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Preliminary report on the gold deposits of the An Najadi-Wuday Region, Samirah and Uqlat As Suqur quadrangles, Kingdom of Saudi Arabia

By

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OF THE

AN NAJADI-WUDAY REGION,

SAMIRAH AND UQLAT AS SUQUR QUADRANGLES,

KINGDOM OF SAUDI ARABIA

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C. W. Smith[1], R. M. Samater, M. A. Hussain, M. A. Basheer, and V. A. Trent [2]

ABSTRACT

A great number of ancient workings on quartz veins in metasediments are in an area 4 km long and as much as 700 m wide at An Najadi. The mining activity was apparently in quest of gold, since the quartz is nearly barren of other metals. Further evidence of ancient activity in gold recovery from quartz is a large area covered by mill tailings and numerous stone crushers. Few exposures of quartz veins in place are available for examination, but quartz on dumps is milky white and moderately iron stained and contains only sparse pyrite. Detailed sampling of quartz and hydrothermally altered wall rock from mine dumps resulted in gold analyses much lower than those reported in similar studies of other ancient mines in the area, and no information was gained as to the reason for the apparent discrepancy between these low values and the evidence of a great amount of mining activity over a large area.

The ancient mines at nearby Agob are a single line of workings extending 800 m. Quartz on dumps is similar to that of An Najadi, but dump sampling gave higher assay results for gold, similar to past sampling efforts. Agob North is also a single line of workings about 300 m long, located 4 km north of Agob. The quartz veins are associated with diorite dikes, and preliminary dump sampling resulted in moderate gold values.

Unworked quartz veins at Wuday, 12 km from An Najadi, are in metasediments near a contact with a large granodiorite pluton. Detailed mapping and sampling of the veins indicate an erratic distribution and wide range of gold values. Ancient workings at Ar Rahail, located 9 km from An Najadi, are moderately extensive and follow quartz veins associated with hydro-thermally altered felsic intrusive rocks. Preliminary dump sampling resulted in moderate gold values.

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INTRODUCTION

The ancient workings at An Najadi, at 26°00'00"N, 42°05'30"E (figs. 1 and 2), have their southern part in the Uqlat as Suqur quadrangle (sheet 25/42A) and their northern part in the Samirah quadrangle (sheet 26/42C). Figure 2 shows the locations of the ancient mines at Agob and Ar Rahail, and the gold-quartz veins at Wuday in respect to the location of An Najadi. The An Najadi mines are 22 km north-northwest of the village of Uqlat as Suqur, and all of the area of this report is easily accessible by desert tracks.

Previous Work

The ancient mine workings at An Najadi were apparently known in Bedouin lore in 1937, because their earliest mention in Deputy Ministry for Mineral Resources records is in a memorandum of that date, in which K. S. Twitchell of the Saudi Arabian Mining Syndicate states that this group of workings had not been found by his company at that time. Ahmed O. Fakhry of the same organization evidently succeeded in finding the mines a few years later and made a rough plot of the workings and sampled many of the ancient dumps (Fakhry, 1941). D. F. Schaffner, of the Directorate General for Mineral Resources, later sampled the ancient mine dumps by pitting and grab sampling (Schaffner, 1956). Subsequently, Mytton (1970) of the U.S. Geological Survey (USGS) visited the mines and described them in a report.

The An Najadi mines apparently have been called by other names, since Twitchell and Schaffner both referred to "Amayer al Ma'dan," and Schaffner also to "Amayer al Mahalanie." The mines are listed as Amayer al Madan (An Najadi) in the Mineral Occurrence Documentation System (MODS) of the Deputy Ministry for Mineral Resources. For the sake of brevity, only the name An Najadi will be used in this report.

Schaffner (1956) also sampled the ancient workings at Agob and other ancient mines in the general region, but no known previous work is recorded for the gold-quartz veins at Wuday, or the ancient workings at Ar Rahail.

Low-level aerial photography in 1963 produced black and white photographs, at a scale of 1:12,500, of an area including the mines at An Najadi and those at Agob, about 3 km northeast.

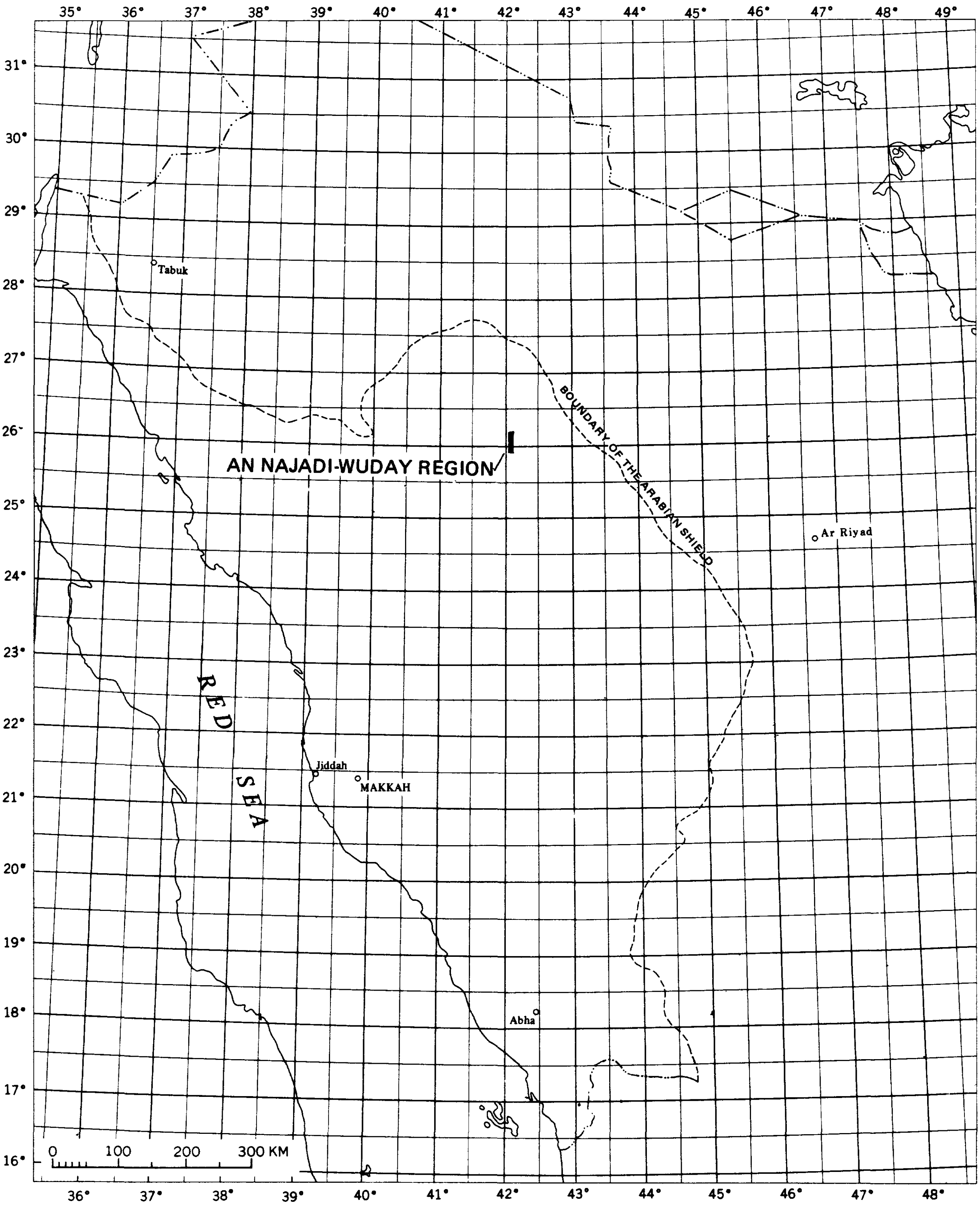
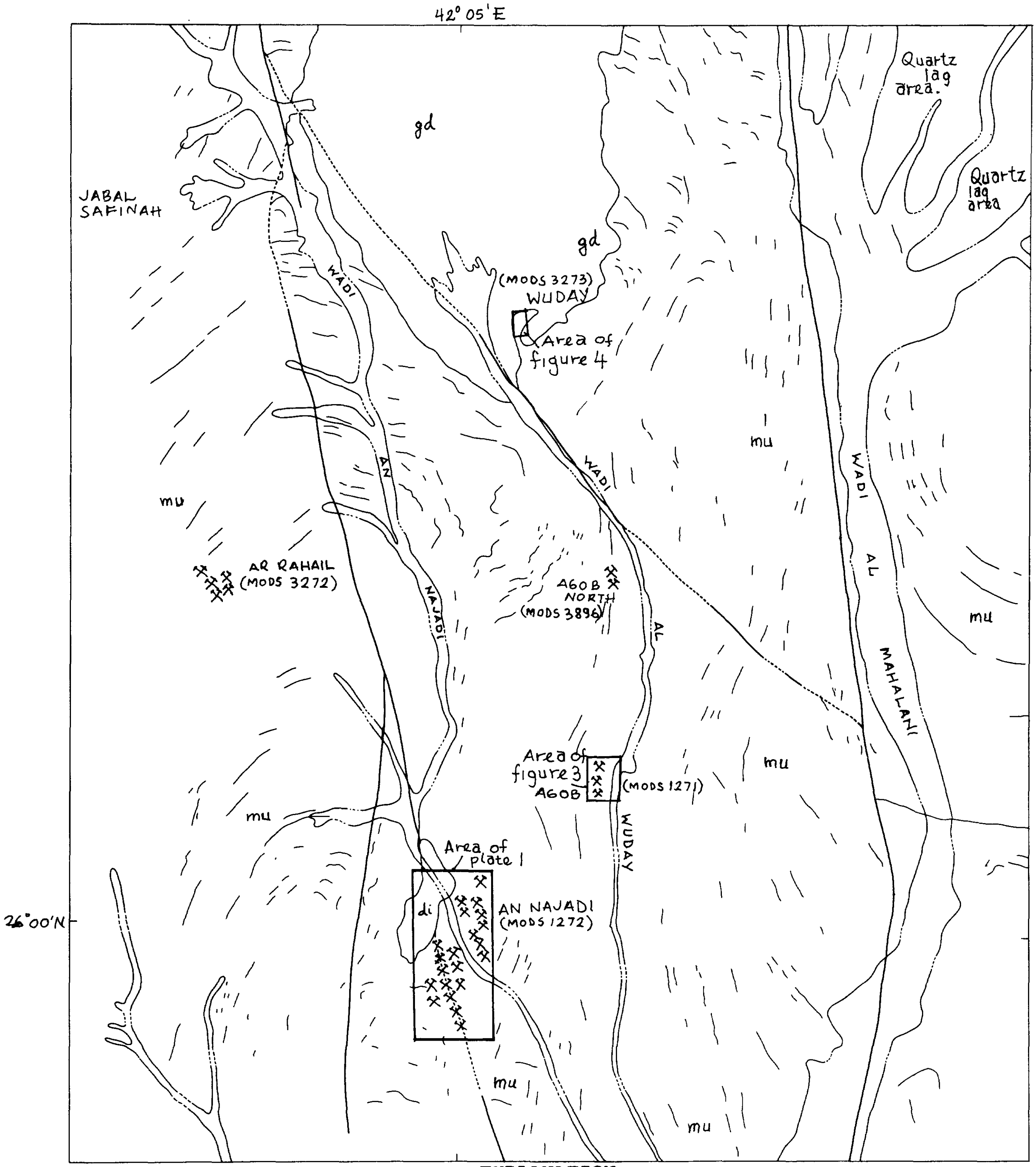


Figure 1.--Index map showing the location of the An Najadi-Wuday region.



EXPLANATION

di	Diorite; gray, medium-grained equigranular rock of granodiorite to quartz diorite composition
gd	Granodiorite; similar to di, above
mu	Murdama group metasedimentary rocks; fine-grained graywacke, calcareous sandstone, and argillite. Minor thin felsic tuff layers are found in the An Najadi area

—— Geologic contact

—— Regional fault as interpreted from studies of aerial photographs. Dotted where inferred

Lineations as observed on aerial photographs. Probably result mainly from layering, but also from shearing, faulting, and dikes

Wadi (stream bed)

AGOB (MODS 1271) Ancient mine site with name and with number used in the Mineral Occurrence Documentation system

0 1 2 3 4 Km

Figure 2.--Index map and photogeologic interpretation of the An Najadi-Wuday region.

Present work

The present study began in the field season 1401-02 A.H. and consisted of a field party including geologists M. A. Hussain and M. A. Basheer, prospector Ghanim Jerri, and field assistants Waiss Issa Assumali and Ali Dualeh. Work during that time consisted of dump sampling at An Najadi and Agob. V. A. Trent, USGS, acted as general supervisor, and C. W. Smith made occasional visits to observe sampling procedures. F. J. Fuller, USGS, provided a map of the An Najadi and Agob ancient workings by use of a stereoplotter and 1:12,500-scale aerial photographs.

Further field work was done in the field season 1402-03 A.H. by Smith and R. M. Samater, when sample localities were plotted on detailed maps, additional samples were collected, and the general geology around An Najadi and Agob was mapped. Smith and Samater also mapped and sampled the gold-quartz veins at Wuday and briefly examined and sampled the ancient workings at Ar Rahail during this time.

Since ancient workings in the area are linear, sampling procedure consisted of collecting quartz from dumps along 50-m transects without regard to obvious mineralization. Each 50-m transect constituted one sample, but dumps that measured less than 50 m also constituted one sample. Sample transects were marked by rock cairns and spray painted, and the last three digits of the sample number were painted on the surface near the rock cairn.

Samples were assayed in the Deputy Ministry for Mineral Resources laboratories in Jiddah under the direction of K. J. Curry, USGS. Atomic absorption analytical methods were used for the analyses of gold, silver, copper, lead, zinc, cobalt, and nickel; and chemical methods were used for the analyses of arsenic, antimony, molybdenum, and tungsten. In addition, semiquantitative emission spectrographic methods were used for these and 20 other elements. All assay data are retained by the U.S. Geological Survey in Jiddah. G. L. Selner, USGS, made statistical studies of the analytical data for An Najadi, including correlation coefficients for 11 elements. Much of the data on general geology was taken from Williams (1983) and Cole (in press) who mapped the 1:100,000-scale quadrangles where the gold deposits are located. All assistance is gratefully acknowledged.

These studies were made generally in accordance with an agreement by the U.S. Geological Survey and the Saudi Arabian Ministry of Petroleum and Mineral Resources, and specifically according to sub-project 3.12.29 of the work plan for the Deputy Ministry for Mineral Resources for 1402-03 A.H., entitled "Prospecting for gold--An Najadi-Agob district".

GENERAL GEOLOGY

Johnson and Williams (1984) following du Bray (in press), have designated metasedimentary rocks in the An Najadi-Wuday region as belonging to the Maraghan formation of the Murdama group. The rocks include calcareous siltstone, shale, and fine graywacke; dark-green, massive greenstone; gray, calcareous argillite; and sparse, thin beds of dark-gray limestone and marble. These rocks weather gray or gray-brown, and no marker beds were recognized in the area. According to Williams, deformation resulting from north- and northwest-directed compression of Murdama group metasediments, which probably began early in the deformational history, formed a large syncline with a north-northeast-trending axis adjacent to and east of the An Najadi-Wuday region. Cole (in press) mapped a north-northwest-plunging anticlinorium adjacent to and west of An Najadi. The metasediments are intruded by a large granodiorite pluton at Wuday and a smaller pluton at An Najadi classed by Cole (in press) as diorite. Both plutons are eroded below the level of metasedimentary outcrop, form topographic depressions, and are mostly covered by thin layers of alluvium and colluvium. In outcrop the granodiorite is medium grained and gray and closely resembles granodiorites in the Meshaheed area and those southeast of Jabal Qutn (Smith and Samater, 1984; Cole, in press; and Williams, 1983). C.E. Hedge and J.C. Cole (unpub. data), using U-Pb zircon dating methods, obtained an age of 614 ± 4 million years for a similar pluton southeast of Jabal Qutn. Hedge and Cole also dated five additional plutons of the same character, mainly in 1:250,000-scale quadrangles 25F and 26F. Ages of the plutons were found to be in the range 630-610 ± 4 million years.

Metasedimentary rocks in the An Najadi, Agob, and Wuday areas have been affected by contact metamorphism as a result of granodiorite intrusive activity. Within these areas the normally calcareous sediments contain metamorphically derived calcium silicate minerals and scattered clasts of dense, fine-grained quartz and muscovite. In some areas recrystallization has completely obliterated the original sedimentary structure.

ECONOMIC GEOLOGY

Photogeologic studies of the An Najadi-Wuday region (fig. 2) indicated folding, faulting and intrusion of granodiorite and diorite plutons into metasediments as the most important structural elements. Regional north-northwest faulting is probably the structural control for the small diorite intrusion and accompanying gold-quartz vein deposition at An Najadi, as are north-northeast faults controls for vein deposition at Agob, Agob North, and Wuday (figs. 2, 3, and 4). Because all of the deposits studied in this report are close to igneoous intrusives, it is probable that the gold-bearing quartz veins were deposited in fractures as a result of hydrothermal activity directly related to the intrusions. Similar geology exists at Meshaheed, about 35 km northeast, where stibnite and gold-bearing quartz veins occur near plutons and cupolas of diorite to granodiorite composition, although here the relationships are obscured by the effects of intrusive peraluminous granite at Jabal Qutn. At Ar Rahail, gold-bearing quartz veins are associated with very small plutons and dikes of a more felsic composition, but the geology has not been studied in detail. The gold deposits in proximity to diorite-granodiorite intrusions were probably formed immediately after the magmatic stage and would therefore be slightly younger than the parent magmas in the age range 630-610 $\pm$ 4 million years.

Hydrothermal alteration of metasediments and igneous rocks appears to be generally confined to vein selvages in most of the ancient workings studied. However, Gary Raines (oral commun., 1983) reports that LANDSAT studies show a large area around An Najadi is affected by slight kaolinization. Much of the study area is covered by quartz lag, some of which contains pyrite, but no regional studies were made concerning the source of the veins or their metal content.

AN NAJADI (MODS 1272)

A great amount of ancient mining and milling activity took place over a wide area at An Najadi. Building ruins, a large mill tailings area, numerous grinding stones, and the great number of ancient workings are evidence of the intensity of the mining and milling effort.

Stone carvings found in the area show neatly carved Khufic inscriptions, but to date no translation this work is available.

Geology

Ancient mine workings trending approximately N 15° W are in an area more than 4 km long and as much as 700 m wide at An Najadi (plate 1). The workings follow quartz veins in mainly calcareous metasedimentary rocks of the Murdama group near a contact with a small diorite pluton (plate 1; fig. 2). Most of the individual workings are trenches excavated by under-hand stoping methods along the quartz veins. Most of this large area, which is in relatively flat terrain, is now covered by mining debris. Quartz veins are rarely exposed, but most of the quartz on dumps is milky white, moderately stained by hematite, and relatively free of pyrite. The metasedimentary rocks are composed of argillite, fine-grained calcareous sandstone, fine-grained graywacke and thin pebble conglomerate beds. A tan to light-brown tuffaceous member about 1 m thick containing feldspar laths was mapped at one locality. Fresh metasediments are gray, or gray-green, but mine dumps contain kaolinized sediments that are tan to brown and stained by iron oxides.

In most places the effects of hydrothermal alteration extend only a few centimeters from vein walls into the metasediments. Contact metamorphism of the metasediments resulting from the intrusion of the nearby diorite pluton (plate 1) is not particularly evident in the mine area, except in a few local exposures containing dense, black, flint-like, hornfels-facies material. One small diorite apophysis and numerous diorite dikes were mapped on the east bank of Wadi An Najadi, where the rocks are locally hydrothermally altered to pink potassium feldspar. Dike rocks were also found on dumps in a number of places in the mine workings area west of the wadi.

The shapes and arrangement of mine workings suggest the quartz veins are probably lenticular and discontinuous, but single veins may continue intermittently for as much as 500 m. There are perhaps seven principal vein systems in a 700-m-wide zone, but undoubtedly there are numerous other quartz veins, veinlets, stringers and stockworks. Much of the wall rock on dumps contains pyritized quartz stringers, but free gold was not observed in the area. Vein thicknesses probably average less than one meter.

Dump sampling results

Eighty seven dump samples were collected in the An Najadi ancient mine area, and assay values for gold, silver, copper, lead, zinc, cobalt, nickel, arsenic, antimony, molybdenum, and tungsten are listed in table 1. Arithmetic means for gold and silver were calculated for all of the dump samples by weighting the sample transects according to their length. The sampled area was divided into three parts (plate 1) in order to detect local variation in gold and silver grade; nine mill-tailing samples were excluded from this assessment. The following are results of the calculations:

Area	No. of samples	Total transect distance (m)	Gold (ppm)		Silver (ppm)		Au/Ag ratio
			Range	Mean	Range	Mean	
1	9	416	0- 3.13	0.62	0.5 -1.7	0.95	0.65
2	46	2020	0-18.67	1.36	0.25-3.9	0.91	1.49
3	23	1813	0.14- 8.05	1.01	0.5 -5.0	1.02	0.99

Discussion of dump sampling results

These dump samples yielded extremely low assay values for gold and silver. The dump sampling done in this study is considered to be a good test of the amounts of these metals contained in quartz on ancient dumps, but our sampling results for gold do not agree with those of Schaffner (1956). He collected 17 dump samples along 1255 m of workings and obtained an average of 3 grams gold per ton, and samples from 11 test pits in the dumps averaged 2.4 grams of gold per ton. This is about two to three times the amount of gold obtained in our sampling. If sampling procedures were more or less the same, then the differences would probably result from the different assay methods used by the two studies: i.e., fire assay versus atomic absorption after chemical digestion. Atomic absorption methods were not used in this area at the time Schaffner sampled the mine dumps. On the other hand, our atomic-absorption dump sampling results for gold at Al Habla (Smith and others, 1984a) correlated reasonably well with Schaffner's fire-assay results and with those of G.A. Dirom, another early worker. In any case, even an average of 3 grams gold per ton is low, compared to results of other dump sampling recently carried out in the region (Smith and others, 1984a; Smith and Samater, 1984; and Boyle and Howes, 1983).

Notwithstanding a great amount of mining activity over a large area by ancient miners, repeated sampling efforts at An Najadi have failed to detect gold in quartz that approaches commercial grade. Our examination of the mineral zone revealed an area on the east bank of Wadi An Najadi, measuring 250 by 150 m, where ancient mill tailings are about 1 meter deep. The tailings appear to consist mainly of quartz, which resembles that on the dumps, and our sampling indicates that most of this mineral contains gold, some of which is high grade (plate 1, table 1). Some of this material has undoubtedly been washed away by floods, and it may be inferred that the original tailings volume was much greater. Minerals other than gold were apparently not sought by the ancients, and no evidence of base metals or other sulfides was observed in quartz or wall rock during our studies (table 1). Silver values in quartz on dumps were low, but one sample from the tailings ran 350 ppm in that metal.

In view of the contradictory evidence cited above, it may be advantageous to probe the reasons for the low gold assays obtained in the ancient dump sampling. A few possibilities are given below:

1. The ancient miners were adept in recognizing gold-bearing quartz and all discarded material is nearly gold-free.

2. The gold occurs mostly in high-grade pockets, and miners who were familiar with the nature of the dispersion mined all of the low-grade quartz in their search for high-grade material.

3. The gold is mainly in vein selvages, perhaps in veinlets. This would imply that the principal gold deposition was not cogenetic with quartz veins.

4. The gold is intimately associated with sulfides; mainly arsenopyrite. This mineral, easily recognized by the miners, was extracted and fully recovered. Their knowledge of sulfide roasting and gold extraction was sufficient to employ these methods, at least during the latter phases of mining activity in the area.

5. A great number of miners were employed in mining material of low grade. Since mining costs were of little consequence, the amount of gold recovered, even though small in comparison to the amount of material mined, was a positive factor in keeping the miners employed in the area.

6. Because of a sufficient water supply at An Najadi, the milling site was used to crush ores from different areas as well as those from the An Najadi mines. This could explain why samples from the tailings area assayed high in base metals and silver (table 1).

Atomic absorption and chemical analytical data for copper, zinc, lead, cobalt, nickel, antimony, molybdenum, and tungsten show very low values for quartz samples from ancient dumps (table 1). Only arsenic values are significant, with a range of 190-3600 ppm and a mean value of 895 ppm. A matrix of correlation coefficients between the various metal pairs (table 3) shows only a strong correlation between gold and arsenic and a lesser correlation between gold and tungsten; otherwise gold has weak correlations with chromium, silver, and molybdenum and negative correlations with the remaining elements, including the base metals and antimony. This pattern of correlations indicates that gold and arsenic were deposited separately from most of the other metals in a distinct hydrothermal event.

Miscellaneous sampling

Samples of wall rock mineralized with iron oxide pseudomorphs after pyrite or with quartz veinlets and samples of dike rock and kaolinized rock were collected throughout much of the mine area (plate 1, table 2). Analytical data indicate these rocks are much the same, geochemically, as the quartz from dumps: samples yield low gold and silver values and correspondingly high arsenic values.

AGOB (MODS 1271)

The ancient workings at Agob are at 26°01'38"N, 42°07'00"E, or 3 km northeast of An Najadi (fig. 2). The ancient mines consist of a single line of workings extending approximately 800 m (fig. 3).

Geology

The geology at Agob is similar in most respects to that of An Najadi. The metasedimentary rocks are of the same character, but in this area they have been regionally faulted on a north-northeast trend (figs. 2 and 3). Quartz on mine dumps appears to be much the same as that found at An Najadi, being mostly the milky-white variety, moderately stained with iron oxides, and largely free of base metals. Mine dumps were found to contain a large quantity of igneous rocks, many of which are fine-grained equivalents of the diorite or granodiorite plutons in the region and are probably dike rocks. Some of these rocks have been kaolinized and pyritized. Dumps also locally contain fine-grained, silicified, pyritized felsic dike rocks.

Dump sampling results

Twelve dump samples collected over a total transect length of 580 m gave the following results:

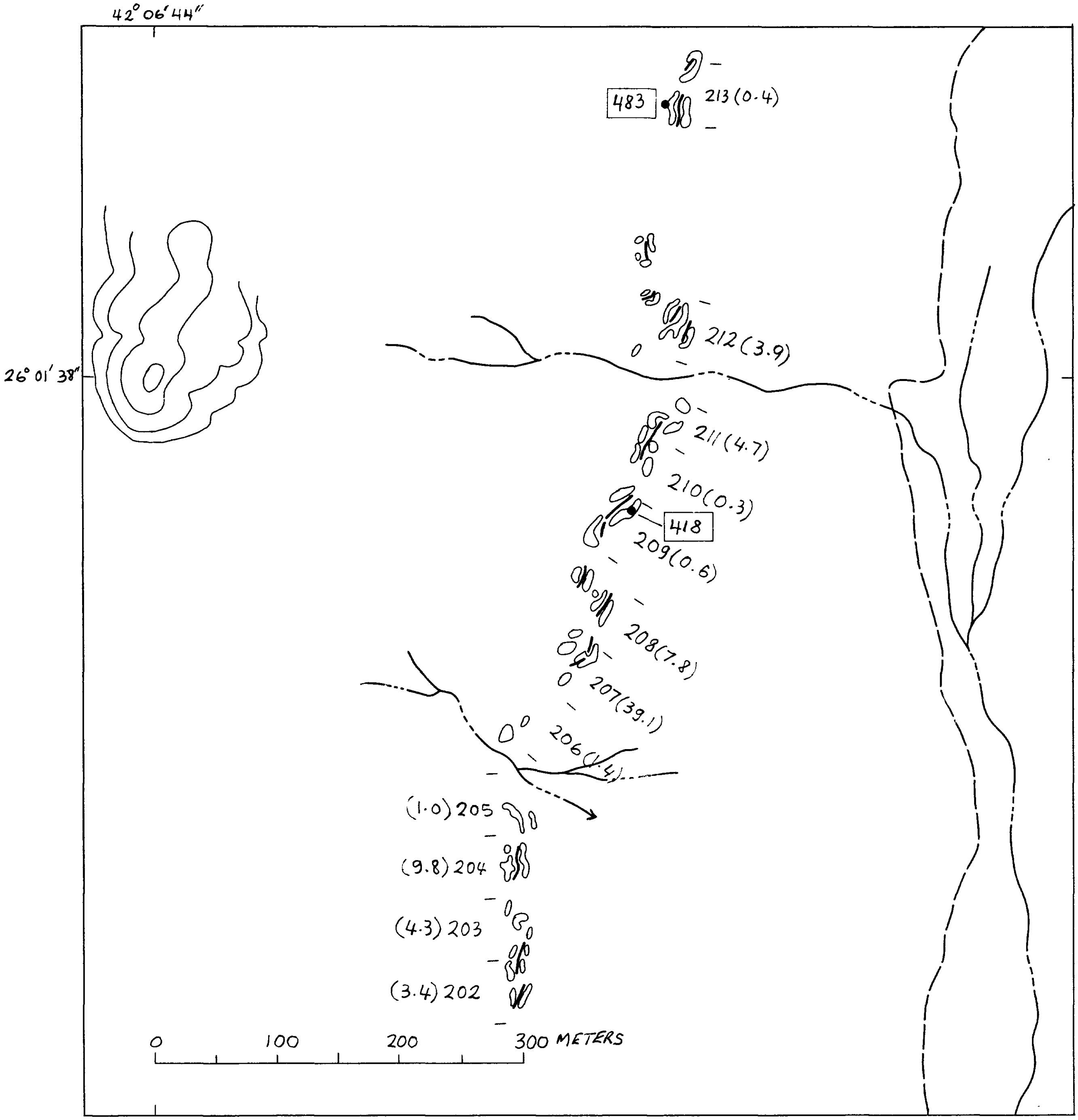
Range (ppm)
Gold....0.32-39.13
Silver....0.6-19.0

Mean (ppm)
Gold....6.67
Silver....3.44

Gold/silver ratio
1.94

Discussion of dump sampling results

Schaffner (1956) sampled the dumps at Agob and reported gold values of 18.85 ppm for a 61-m segment at the north workings, and 4.11 ppm for 304 m of transect at the middle and south workings. Our sampling did not encounter the high grade gold at the north workings (fig. 3, table 1), but generally our results are comparable. Although the quartz on dumps is of a higher grade than that of An Najadi, the geochemistry appears very similar; only



EXPLANATION

Ancient mine dump

Trend of ancient excavation

206(3.2) Dump-sampling transect between stone cairns, showing sample number (last three digits of number in the 190,000 sample series) and gold-assay value (ppm Au; in parentheses)

418 Wall-rock sample locality and number (last three digits of number in the 200,000 sample series)

Outline of low hill (lines are not actual topographic contours)

Outline of large wadi

Stream channel

Figure 3.--Detailed map of the Agob ancient mine workings. Country rock on all sides is fine-grained graywacke, calcareous sandstone, and argillite of the Precambrian Murdama group; weathers gray to gray-brown.

arsenic was found in what are probably anomalous amounts (table 1). Two samples of wall rock were collected from dumps: one (sample 200418) was of kaolinized diorite from the middle workings and had 0.6 ppm Au and a trace of silver; and the other (200483), a sample of kaolinized, pyritized, iron-stained metasedimentary wall rock from the north workings, ran 16.56 ppm Au and 3.5 ppm Ag.

AGOB NORTH (MODS 3896)

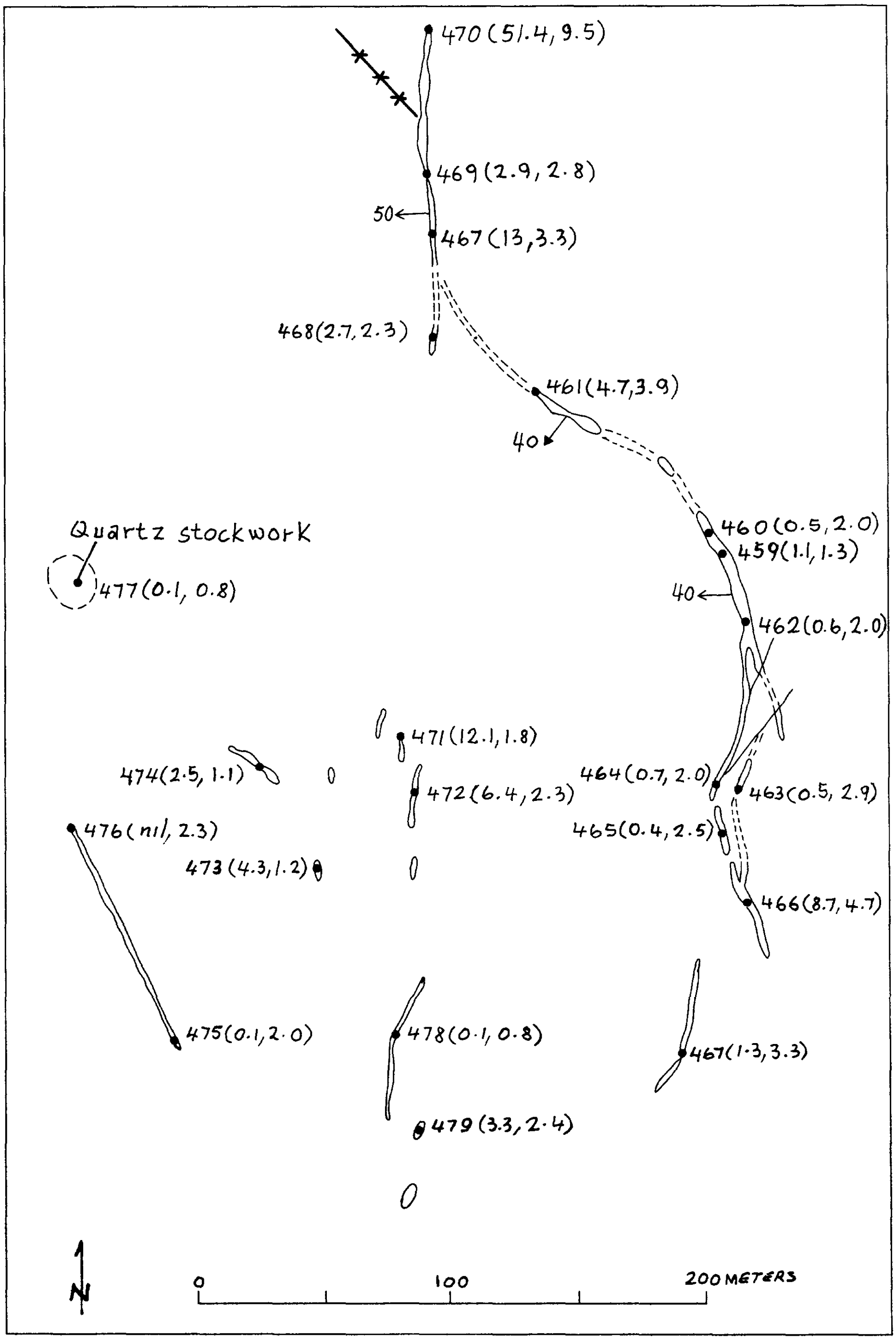
These ancient mines also consist of a single line of workings (fig. 2). They trend slightly east of north and are scattered along a distance of 300 m. The largest single trench is 70 m long. Numerous diorite dikes are found in the area, and a zone of hydrothermal alteration trends east-west across the central part of the worked area. The workings are mainly in hydrothermally altered metasediments, and these rocks constitute a large percentage of the material in dumps. Free gold in quartz was sighted in dump material, and some of the quartz is copper stained and contains bornite. Two samples were collected: one, a 70-m dump sample from workings on the north end, ran 1.04 ppm Au and 5.4 ppm Ag; the second was a grab sample along the remainder of the workings that ran 4.22 ppm Au and 18.6 ppm Ag.

WUDAY (MODS 3273)

Wuday, a series of quartz veins in metasediments, was discovered by USGS prospector Ghanim Jerri, who found visible gold in quartz and brought the area to our attention.

Geology

The quartz veins are in a slightly elevated areas in an extremely flat terrain near the contact with a large granodiorite pluton (fig. 2). The diorite has been eroded below the level of the metasediments and is nearly completely covered by a thin veneer of alluvium and colluvium. The area has been subjected to a great amount of folding and shearing, but these features are not readily mappable because of the quartz rubble cover. Figure 4 shows the configuration of the vein system, which consists of one large curving quartz vein and a smaller vein which is now a series of sheared quartz pods. The quartz is white to tan and saccharoidal, and it contains disseminated pyrite. No free gold was sighted during our examination. The large vein dips west 40°-50° and is as much as 4 m thick. A small area of quartz stockwork is exposed in the western part of the area. The westernmost quartz vein mapped is tan to cream, cryptocrystalline, and brecciated; it contains no sulfides and is probably a variety of low-temperature quartz. Aplite dikes are found near the north end of the quartz vein system.



EXPLANATION

Quartz, cream to tan, moderately iron stained, especially near limonitic pyrite relicts. Dashed where buried beneath surface rubble

Aplite dike

461(4.7,3.9) Sample locality, sample number (last three digits of number in the 200,000 sample series), and gold and silver assay values (in parentheses: Au first, Ag second, in ppm)

50 ← Dip of vein, in degrees

Figure 4.--Detailed map of the gold-quartz veins at Wuday. Country rock on all sides is fine-grained graywacke, calcareous sandstone, and argillite of the Precambrian Murdama group; weathers gray to gray-brown.

Sampling results

Twenty two samples were chipped across quartz veins, and sample localities and gold and silver values are shown on figure 4. The following are statistics of sampling results:

Range (ppm)
Gold....nil-51.4
Silver....0.8-9.5

Mean (ppm)
Gold....4.76
Silver....2.56

Gold/silver ratio
1.86

Discussion of sampling results

Atomic-absorption analytical methods were used for gold and silver, and emission spectrographic methods were used for 29 other elements. These data, which are not given in tables in this report, show that gold values are erratic but are anomalous in nearly all samples. Silver is less abundant, as the gold/silver ratio indicates. Arsenic is present in 5 samples in the range 200-1500 ppm; bismuth, 15 samples in the range 10-700 ppm; molybdenum, 14 samples in the range 7-70 ppm; and tungsten, 2 samples in the amounts 50 and 100 ppm. Other elements were not found in anomalous amounts.

These sampling results are unusually high for veins that are unworked. Helicopter reconnaissance by the senior author indicated numerous other quartz veins near the contact with the large diorite pluton in this locality. These veins are as yet untested.

AR RAHAIL (MODS 3272)

The location of the ancient workings at Ar Rahail was not known at the beginning of our studies in the region, but a search found them at 26°03'40"N, 42°02'40"E (fig. 2). A few dumps were sampled in a preliminary fashion, and, although much more detailed work is required, a summary report is included to enable a more thorough evaluation of the gold potential of the area.

Geology

Ancient workings at Ar Rahail are located on a small rise in the very flat, peneplained terrain that is typical of this region. Here, meta-sedimentary sandstones and graywacke of the Murdama group have been intruded by felsic dikes that are silicified and contain disseminated pyrite. Quartz veins in place were not observed, but iron-stained, milky quartz containing limonitic psuedomorphs after pyrite was found in ancient dumps along with the metasedimentary and dike rocks. Some of the quartz is gray. One line of workings trending N 50° W is more than 300 m long, and adjacent to the linear workings is a series of pits in an area measuring 300 by 50 m. Other workings are scattered in the area.

Sampling results

Five grab samples were collected along 50-m segments of the line of ancient workings and yielded the following results:

Sample number	Au (ppm)	Ag (ppm)
200484	0.4	3.7
200485	7.1	1.6
200486	8.1	2.0
200487	3.7	1.3
200488	0.8	1.3

Two quartz samples were gathered from the pit dumps with the following results:

200489	0.4	1.1
200490	7.3	1.7

Emission spectrographic analytical data show a range of 200-700 ppm arsenic in six samples and 50 ppm tungsten in one sample. Other elements were not anomalous.

Discussion of sampling results

Moderately high gold and silver assay values and the presence of hydrothermally altered rocks in the area indicate that a more complete study of the zone is warranted.

GENESIS AND MODELING OF REGIONAL GOLD-QUARTZ DEPOSITION

Studies of individual deposits in the An Najadi-Wuday region indicate that gold was typically deposited in quartz veins, probably as a result of fracture filling, in metasediments near contacts with granodiorite-diorite plutons, or adjacent to dikes of the same rock type. Hydrothermal alteration is not pervasive in most of the deposits: ordinarily, meta-sediments are kaolinized and pyritized only locally in vein selvages. The quartz veins have little or no base-metal content; pyrite is the only accessory mineral in most places. Such an environment suggests that the deposition of the gold-bearing quartz is intimately associated with granodiorite-diorite magmas and probably resulted from late-phase hydrothermal stages of the individual magmas.

The presence of numerous gold-bearing quartz veins in calcareous sandstone of the Murdama group within a large area in the 1:250,000-scale quadrangles 26F and 25F suggests that perhaps the metasediments are the source of the gold and that the element has only been concentrated by magmatic and hydrothermal action. Mineral suites and geochemistry of the quartz veins vary somewhat from area to area: in places stibnite is the predominant accessory mineral, whereas in other places pyrite or a mixture of base-metal sulfides is found in the quartz. Arsenic is present in amounts as great as 2000 ppm in most vein systems, but generally the accessory minerals are minor constituents; only gold is ubiquitous in the region. Such mineral suites indicate conditions of moderate temperature and pressure during deposition. In many places gold was deposited in single veins of short strike length, or in several narrow veins. The deposits at An Najadi constitute the largest single concentration of gold-bearing quartz veins presently known in the region.

CONCLUSIONS AND RECOMMENDATIONS

Individual deposit studies and a very brief reconnaissance of the An Najadi-Wuday region have shown that gold occurs in quartz in several places. Most of the veins have been worked by ancient miners, but those at Wuday were evidently bypassed. Most of the region consists of a flat, peneplained topography; drainage is poor, and large areas are covered by sand, silt, and gravel. A considerable amount of quartz lag was observed in the area around An Najadi, and, according to Williams (1983), a very large area covered by quartz lag lies in the northeast corner of our mapped area (fig. 2) and beyond. He described the lag as being derived from 0.5- to 5-cm-thick quartz veinlets in the Maraghan formation. No analytical data are yet available for the quartz lag, but it is notable that 15 ppm gold was determined in a sediment sample from a branch of Wadi al Mahalanie that drains the quartz lag area (Allen and others, 1984).

Because of the potential for the discovery of additional gold deposits it is recommended that a large region including the An Najadi-Wuday area be flown for low-level aerial photography to be used as a base for geologic mapping and mineral reconnaissance. In addition, very detailed wadi sediment sampling and sensitive analytical methods should be used for the detection of gold. Upon completion of this work and further detailed mapping, it is recommended that all of the known deposits and any additional discoveries be drilled. Presently vein structures and thicknesses, depositional controls for gold, and gold grades are poorly known in mined areas because of cover. Although sampling by drilling is unsatisfactory in some deposits because of the small size of the sample, it is believed that sampling at depth by drilling in these zones would be advantageous in regards to costs and timeliness in sample gathering. The ancient workings at An Najadi are some of the largest in the Arabian Shield, although analyses of dump samples indicate low gold values. It is believed that drilling will be of aid in understanding the reason for this apparent discrepancy and, in addition, will result in a much better knowledge of the gold potential of the deposit.

DATA STORAGE

Petrographic descriptions, sample localities, thin sections, and results of chemical analyses are stored in data-file USGS-DF-04-26 (Smith and others, 1984b) in the Jiddah office of the U.S. Geological Survey Saudi Arabian Mission.

Data on mineral occurrences in the An Najadi-Wuday region have been updated and entered in the Mineral Occurrence Documentation System (MODS) of the Deputy Ministry for Mineral Resources under the following numbers:

1272	Amayer al Madan (An Najadi)	Au	Updated 4/84
1271	Agob	Au	Updated 4/84
3896	Agob North	Au	New entry 4/84
3273	Wuday	Au	Updated 4/84
3272	Ar Rahail	Au	Updated 4/84

REFERENCES CITED

Allen, M. S., Tidball, R. R., Samater, R. M. and Selner, G. L., 1984, Interpretation of geochemical data from panned concentrates of wadi sediments using R-mode factor analysis, Jabal Habashi quadrangle, sheet 26F, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-45; also, 1985, U.S. Geological Survey Open-File Report 85-5.

Boyle, D. M., and Howes, D. R., 1983, Assessment of the gold potential of the Nafud al Urayq area, northwest Najd: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report RF-OF-03-9, 58 p.

Cole, J. C., in press, Reconnaissance geology of the Uqlat as Suqur quadrangle, sheet 25/42A, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report.

du Bray, E. A., in press, Reconnaissance geology of the Jabal as Silsilah quadrangle, sheet 26/42D, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Map series, 52 p., scale 1:100,000.

Fakhry, A. O., 1941, Number 2 report, trip (in northeastern Al Hijaz) from 1st March to 30th May 1941: Saudi Arabian Directorate General for Mineral Resources Miscellaneous Record 20, 22 p.

Johnson, P. R., and Williams, P. L., 1984, Geology of the Jabal Habashi quadrangle, sheet 26F, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-10, 87 p., 2 pl; also, 1985, U.S. Geological Survey Open-File Report 85-3.

Mytton, J. W., 1970, Reconnaissance for mineral deposits in the Precambrian rocks of the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report (IR)SA-121, 75 p.

Schaffner, D. F., 1956, Report for the year 1375 A.H. (1955-56) on 53 ancient workings: Saudi Arabian Directorate General for Mineral Resources Open-File Report 65, 63 p.

Smith, C. W., and Samater, R. W., 1984, Preliminary report on gold deposits at Meshaheed, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-29; also, 1985, U.S. Geological Survey Open-File Report 85-9.

Smith, C. W., Samater, R. M., Hussain, M. A, Basheer, M. A., and Trent, V. A., 1984a, Preliminary report on the gold deposits at Al Habla, Kingdom of Saudi Arabia, with a section on Geologic setting and igneous controls of mineralization, by J. C. Cole: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-54. also, 1985, U.S. Geological Survey Open-File Report 85-128.

__________ 1984b, Supporting data for preliminary report on the on gold deposits in the An Najadi-Wuday region, Samirah and Uqlat as Suqur quadrangles, Kingdom of Saudi Arabia: Available from Saudi Arabian Deputy Ministry for Mineral Resources Data File USGS-DF-04-26.

Williams, P. L., 1983, Reconnaissance geology of the Samirah quadragle, sheet 26/42C, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-04-3, 33 p., 2 pl.; also, 1984, U.S. Geological Survey Open-File Report 84-383.

TABLE 1.--Atomic absorption analytical data for ancient dump sampling at An Najadi and Agob, and ancient mill tailings sampling at An Najadi

[Values in parts per million]

Sample number	Au	Ag	Cu	Pb	Zn	Co	Ni	Sb	Mo	W	As
					An Najadi						
190121	< 0.05	0.5	20	15	15	20	20	3	5	1	660
190122	3.1	1.7	45	135	30	10	12	12	5	0	640
190123	2.1	1.7	30	40	55	25	55	16	5	2	600
190124	0.2	0.9	25	10	25	30	15	8	5	5	350
190125	< 0.05	0.7	23	20	20	10	15	5	5	20	350
190126	< 0.05	1.0	20	30	40	20	15	4	5	0	350
190127	< 0.05	0.6	20	15	20	15	40	4	10	0	440
190128	< 0.05	0.7	30	15	35	10	35	2	5	2	240
190129	< 0.05	0.7	85	15	25	20	25	2	15	3	190
190130	1.40	1.1	35	30	30	20	50	2	0	9	350
190131	< 0.05	0.5	40	35	25	20	35	4	<5	9	330
190132	0.4	0.8	20	30	45	20	45	5	15	3	640
190133	0.3	0.8	30	30	75	20	45	6	5	2	560
190134	0.1	1.1	40	35	25	20	60	7	10	2	360
190135	1.1	0.5	20	20	25	15	40	1	5	2	280
190136	0.2	0.6	40	25	25	15	140	5	10	5	800
190137	7.2	0.5	<0.5	10	10	15	25	3	10	8	1600
190138	0.7	0.5	5	10	10	<10	30	0	5	0	900
190139	0.4	0.5	10	10	10	10	30	1	5	1	1000
190140	< 0.05	0.6	10	10	20	10	35	0	5	1	160
190141	0.4	<0.5	0.5	10	25	10	30	2	5	0	400
190142	0.5	0.8	10	10	20	<10	60	1	10	2	800
191143	18.7	3.9	15	10	10	<10	30	2	5	3	600
190144	0.4	0.5	15	30	15	<10	55	2	15	3	1100
190145	1.7	0.5	15	10	10	15	30	2	50	3	560
190146	< 0.05	1.1	10	35	20	10	30	7	5	4	1700
190147	1.8	0.5	15	30	15	<10	15	5	10	5	1150
190148	1.1	0.7	30	<10	10	15	25	2	10	3	640
190149	1.2	<0.5	10	10	15	10	15	0	15	5	450
190150	9.7	2.4	55	15	45	20	30	18	25	3	2500
190151	0	0.5	20	10	40	20	15	1	5	3	200
190152	1.5	0.7	30	30	65	30	35	39	15	6	3600
190153	0.3	0.6	15	<10	20	10	40	0	5	5	350
190154	0.2	5.0	15	100	25	15	15	10	5	2	350
190155	0.5	1.3	35	20	80	10	40	16	10	7	3300
190156	0.1	0.5	20	15	50	25	30	4	15	0	2200
190157	< 0.05	0.5	25	10	45	30	40	0	5	5	230
190158	< 0.05	0.6	20	15	35	25	35	5	5	0	1250
190159	< 10.5	0.7	30	<10	50	10	40	6	10	6	700

TABLE 1.--Atomic absorption data for dump sampling--Continued

Sample Number	Au	Ag	Cu	Pb	Zn	Co	Ni	Sb	Mo	W	As
					An Najadi--Continued						
190160	0	0.8	25	20	55	15	35	8	25	2	740
190161	< 0.05	0.9	20	15	45	10	40	12	5	4	800
190162	0.5	0.7	20	15	45	25	35	17	10	2	1300
190163	1.4	0.8	35	15	35	15	55	8	10	6	1400
190164	1.4	0.7	25	20	45	30	45	18	10	3	1900
190165	0.9	0.8	25	20	55	<10	40	4	5	5	460
190166	0.5	0.9	20	15	40	<10	30	5	5	6	720
190167	0.4	0.9	35	25	45	15	70	6	5	5	900
190168	0.4	1.2	35	30	70	15	35	7	10	10	760
190169	0.4	1.2	30	35	45	10	40	4	30	3	1750
190170	0.3	1.1	25	20	95	20	35	7	10	24	1500
190171	< 0.05	1.0	130	25	65	15	50	9	25	9	880
190172	0.3	0.9	20	10	85	15	35	4	10	6	900
190173	0.2	1.8	20	15	60	20	30	6	20	5	740
190174	1.2	1.2	45	15	65	30	50	8	5	5	1800
190175	6.7	1.4	20	25	40	20	45	8	10	6	1750
190186	7.4	1.4	20	<10	30	10	20	13	10	10	460
190187	0.9	0.6	10	10	25	20	25	0	10	1	380
190188	0.1	5.0	40	20	105	35	95	6	10	7	200
190189	0.7	0.6	35	15	55	10	30	24	25	7	1750
190190	4.3	1.2	20	<10	30	10	35	0	5	2	400
190191	0.8	0.7	0.5	<)10	25	10	30	0	10	10	800
190192	0.5	0.8	20	15	40	<10	35	0	10	9	400
190193	0.2	0.7	10	10	25	<10	20	2	15	4	500
190194	8.0	1.5	15	15	25	<10	25	0	10	8	960
190195	1.2	0.7	15	<10	35	20	25	0	30	7	740
190196	6.0	1.6	15	20	35	20	20	6	60	4	1000
190197	0.4	0.5	30	10	50	10	35	7	5	4	1850
190198	0.5	<0.5	20	20	20	<10	30	0	30	2	400
190199	1.9	1.0	15	25	30	20	55	0	20	17	800
190200	0.9	0.6	15	10	15	10	25	0	5	1	220
190201	0.5	<0.5	10	15	10	<10	45	0	200	8	600
200448	0.4	2.9									
200450	0.5	1.9									
200451	0.6	3.7									
200453	1.4	4.6									
200454	1.4	1.5									
200455	0.8	2.6									

TABLE 1.--Atomic absorption data for dump sampling--Continued

Sample number	Au	Ag	Cu	Pb	Zn	Co	Ni	Sb	Mo	W	As
					Agob						
190202	3.4	0.6	15	10	30	10	60	22	10	15	4000
190203	4.3	0.9	15	15	15	15	25	9	5	4	580
190204	9.8	5.0	120	45	15	15	20	12	0	4	320
190205	1.0	2.2	55	140	15	<10	10	96	10	1	460
190206	1.4	1.6	60	75	25	<10	15	83	5	5	800
190207	39.1	4.0	20	50	15	<10	15	63	5	3	380
190208	7.8	1.8	15	30	5	<10	25	9	5	2	380
190209	0.6	0.7	30	35	10	<10	30	9	5	2	320
190210	0.3	<0.5	10	10	5	<10	10	0	5	0	120
190211	4.7	19.0	60	440	10	10	<10	183	0	0	440
190212	3.9	2.4	40	45	15	<10	55	21	5	3	180
190213	0.4	0.8	35	50	5	10	100	4	5	2	80
					Ancient mill tailings--An Najadi						
190176	0	0.7	10	10	30	20	40	5	10	2	200
190177	0	350	300	5950	1600	<10	30	420	15	2	240
190178	0	1	850	10	60	20	15	7	15	2	300
190179	0.5	1	10	20	15	<10	<10	7	10	0	260
190180	0.2	0.7	15	20	5	<10	20	7	5	1	310
190181	1.0	1.0	15	20	25	10	<10	5	5	5	1000
190182	26.44	5.5	2000	35	85	40	10	10	5	0	2500
190183	0	1.1	50	25	45	15	25	4	10	3	400
190184	1.6	0.8	10	15	30	<10	15	0	15	2	200
190185	0	0.8	35	20	60	15	40	5	10	2	240

TABLE 2.--Analytical data for miscellaneous sampling in the An Najadi area

[Values in parts per million; sample localities are shown on plate 1]

Sample Number	Description	Atomic absorption analyses Au	Ag	Noteworthy semi-quantitative analysis
200419	Large silicified fault.	0.8	1.3	
200420	Calcareous wall rock with quartz stringers.	0.2	<0.5	
200421	Wall rock, pyritized.	1.8	1.3	As -2000
200422	As above.	0.3	1.2	As - 300
200423	Quartz, milky white.	1.9	2.2	As - 200
200424	Wall rock, pyrtized, with tiny quartz stringers.	0.7	<0.5	As -3000
200425	Diorite dike in workings.	1.0	1.1	As - 300
200426	Wall rock, pyritized, very thin quartz veinlets, abundant FeO.	0.6	0.7	As - 700
200427	As above.	0.7	0.5	As - 500
200428	As above.	4.1	<0.5	As -1500
200429	As above.	1.6	1.6	As -5000
200430	Quartz, hematite stain.	0.2	<0.5	
200431	Wall rock, disseminated pyrite.	0.2	<0.5	As - 700
200432	As above, few quartz veinlets.	0.2	1.5	
200433	Wall rock, as above.	<0.05	<0.5	
200432	As above.	0.3	1.4	As -1500
200435	Plagioclase porphyry tuff, wall rock.	0.3	0.9	
200436	Quartz.	2.1	2.3	
200437	Wall rock, moderate FeO.	0.4	1.6	As -2000
200438	Wall rock, siliceous, with numerous quartz stringers.	0.3	1.1	As -2000, Ba ->5000
200439	Wall rock, FeO stain.	0.7	1.5	As -1500
200440	As above, few quartz stringers.	0.5	0.8	As - 700
200441	Wall rock, disseminated cubic pyrite.	0.4	1.3	As -1500
200442	As above.	0.4	1.0	
200443	As above.	0.4	1.3	
200444	As above.	3.2	1.4	
200446	Large silicified fault.	<0.05	1.4	
200447	Quartz.	0.6	2.7	
200449	Quartz, hematitic stain.	0.4	3.5	
200452	Large silicified fault.	0.2	1.1	

TABLE 3.--Correlation coefficients for metal pairs, dump-sample analytical data, An Najadi

[Letters in parentheses indicate type of analysis: AAP, atomic absorption following partial digestion of sample; AAT, atomic absorption following total digestion of sample; CM, colorimetric analysis; S, semiquantitative spectrographic analysis]

	Fe (S)	Mg (S)	Ca (S)	Ti (S)	Mn (S)	B (S)	Ba (S)	Cr (S)	Sc (S)	Sr (S)
Fe (S)	1.000	0.7905	0.5268	0.7149	0.5414	0.5028	0.6990	0.3528	0.7472	0.5323
Mg (S)	0.7905	1.000	0.4886	0.8429	0.5897	0.5468	0.8189	0.4389	0.8195	0.5213
Ca (S)	0.5268	0.4886	1.0000	0.2903	0.7866	0.2260	0.4369	0.2534	0.3111	0.5633
Ti (S)	0.7149	0.8429	0.2903	1.000	0.3975	0.6785	0.8140	0.3352	0.8523	0.3938
Mn (S)	0.5414	0.5897	0.7866	0.3975	1.0000	0.2616	0.5834	0.2359	0.4516	0.4736
B (S)	0.5028	0.5468	0.2260	0.6785	0.2616	1.000	0.7194	0.1330	0.5752	0.1676
Ba (S)	0.6990	0.8189	0.4369	0.8140	0.5834	0.7194	1.000	0.3478	0.7126	0.4118
Cr (S)	0.3528	0.4389	0.2534	0.3352	0.2359	0.1330	0.3478	1.000	0.2170	0.3480
Sc (S)	0.7472	0.8195	0.3111	0.8523	0.4517	0.5752	0.7126	0.2170	1.000	0.4547
Sr (S)	0.5323	0.5213	0.5633	0.3938	0.4736	0.1676	0.4118	0.3480	0.4547	1.0000
V (S)	0.7071	0.8485	0.3445	0.9050	0.4859	0.6873	0.8326	0.3263	0.8216	0.3743
Y (S)	0.7259	0.7397	0.4260	0.6412	0.5769	0.5861	0.6618	0.2620	0.7628	0.4126
Zr (S)	0.6367	0.7671	0.2057	0.8314	0.3783	0.6987	0.7637	0.3145	0.7554	0.3598
Cu (AAP)	0.5514	0.3151	0.2887	0.2708	0.2546	0.2970	0.2607	-0.0453	0.4182	0.3371
Pb (AAP)	0.1771	0.0973	0.3874	-0.0483	0.2815	-0.0482	0.0128	0.0750	-0.0240	0.1815
Zn (AAP)	0.5493	0.5337	0.5162	0.4490	0.5208	0.3710	0.4946	0.0313	0.5381	0.4222
Co (AAP)	0.3229	0.3127	0.0633	0.3157	0.2629	0.2635	0.2376	-0.0037	0.4319	0.1910
Ni (AAP)	0.3512	0.3956	0.1213	0.3864	0.0548	0.1567	0.2529	0.1356	0.3645	0.2269
Au (AAT)	-0.1531	-0.2293	-0.1985	-0.0938	-0.2618	-0.0029	-0.0817	0.1251	-0.1531	-0.1550
Ag (AAT)	0.1825	0.0141	0.3260	-0.0739	0.2408	-0.0176	0.0190	0.0403	-0.0400	0.2198
As (CM)	0.1678	0.2048	0.2272	0.3290	0.1508	0.4690	0.3443	0.1926	0.2055	0.0196
Sb (CM)	0.4378	0.3013	0.4623	0.2597	0.3971	0.4417	0.3467	0.0864	0.2488	0.3513
Mo (CM)	-0.0659	-0.0070	-0.0448	0.0829	-0.0143	0.1955	0.1597	0.0950	-0.0566	-0.1936
W (CM)	0.2317	0.3154	-0.0087	0.3923	0.0306	0.3624	0.3633	0.1916	0.3128	0.1703

Table 3.--Correlation coefficients for metal pairs--Continued

	V (S)	Y (S)	Zr (S)	Cu (AAP)	Pb (AAP)	Zn (AAP)	Co (AAP)	Ni (AAP)	Au (AAT)	Ag (AAT)
Fe (S)	0.7071	0.7259	0.6367	0.5514	0.1771	0.5493	0.3229	0.3512	-0.1531	0.1825
Mg (S)	0.8485	0.7397	0.7671	0.3151	0.0973	0.5337	0.3127	0.3956	-0.2293	0.0141
Ca (S)	0.3445	0.4260	0.2057	0.2887	0.3074	0.5162	0.0633	0.1213	-0.1985	0.3260
Ti (S)	0.9050	0.6412	0.8314	0.2708	-0.0483	0.4490	0.3157	0.3864	-0.0938	-0.0739
Mn (S)	0.4859	0.5769	0.3783	0.2546	0.2815	0.5708	0.2629	0.0548	-0.2618	0.2408
B (S)	0.6873	0.5861	0.6987	0.2970	0.0482	0.3710	0.2536	0.1567	-0.0029	-0.0176
Ba (S)	0.8326	0.6618	0.7637	0.2607	0.0218	0.4946	0.2376	0.2529	-0.0817	0.0190
Cr (S)	0.3663	0.2620	0.3145	-0.0453	-0.0750	0.0313	-0.0037	0.1356	0.1251	0.0403
Sc (S)	0.8216	0.7628	0.7554	0.4182	-0.0240	0.5381	0.4319	0.3645	-0.1531	0.0400
Sr (S)	0.3743	0.4126	0.3598	0.3371	0.1815	0.4222	0.1910	0.2269	0.1550	0.2198
V (S)	1.0000	0.6988	0.7960	0.3347	0.0118	0.5265	0.3326	0.3809	-0.0937	0.0577
Y (S)	0.6988	1.0000	0.7084	0.5216	0.2269	0.5939	0.4749	0.3033	-0.2229	0.1390
Zr (S)	0.7960	0.7084	1.0000	0.3483	-0.0957	0.3913	0.4195	0.3078	-0.1808	-0.1665
Cu (AAP)	0.3347	0.5216	0.3483	1.0000	0.4063	0.6182	0.2589	0.3151	-0.2532	0.4267
Pb (AAP)	0.0118	0.2269	-0.0957	0.4063	1.0000	0.5142	-0.0651	0.3156	-0.1721	0.6545
Zn (AAP)	0.5265	0.5939	0.3913	0.6182	0.5142	1.0000	0.2768	0.4497	-0.2286	0.5998
Co (AAP)	0.3326	0.4749	0.4195	0.2589	-0.0651	0.2668	1.0000	0.1371	-0.1046	-0.0062
Ni (AAP)	0.3809	0.3033	0.3078	0.3151	0.3156	0.4497	0.1371	1.0000	-0.1267	0.3291
Au (AAT)	-0.0937	-0.2229	-0.1808	-0.2532	-0.1721	-0.2286	-0.1046	-0.1267	1.0000	0.0469
Ag (AAG)	0.0577	0.1390	-0.1665	0.4267	0.6545	0.5998	-0.0062	0.3291	0.0469	1.0000
Cs (CM)	0.3648	0.2972	0.2628	-0.0595	-0.0152	0.0979	0.1422	0.0919	0.4052	-0.0781
Sb (CM)	0.3557	0.5263	0.3390	0.5112	0.5576	0.5440	0.2558	0.1592	-0.0653	0.4953
Mo (CM)	0.1439	-0.0030	0.0512	-0.0120	-0.0020	0.0531	-0.0570	0.0678	0.0642	0.0030
W (CM)	0.3920	0.2521	0.2988	0.0989	-0.1173	0.2192	0.0852	0.2340	0.3024	0.0638