USGS-DF-04-40 (Smith and Samater, 1984) in the Jeddah office of the U. S. Geological Survey Saudi Arabian Mission.

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

3941	Al Khaymah	Au	prospect	new input 5/84
3944	Mibari	Cu, Mo	prospect	new input 5/84
3943	Mibari South	Au, Cu	prospect	new input 5/84

Table 1.--Analytical data for samples of quartz from ancient dumps, quartz veins, and a quartz stockwork zone in the Al Khaymah region.

[The three values for gold shown are analytical data for an original and two repeat assays. Nil indicates none detected, tr indicates trace amounts detected. Values in parts per million.]

Sample number	Atomic absorption analyses				Spectrographic analyses
	Au	Au	Au	Ag	Notable values
			Working No. 1		
200738	nil	1.2	nil	nil	
200739	0.5	0.3	0.4	nil	
200740	1.6	2.6	30.0	0.2	Cu-150, Zn-300
200741	2.6	13.8	1.2	0.6	Zn-500
200742	6.6	13.4	56.0	1.7	Zn-700
200743	62.6	6.4	5.4	2.3	Zn-2000
			Working No. 2		
200746	52.2	47.4	52.0	1.7	Cu-500
200747	3.7	3.0	2.4	0.4	
			Working No. 3		
200744	3.7	3.4	9.2	0.4	
200745	3.4	2.7	4.4	0.7	Cu-300
			Working No. 4		
200726	29.2	68.0	4.0	0.5	B-1000
200727	2.2	1.0	23.0	0.2	B-500
200728	0.7	0.6	0.8	0.1	B-500
200729	10.6	20.6	4.4	0.1	Cu-500
200730	nil	0.6	0.2	0.1	B-300
200731	0.2	1.2	0.4	0.6	B-200
200732	0.8	7.6	1.0	tr	B-300
			Working No. 5		
200733	0.7	35.6	6.6	0.1	
200734	0.6	0.6	1.0	nil	
200735	6.0	6.0	7.2	0.1	
200736	3.7	6.6	4.6	tr	
200737	8.0	14.8	18.8	0.9	Cu-700

Table 1.--Analytical data of quartz - Continued

Reconnaissance quartz-vein sampling

200550	0.3	3.8	8.6	0.7	
200551	2.3	6.6	19.1	1.6	Cu-150
200552	3.1	nil	nil	0.1	
200553	nil	nil	nil	0.2	
200554	0.1	0.4	0.4	0.6	
200555	nil	nil	nil	0.1	
200556	nil	nil	nil	0.1	
200557	nil	nil	nil	0.1	
200558	0.3	nil	nil	nil	
200559	0.8	nil	nil	tr	
200560	119.2	nil	nil	nil	
200561	nil	nil	nil	0.1	
200562	0.1	nil	nil	nil	
200563	nil	nil	nil	nil	
200564	nil	nil	nil	0.1	
200565	nil	nil	nil	0.1	
200566	tr	nil	nil	nil	
200567	tr	nil	nil	0.1	
200568	5.5	nil	nil	nil	
200569	tr	2.0	2.4	1.3	
200570	nil	90.0	86.0	1.0	
200571	3.1	nil	nil	nil	
200572	tr	3.8	6.2	1.1	
200573	15.6	10.8	11.2	0.7	
200574	0.3	nil	nil	0.1	
200575	36.8	34.0	33.0	2.4	B-500
200576	161.6	184.0	156.0	13.6	B-500
200577	0.7	nil	nil	0.1	B-500
200578	tr	nil	nil	tr	
200579	tr	nil	nil	nil	
200580	tr	nil	nil	tr	B-200
200581	tr	nil	nil	tr	B-150
200582	0.3	0.3	0.4	nil	
200583	nil	nil	nil	nil	
200584	tr	nil	nil	nil	B-200
200585	tr	nil	nil	0.1	
200586	nil	nil	nil	nil	B-200, Cu-150
200587	nil	nil	nil	nil	
200588	0.1	nil	nil	0.1	B-500
200589	tr	nil	nil	nil	
200590	tr	nil	nil	tr	B-150
200591	tr	nil	nil	0.2	B-500
200592	0.2	nil	nil	0.4	B-200
200593	tr	nil	nil	0.3	B-1500
200594	0.6	nil	nil	0.6	B-500
200595	tr	nil	nil	nil	
200596	0.5	0.2	0.3	nil	
200597	1.6	nil	nil	0.1	
200598	0.5	nil	nil	0.1	
200599	tr			nil	
200314	22.3			4.6	

Table 1.--Analytical data of quarts - Continued

		Mibari quartz stockwork zone	
200653	0.1	0.5	Cu-150
200654	0.1	tr	Cu-200
200655	tr	tr	Cu-300
200656	tr	tr	Cu-1500, Mo-70
200657	0.1	tr	Cu-1000, Mo-100
200658	0.3	0.5	Cu-2000
200659	0.1	0.5	Cu-700
200660	0.2	0.8	Cu-2000
200661	0.1	tr	Cu-1000
200662	0.6	1.9	Cu-10000
200663	0.9	tr	Cu-1000
200664	0.1	tr	Cu-300
200665	tr	tr	Cu-500
200668	nil	0.1	
200719	0.1	0.5	Cu-500
200720	tr	tr	
200721	nil	0.9	
		Quartz veins-southeast area	
200605	0.1	nil	
200606	0.1	nil	
200607	0.1	2.5	Cu-3000
200608	0.1	nil	
200609	tr	nil	
200666	tr	tr	
200667	tr	tr	
200722	tr	tr	
200723	nil	tr	Cu-300
200724	0.4	tr	Cu-300
200725	tr	1.2	Cu-200
		Gossan from dumps of two workings south of Wadi ar Rimah	
147712	0.8	4.5	Cu-11000 Mo-300
147713	2.1	3.5	Cu-34000, Sb-500

Table 2.--Analytical data for rock-chip sampling in the Al Khaymah region.
[Values in parts per million. Leaders indicate none detected; tr indicates trace values detected.]

Sample number	Description	A.A. analyses		Spectrographic analyses
		Au	Ag	Notable values
200600	Intrusive?, silica and chlorite alteration.	0.06	tr	
200601	Listwaenite, brown-violet	tr	-	Cr-<5000. Ni-500
200602	Nearly pure silica	0.06	-	Cr-1500, Ni-200
200603	As above	0.06	-	
200604	Siliceous, with large amphiboles	tr	-	Ba-2000, Sr-1000
200610	Carbonate, brown, massive	0.06	0.1	
200611	Diabase dikes with dissem. py., intrudes carbonates	-	-	Cr-1000
200612	Carbonate rock, light gray	-	-	
200613	Carbonate rock, dark gray	0.08	-	
200617	Siliceous, with chlorite-alt. product	0.06	-	Mo-200
200618	As above, sparse FeO	0.08	0.2	Mo-200
200619	As above	0.08	-	Mo-30
200620	Schist, kaolinized	0.06	-	Mo-70
200622	Silicified rock	0.06	-	
200623	As above, with secondary pyrox.	0.06	-	
200624	Conglomerate	0.06	-	
200625	Conglomerate, dark green	tr	-	
200626	Conglomerate, pebble, greenish	tr	-	
200627	Conglomerate with tuff	0.06	-	
200628	Tuff, red-brown, with epidote	tr	-	
200629	Conglomerate, greenish	tr	-	
200630	Siltstone, layer above boulder conglomerate	tr	-	
200631	Tuff, porphyritic	tr	-	
200632	Conglomerate, pebble to cobble	0.08	-	
200633	Tuff, plagioclase phenocrysts	0.06	-	
200634	Conglomerate, pebble	0.06	-	
200635	Conglomerate, pebble	tr	-	
200636	Tuff, plagioclase phenocrysts	0.06	-	

Table 2.--Analytical data for rock-chip sampling--Continued

200639	Conglomerate, silicified	tr	-	
200640	Silicified rock, sparse FeO	tr	-	B-1000, Mo-30
200641	Silicified rock, very sparse py.	tr	-	
200642	Silicified and epidotized rock	-	-	Ba-1000, B-70
200643	Detrital rock?, silicified and kaolinized	-	-	Ba-1500, B-100
200644	Volcanic, silicified, kaolinized, epidotized	-	-	Ba-1500
200645	As above	-	-	Ba-1500, B-100
200646	As above	-	-	Ba-1500, B-70
200647	Carbonate rock, silicified	-	-	
200649	Rhyolite	-	-	
200651	Silicified rock	-	-	
200652	Conglomerate, pebble	-	-	
200653	Volcanic, plagioclase porphyry	0.1	0.5	Mo-15
200670	Breccia zone, silicified	0.08	-	
200671	Listwaenite, brown, isolated serpentine residuals	-	-	As-500, Cr-1500 Ni-700, Pb-150
200672	Listwaenite with nickel stain	-	-	As-700, Cr-2000, Ni-700
200673	Sediments?, siliceous, along fault	-	-	Pb-100
200674	Listwaenite, with fine quartz stockwork	-	-	Cr-3000, Ni-1000
200675	Listwaenite with nickel stain and fine quartz stockwork	-	-	Cr-2000, Ni-700
200676	Silicified, along fault	-	-	
200677	Listwaenite, fine quartz stockwork	-	-	As-1500, Cr-1500 Ni-1000
200678	Listwaenite, moderately silic	-	-	As-700, Cr-1000, Ni-700
200679	As above	-	-	Cr-1500, Ni-700
200680	As above	-	-	As-1000, B-200, Cr-700, Ni-700
200681	Listwaenite with abundant secondary nickel	-	-	Cr-3000, Ni-2000
200682	Listwaenite, siliceous	-	-	Cr-5000, Ni-1500
200683	Listwaenite, brown	-	-	Pb-200, Cr-500, Ni-200
200684	Listwaenite in large outcrop	-	-	Cr-3000, Ni-1500
200685	Tuff, dense, porphyritic	-	-	Ba-1000
200686	Sandstone, epidotized	-	-	Ba-1500
200687	Graywacke, coarse	-	-	Ba-1500

Table 2.--Continued

200688	Graywacke	-	-	Ba-1500
200689	Graywacke	-	-	Ba-1000
200690	Graywacke	-	-	Ba-1500
200691	Graywacke	-	-	Ba-2000
200692	Graywacke	-	-	Ba-1500
200693	Graywacke	-	-	Ba-1000
200694	Volcanics, few quartz crystals	-	-	Ba-5000
200695	As above	-	-	Ba-3000
200696	As above	-	-	Ba-1000
200697	As above	-	-	Ba-1500
200698	Volcanics?, silicified, with secondary amphiboles	-	-	B-200, Ba-1500
200699	Volcanics?, silicified	-	-	B-300, Pb-100
200700	As above	-	-	B-200, Ba-1500
200701	Volcanics, layered, fine grained	-	-	Ba-1000
200705	Silicified rock	-	-	B-500
200713	Listwaenite, brown carbonate	-	-	
200714	Silicified fault zone	-	-	
200715	Silicified fault zone	-	-	
200716	Diorite, dark gray, fine grained	-	-	Ba-1500
200717	Silicified fault zone	-	-	Zn-150
200718	Fault zone, silicified, with epidote	-	-	Pb-2000, Sb-300, Sn-200, Mo-7

Table 2.--Continued--Atomic absorption analyses for arsenic, antimony and zinc. Values in parts per million. [Leaders indicate none detected; tr indicates trace amounts detected.]

Sample number	As	Sb	Zn
200642	5	-	55
200643	-	-	75
200644	-	-	80
200645	tr	-	55
200646	tr	tr	90
200647	tr	-	6
200649	tr	-	30
200652	5	1	83
200671	450	15	53
200672	740	tr	72
200673	tr	3	85
200674	93	-	75
200675	29	-	35
200676	5	tr	7

Table 2.--Atomic absorption analyses--Continued

Sample number	As	Sb	Zn
200680	1000	33	27
200681	10	8	41
200682	13	5	35
200683	7	7	33
200684	13	-	37
200685	5	-	68
200686	10	-	52
200687	5	-	72
200688	tr	-	72
200689	tr	-	83
200690	10	tr	84
200691	9	-	67
200692	10	tr	84
200693	8	-	74
200694	-	-	81
200695	-	-	78
200696	tr	-	86
200697	tr	-	84
200698	tr	1	70
200699	-	2	70
200700	-	-	72

Table 3.—Analytical data for chip sampling across quartz veins near Al Khaymah ancient working No. 5.

Sample Number	Length (meters)	Au (ppm)	Au (ppm)	Au (ppm)	Ag (ppm)
200501	0.4	0.1	Nil	Nil	Nil
200502	3.0	1.4	11.4	11.8	0.1
200503	(dump)	0.5	1.4	2.1	0.2
200504	1.5	0.4	Nil	<.05	0.1
200505	4.0	2.1	3.6	1.8	0.3
200506	0.3	0.3	1.0	3.6	<0.1
200507	0.3	11.4	Nil	Nil	0.8
200508	0.5	1.2	2.2	4.2	0.1
200509	(diorite)	Nil	1.2	1.0	0.6
200510	0.2	Nil	Nil	Nil	Nil
200511	0.2	<.05	Nil	Nil	Nil
200512	0.2	Nil	Nil	Nil	Nil
200513	0.2	Nil	Nil	Nil	Nil
200514	0.2	Nil	Nil	Nil	Nil
200515	0.4	<.05	Nil	Nil	Nil
200516	1.2	Nil	Nil	Nil	Nil
200517	1.2	Nil	Nil	Nil	0.1
200518	1.0	Nil	Nil	Nil	Nil
200519	0.3	Nil	Nil	Nil	Nil
200520	0.3	0.1	0.5	0.2	Nil
200521	0.3	<.05	Nil	Nil	Nil
200522	1.0	0.5	0.2	4.3	0.1
200523	1.2	3.2	0.9	0.8	0.2
200524	1.2	<.05	Nil	Nil	0.1
200525	0.3	0.3	2.9	Nil	Nil
200526	0.6	0.6	4.6	3.9	0.1
200527	0.5	<.05	Nil	Nil	Nil
200528	0.5	31.8	9.4	12.8	<0.1
200529	0.8	1.1	1.0	3.3	0.2
200530	0.8	0.4	0.2	0.2	0.1
200531	0.4	<.05	Nil	Nil	Nil
200532	0.2	Nil	Nil	Nil	<0.1
200533	0.2	0.2	0.4	Nil	Nil
200534	1.0	0.8	1.0	6.5	0.1
200535	3.0	0.2	0.1	0.2	0.1
200536	(dump)	3.8	3.8	2.6	0.2
200537	(dump)	<.05	1.9	9.2	0.3
200538	(dump)	7.4	2.2	2.2	0.3
200539	0.4	6.1	0.4	0.2	0.1
200540	0.4	0.2	Nil	0.2	Nil
200541	1.0	<.05	0.9	Nil	0.4
200542	1.2	<.05	42.0	11.2	0.8
200543	1.2	0.3	0.1	Nil	0.1
200544	2.0	0.4	36.6	14.6	0.5
200545	1.0	27.6	0.7	0.4	0.1
200546	1.0	<.05	0.3	0.9	0.1
200547	3.0	10.8	Nil	Nil	Nil
200548	3.0	4.9	3.7	Nil	Nil
200549	3.0	<.05	0.2	0.2	Nil

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