DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Preliminary report on gold deposits at Meshaheed, Kingdom of Saudi Arabia

by

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Open-File Report 85-9

Prepared for the Ministry of Petroleum and Mineral Resources, Deputy Ministry for Mineral Resources, Jiddah, Kingdom of Saudi Arabia

1/ U.S. Geological Survey Saudi Arabian Mission

1985

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PRELIMINARY REPORT ON GOLD DEPOSITS AT MESHAHEED, KINGDOM OF SAUDI ARABIA

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ABSTRACT

A fault-controlled, hydrothermal system deposited gold, stibnite, and quartz in metasediments, intrusive basalt, and diorite in an area approximately 3 by 5 km in the Meshaheed area of the northeastern Arabian Shield. Veins in metasediments appear to be lenticular and average less than 1 m thick. A related, quartz-pyrite stockwork in fractured, hydrothermally altered basalt is approximately 1 km long and at least 100 m wide. Poorly defined veins and veinlets bear gold, stibnite, and quartz. A few areas of ancient gold-mining activity are in metasediments at the perimeter of a large diorite pluton. The arrangement of the pits also indicates that unexposed veinlet systems may be as much as 40 m wide. Small areas of diorite have also been hydrothermally altered where gold-stibnite-quartz veins were emplaced.

A molybdenite-quartz stockwork and other quartz stockworks bearing traces of molybdenum, bismuth, and silver are in small diorite plutons. Large areas of moderately hydrothermally altered metasediments bearing trace molybdenum are also present. These mineralized zones are not cogenetic with the gold-stibnite-quartz deposits.

A separate stream-sediment sampling program has shown the area southeast of Meshaheed to be anomalous in lead, copper, boron, tin, iron, and molybdenum, and a preliminary geophysical survey found resistivity anomalies coincident with the altered, intrusive basalt.

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INTRODUCTION

The area of this report is approximately 18 by 10 km, extending northeast of Jabal Qut'n, a large granitic inselberg that serves as a landmark in the northeastern Arabian Shield. Most of the study, however, was made at Meshaheed (MODS 1266), a smaller area of about 3 by 5 km located at lat 26°09'32" N., long 42°25'26" E. (fig. 1), and defined by several groupings of ancient workings. The region in general consists of low hills, broad pediments, and poorly developed drainage systems. At Meshaheed, a group of low, sharp hills occupies the western part of the area.

Previous work in the area in recent times evidently consisted of sampling several of the ancient dumps by pitting. A few of the sample pits were found during our study, but no records appear to be available. This work was probably done by the Saudi Arabian Mining Syndicate headquartered at Mahd adh Dhahab, since they were known to be active in the region. Mytton (1970), U.S. Geological Survey (USGS), made a reconnaissance study of mineral deposits in the Wadi ar Rimah quadrangle and described some of the ancient mines at Meshaheed. Williams (1983), USGS, mapped the geology of the 1:100,000-scale Samirah quadrangle, 26/42 C, which includes the Meshaheed area, and some of his observations are used in this report.

Field work by the authors began in the field season 1401/02 AH and consisted of general reconnaissance from a helicopter. Detailed mapping and sampling of ancient mines and reconnaissance-type geologic mapping of the area, in general, were completed in the latter part of 1402. Ancient workings were sampled by collecting quartz and, in places, altered wall rocks from dumps. Nearly all of the pits and trenches are now filled with mining debris and wind-blown sand. Quartz veins in place are evident in only very limited zones. Hydrothermally altered rocks were sampled by collecting rock chips at various intervals. More than 300 samples were gathered for analyses for gold and silver using the atomic absorption method and for analyses of twenty-eight additional elements using semiquantitative spectrographic methods.

ACKNOWLEDGMENTS

The work upon which this report is based was conducted in accordance with the terms of a work agreement between the U.S. Geological Survey and the Saudi Arabian Ministry of Petroleum and Mineral Resources under subprojects 3.01.03, Assessment of economic potential for 1:250,000-scale quadrangle 26F, and 3.01.35, Assessment for gold--Meshaheed area.

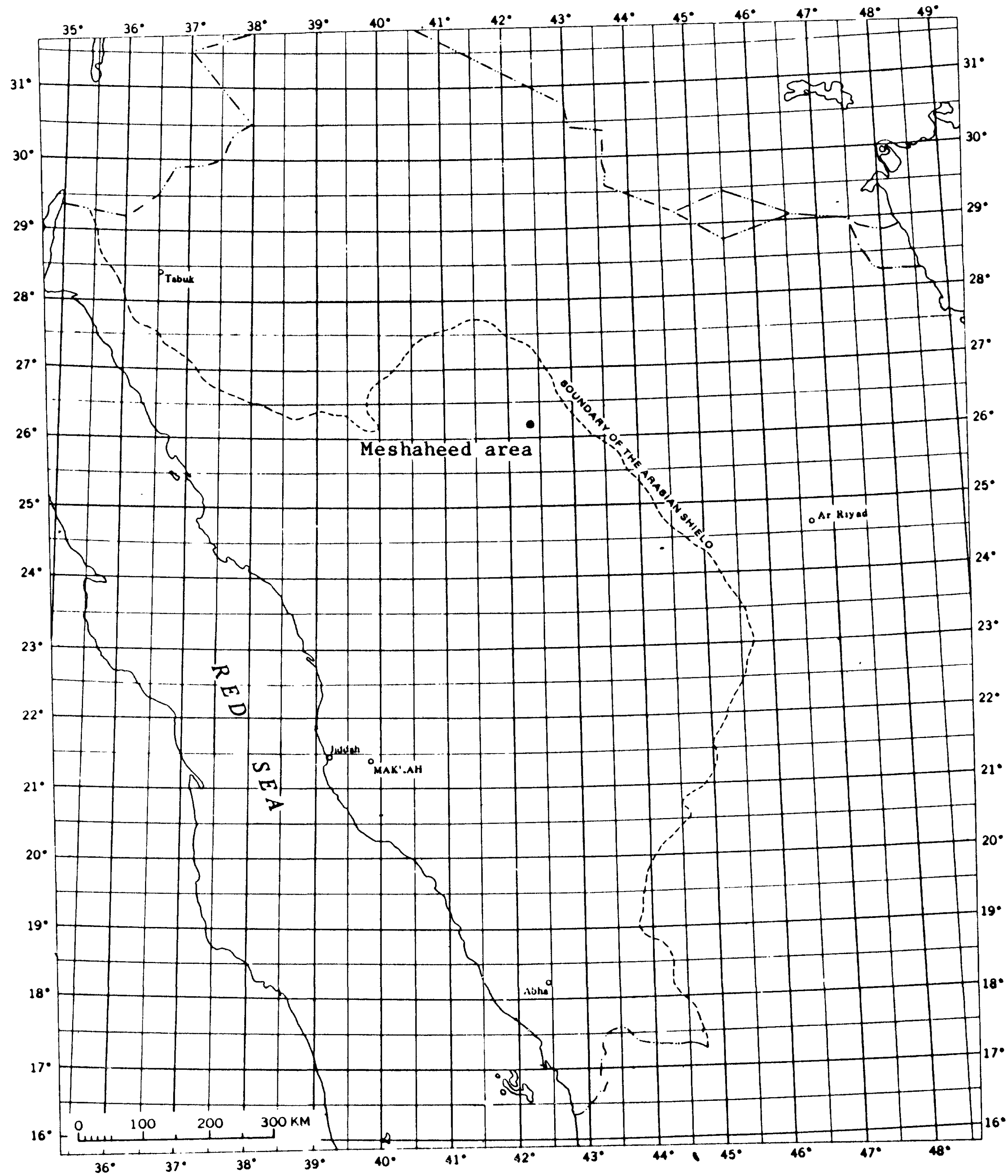


Figure 1.--Index map of western Saudi Arabia showing location of Meshaheed area.

Preliminary field work was done by Ghanim Jerri, prospector, and Wais Issa and Ali Dualeh, field assistants; they successfully located numerous ancient workings. Analytical work was done in the Deputy Ministry for Mineral Resources laboratories in Jiddah under the direction of K. J. Curry, USGS. Polished mounts, thin sections, and polished thin sections of samples from the Meshaheed area were made in the USGS laboratories in Jiddah under the direction of C. R. Thornber. G. I. Selner, USGS, performed statistical studies of analytical data and helped with interpretation. All assistance is gratefully acknowledged.

GENERAL GEOLOGY

Murdama group metasediments

The oldest rocks in the area are in the Murdama group of late Proterozoic age. They are mostly fine- to medium-grained, immature clastic metasediments, including siltstone, lithic sandstone, and graywacke (pl. 1). Most of the sedimentary rocks are somewhat calcareous, slightly metamorphosed, contain minor micaceous minerals, and display incipient cleavage. They form low, rounded hills and weather dark gray. Linear trends indicating stratification and fracture cleavage can be seen on aerial photographs, but are not apparent in many outcrops. The rocks generally have the same appearance over most of the region. Sediments are altered to hornfels near felsic plutons, and the hornfelsic aureole on the northeast side of Jabal Qut'n contains appreciable pyrrhotite. A relatively thin interbed of metabasalt is in the east-central part of the mapped area (pl. 1). These rocks generally dip steeply north, weather dark green and, in places, display pillow structures. No other volcanic sequences are known in the area.

Basalt intrusive

A sub-volcanic, basaltic intrusive in Murdama group metasedimentary rocks (pl. 1) is approximately 1.5 km in diameter and forms low hills. The basalt is normally aphanitic, dark gray, and, in places, contains 2-5 percent disseminated pyrrhotite, but locally the rock is porphyritic containing plagioclase phenocrysts.

Some of the basalt has been hydrothermally altered to kaolinite, siliceous, and carbonate minerals with accompanying disseminated pyrite. The altered areas are identified by rock colors of red, brown, tan, maroon, and cream.

Plagioclase porphyry

A small, fine-grained, felsic plagioclase porphyry intrudes the sub-volcanic basalt and Murdama group metasediments (pl. 1). This rock weathers tan, forms small sharp hills, and consists of plagioclase phenocrysts as long as 5 mm set in a groundmass of anhedral quartz, amphibole, and biotite. The plagioclase has been partially altered to sericite and kaolinite, and pyrite is disseminated throughout.

Diorite

Rocks of dioritic composition intrude both Murdama group metasediments and intrusive basalt in the form of small plutons, or large dikes or sills in many places in the Meshaheed area (pl. 1). The largest of the plutons is approximately 4 km long, but most are much smaller. The rock is a medium-grained, hornblende-plagioclase diorite. The largest pluton in the northwest corner of the mapped area, and three satellitic plutons south are deeply eroded and have formed contact metamorphic aureoles in the surrounding metasediments, whereas the other plutons form sharp hills and do not have metamorphic aureoles. Consequently, the present erosion surface is believed to expose different levels of intrusion; rocks with contact aureoles represent the deeper, hotter parts of the magma, and smaller plutons with no metamorphic aureoles are probably cupolas, representing higher and cooler parts.

The diorite has been subjected to moderate kaolinite-sericite hydrothermal alteration in many parts of the plutons. The largest pluton has been intruded by a series of light-gray felsic dikes that were not studied in detail.

Jabal Qut'n granite

The large pluton in the southernmost part of the mapped area (pl. 1) consists of coarse-grained, peraluminous granite (Williams, 1983); deeper parts of the pluton are now exposed by erosion. Fluorite is found locally, but details of geology and geochemistry were not studied by the authors.

Pink granite dike

One large, pink, medium-grained granite dike, evidently controlled by northeast-striking faults, extends into the east part of the mapped area (pl. 1). It stands well above the present erosion surface of the enclosing metasedimentary rocks. It was not studied in detail by the authors.

STRUCTURE

Two major fault systems are prominent in the area: A northeast-trending (N. 40°-60° E.) set that cuts sedimentary rocks in a zone extending from Jabal Qut'n into the Meshaheed mineral zone, and a younger system of west-northwest striking Najd-type faults which offset left-laterally the northeast-trending set (pl. 1). The major vein system at Meshaheed is part of the northeast-trending fault set, which is also occupied by the large, pink granite dike. Both fault sets were controls for intrusion of small diorite plutons and felsic dikes.

Large-scale movement in an area southwest of Meshaheed is indicated by juxtaposed blocks of metasediments on opposite sides of Najd-type faults where strike of bedding is at right angles and where rocks are intensely folded in zones adjacent to both fault systems (pl. 1).

Numerous quartz-filled faults striking from northwest to northeast were mapped at Meshaheed. In addition, a major set striking N. 80° E. has provided access for intrusion of diorite just east of the mineralized zone and at Quartz Hill No. 1. These faults are probably contemporaneous with and subsidiary to the major northeast-striking set. The quartz veins at Asha North (pl. 1) are quartz-filled fractures spatially related to a Najd-type fault which, according to aeromagnetic data, is a major fault that crosscuts a large area in this part of the Shield. The quartz veins here strike N. 55° W. Experience with other veins adjacent to Najd-type faults outside the mapped area indicates that quartz-filled fractures generally follow two directions: N. 45°-55° W. and north. These faults are probably subsidiary to, and contemporaneous with, Najd-type faults.

ECONOMIC GEOLOGY

The most important mineral deposits in the Meshaheed area known at present are gold-stibnite-quartz veins in Murdama group metasedimentary rocks. These veins are also in diorite plutons and sub-volcanic basalt (pl. 1). Stockwork molybdenite-quartz veins are found within the diorite pluton at Quartz Hill No. 1, and quartz-vein stockworks at Quartz Hill Nos. 2 and 3 contain minor amounts of molybdenum; appreciable amounts of silver were found in one vein. Altered metasedimentary wall rocks contain gold in some areas, but the importance of this mineralization has not been investigated thoroughly.

Hydrothermal alteration includes zones of kaolinization and pyritization in small diorite intrusives at Quartz Hill Nos. 1, 2, and 3. Kaolinization, carbonatization, pyritization, and pyrrhotitization have altered sub-volcanic basalt and plagioclase porphyry at Meshaheed. Diorite plutons west of Meshaheed have been kaolinized and sericitized locally. A zone of moderately kaolinized metasediments extends northeast from Jabal Qut'n (pl. 1). Within these areas the normally gray to dark-gray metasediments are tan, light brown, and red brown. The extent of wall rock alteration associated with gold-stibnite-quartz veins in metasediments is difficult to estimate because of lack of exposures, but some of the ancient dumps contain appreciable metasedimentary rocks moderately to intensely altered to kaolinite, sericite, and pyrite.

Northeast-trending gold-stibnite-quartz veins in metasediments and diorite

The principal gold-stibnite-quartz vein system strikes approximately N. 40° E., passes through Quartz Hill No. 1, and was formed mainly by fracture-filling in metasediments (pl. 1, fig. 2). Outcrops at the southwest part of the vein system disclose iron-stained quartz 2 m thick with near vertical dip, but outcrops in the northwest part of the vein system display quartz veins 30-40 cm thick. Between these two zones, there are no vein outcrops and observations must depend on quartz vein fragments on ancient dumps. Judging from the spacing of workings and the size of quartz fragments on dumps, the veins appear to be discontinuous, lenticular, and range in thickness from 40 to 80 cm. Most of the quartz is milky, tan, streaked gray, slightly fractured and iron stained. Only minor pyrite in quartz was noted in veins southwest of Quartz Hill No. 1, but appreciable stibnite in quartz was found in and northeast of the Quartz Hill No. 1 area. Malachite stains appear to correlate with the presence of stibnite, but copper sulfide minerals were not seen. In hand specimen, the stibnite is steel gray, finely crystalline, and ranges from microfracture filling to massive pods in quartz. Weathered stibnite is ordinarily enclosed by a thin layer of yellow-orange secondary mineral. Free gold was not noted during field work on these veins, but microscopic examination of polished stibnite revealed tiny blebs of gold in that mineral.

Summary of analytical data

Quartz veins were sampled wherever possible, but most samples consist of quartz gathered indiscriminately from ancient dumps. Sample locations are shown on plate 1 and figure 2, and atomic absorption data are given in table 1. All the emission spectrographic data are not shown in tables, but notable element values are listed. Of twenty-eight quartz vein samples collected along the vein system, seven

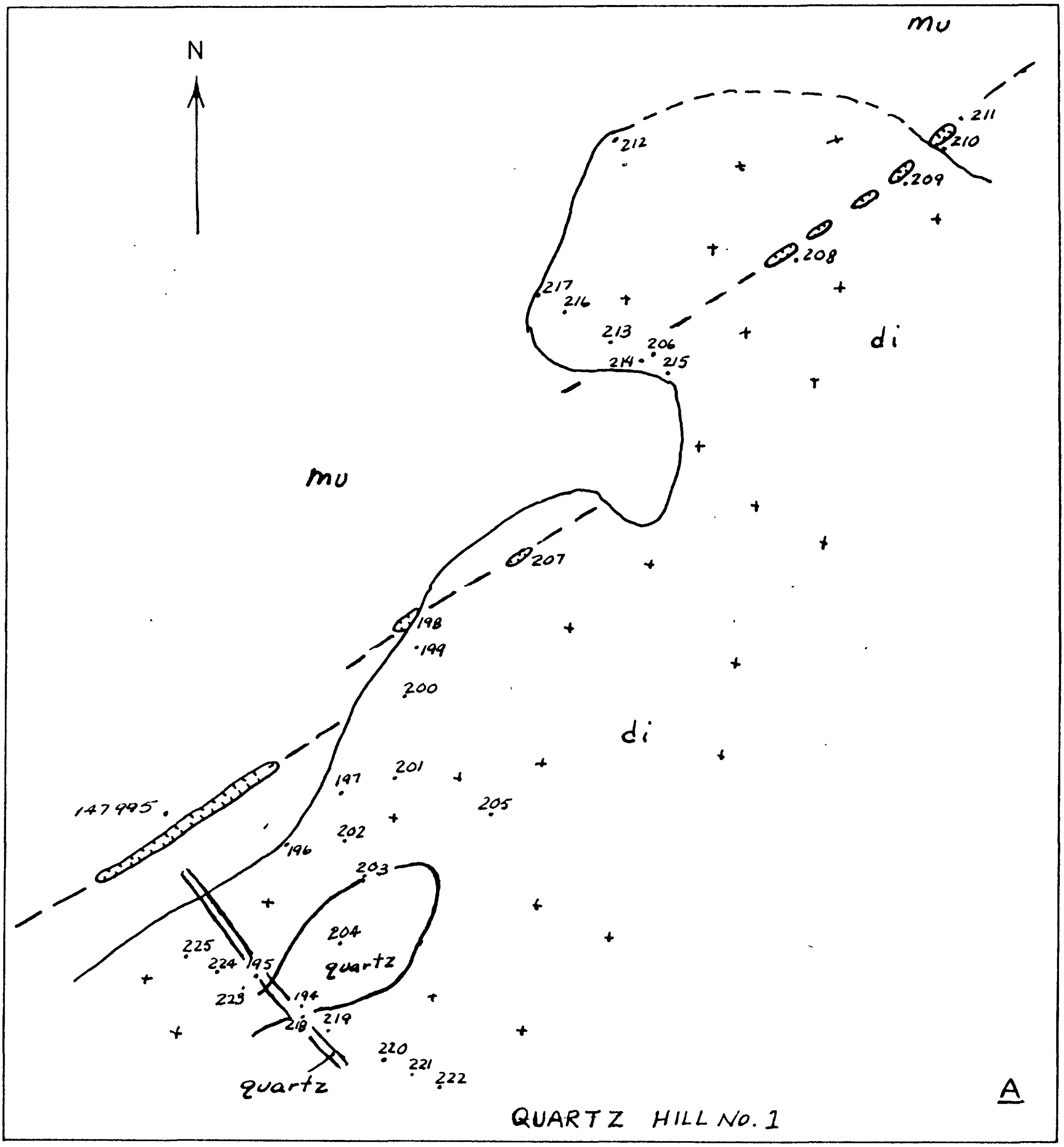


Figure 2.--Inset maps of hydrothermally altered diorite of Quartz Hill Nos. 1, 2, and 3. A, Quartz Hill No. 1; B, Quartz Hill No. 2; C, Quartz Hill No. 3. Inset locations are shown on plate 1.

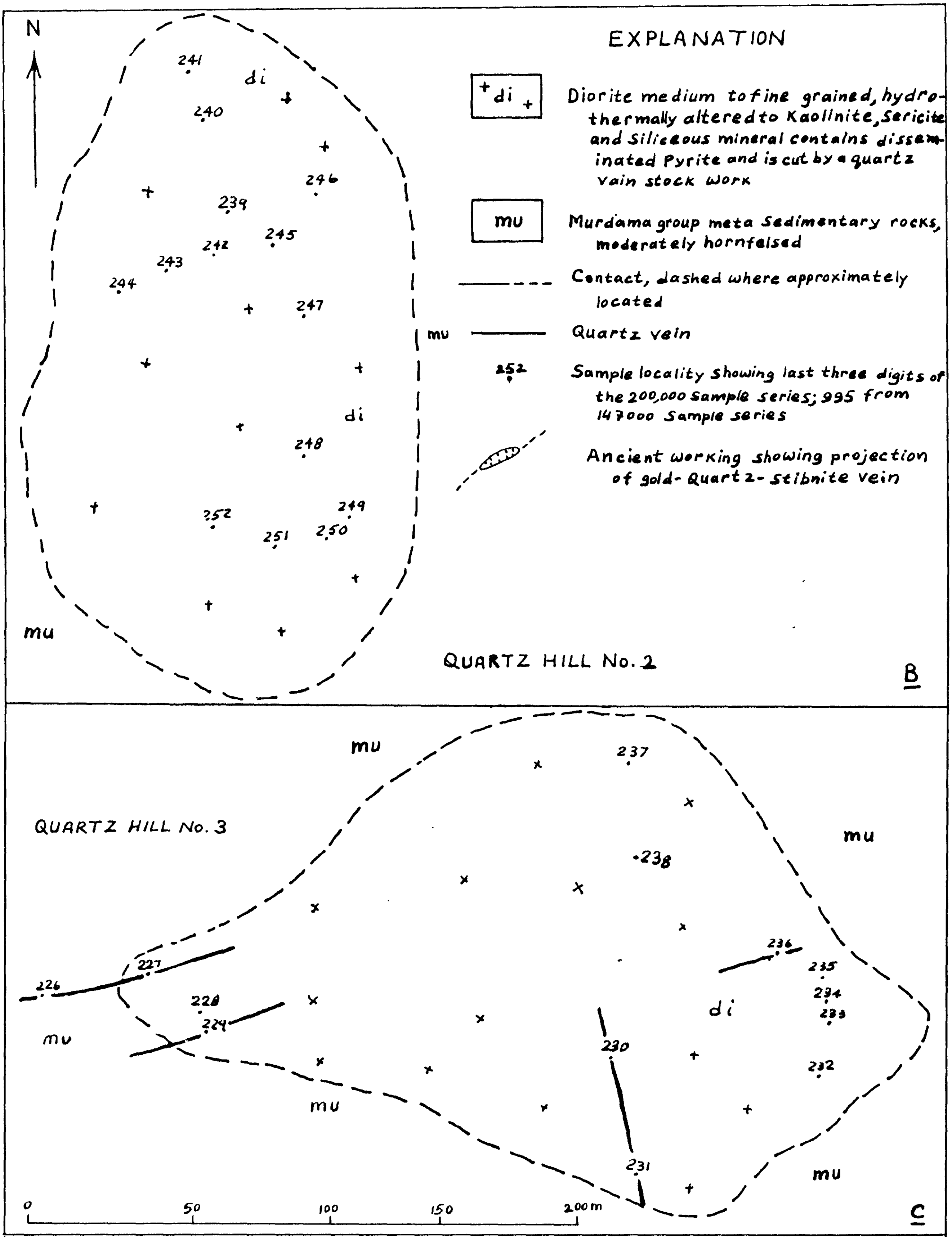


Figure 2.--Continued

Table 1.--Analytical data for sampling in the Meshaheed area--northeast striking gold-stibnite-quartz vein system. [Sample localities are shown on plate 1. Some sample localities also shown on fig. 2-A. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
147988	Quartz, FeO stained, from pit 10 m long, 7 m wide	2.0	1.0	2000	--	--
147989	Quartz vein, 50 cm thick, semi-banded, locally gray quartz	.4	1.3	200	--	--
147990	Quartz from dump, FeO stained, locally gray, pit 8 m long	3.4	2.3	--	--	--
147991	Quartz vein to 80 cm thick, moderate FeO stained, from dump, pit 5 m long	4.0	2.1	--	3000	--
147992	Quartz from dump, streaked gray with cubic pyrite; trench 20 m long	4.0	7.1	300	--	--
147993	Quartz from dump, finely fractured, FeO stained; trench 25 m long	.4	0.8	700	--	--
147994	Quartz from small pit	.6	1.4	1500	--	--
147995	Quartz from dump, contains stibnite, pyrite; trench 52 m long	36.3	56.0	3000	7000	Bi-15, Ba-3000
147996	Felsic dike, intensely altered	< .1	.1	--	--	--
147997	Quartz from sorting pile, ancient village; faint FeO stain	.4	4.1	1000	1500	Mo-70, Bi-20
147998	Quartz with stibnite, slight CuO stain, dump; trench 20 m long	27.9	25.3	--	2000	Bi-30
147999	Quartz with sparse stibnite, dump; trench 75 m long	16.0	9.0	700	300	--
200000	Quartz, streaked gray, moderate, limonite, dump	.4	--	500	300	--
200001	Quartz, streaked gray, moderate, limonite, dump	.3	.2	--	--	--
200002	Quartz, sparse FeO stain, dump; trench 45 m long	.4	.4	700	--	--
200003	Quartz, with stibnite, 30 cm thick, lenticular	.3	10.2	--	7000	--
200004	Quartz vein, 50 cm thick, with minor pyrite	< .1	.4	--	200	--
200005	Quartz with stibnite, from dump; trench 25 m long	.3	3.6	--	7000	--
200006	Wall rock, hydrothermally altered, same trench as No. 200005	.2	.6	500	700	--
200007	Small quartz vein with pyrite	.2	.2	200	--	--
200008	Quartz vein, 50 cm thick, lenticular minor limonite, copper stain	.4	13.5	300	500	
200009	Quartz vein, 30 cm thick, sparse pyrite, chalcopyrite?	< .1	4.3	--	200	
200010	Quartz veinlets, partially dark gray	< .1	.9	--	--	
200011	Quartz, blue-gray, dump; trench 5 m long	< .1	.1	--	--	Mo-300
200012	Quartz, blue-gray, with limonite, dump; trench 90 m long	< .1	.3	--	--	Bi-20
200013	Quartz vein, 40 cm thick, with pyrite	< .1	.1	--	1000	
200198	Small pit near contact to diorite. Quartz from dump	1.3	10.9	1000	10000	Mo-70, Bi-10
200207	Quartz, blue-white, from dump	9.7	3.1	500	>10000	Mo-5
	From Quartz Hill No. 1:					
200208	Quartz with abundant stibnite; dump	29.9	48.7	300	>10000	Mo-7, Bi-20
200209	--Do.--	89.2	90.0	300	>10000	Bi-20, W-50
200210	Quartz with sparse stibnite; dump	7.0	14.7	300	1500	
200211	Quartz with sparse stibnite and CuO; dump	11.7	10.3	1500	700	Mo-7

contained gold in the range 7.0-89.2 ppm, and silver in the range 9.0-90.0 ppm (table 1). All these samples contained stibnite in appreciable amounts, and all were collected near Quartz Hill No. 1 (pl. 1, fig. 2, table 1). Samples of the vein system southwest and northeast of Quartz Hill No. 1 gave ranges of 0.4-4.0 ppm gold, 0.8-7.1 ppm silver; and Trace-0.4 ppm gold, Nil-13.5 ppm silver, respectively. Stibnite-bearing quartz samples collected near the northeast end of the vein system contained minor amounts of gold and moderate amounts of silver. The mean gold and silver contents for 28 samples are 9.1 and 10.7 ppm, respectively, making a gold/silver ratio of 0.85. The northeast end of the vein system contains low values in precious metals and it appears that veins in this area branch, change directions, and terminate. However, low precious metal assays were also obtained from a large outcropping vein on the southwest extension, but here the veins may extend beneath the alluvium further southwest.

Emission spectrographic data indicate that quartz samples have low base metal and high arsenic and antimony contents. Bismuth was found in a few samples in the range 20-30 ppm.

Gold-stibnite-quartz veins and veinlets in basalt

A sub-parallel gold-stibnite-quartz vein system cuts intrusive basalt and centers on a hydrothermally altered zone in that rock (pl. 1). This vein system is much less distinct, and only limited areas show vein-wall rock contacts. In most places, veins are only vaguely defined, mainly by the presence of stibnite; fist-sized fragments of weathered vein rubble containing stibnite were found adjacent and southwest of sample point 200014 (014 on pl. 1). Several other points within the altered zone disclose stibnite in very limited and vaguely defined veins or veinlets. Hydrothermal alteration, and alluvium and talus cover make study of rocks in this zone difficult. However, thin sections from several basalt samples collected within the altered zone showed moderate to intense silicification, kaolinization, carbonatization, pyritization, and pyrrhotitization. All thin sections of the altered and fractured basalt reveal cross-cutting, quartz-and-pyrite-filled fractures and microfractures that are ordinarily less than 1 mm thick. Evidently, the basalt has reacted differently than the metasediments under conditions of shearing and has developed intricate systems of fractures and microfractures enabling quartz, pyrite, and perhaps stibnite and gold to be precipitated in small openings to form quartz stockworks.

A small felsic plagioclase porphyry has intruded basalt and is the only rock of this type found in the mapped area. The feldspar crystals are partially replaced by sericite and kaolinite, and fine pyrite is disseminated throughout. Sample No. 200264 (table 2, pl. 1) of this rock contained a notable 20 ppm tin.

Summary of analytical data

Most samples are from quartz, or altered wall rock gathered from ancient dumps, but one sample of nearly pure stibnite was collected from weathered vein rubble. Sample number 200016 is a 16-m rock-chip sample traverse across hydrothermally altered basalt and the projection of a quartz-stibnite vein. The range of values for ten samples collected within the altered zone (pl. 1, table 2) is gold <0.1-13.6 ppm and silver 0.3-6.0 ppm. Mean gold and silver values are 3.8 and 2.3 ppm, making the gold/silver ratio 1.65 in this area.

Emission spectrographic analytical results show erratic high ranges for the following elements: arsenic, 200-1000 ppm, and antimony, 500->10,000 ppm. One sample contained 20 ppm bismuth, and one contained 50 ppm tungsten. The base metal content of the samples was noticeably low.

Mineral zones of indeterminate character in basalt

Numerous small, ancient workings in the intrusive basalt are east and adjacent to the gold-stibnite-quartz system in the same rock. They are described differently because dump material apparently does not contain the normal quartz-stibnite fragments found in adjacent areas. Dark-gray quartz with abundant hematite and, in places, limonite was collected for sampling, but none of the samples contained gold, arsenic, or antimony (pl. 1, table 2). Some of the basalt on dumps is relatively unaltered and contains disseminated pyrrhotite, but other specimens are altered and cut by quartz-pyrite veinlet stockworks. One such polished specimen contains tiny crystals of sphalerite and chalcopyrite. Detailed examination of rock specimens collected from this zone indicates that many of the workings are on, or near, contacts of basalt with diorite. These are not shown on plate 1 because of the small scale.

These workings trend northeast, northwest, and north, and veins within the zone are probably on subsidiary, second-order fractures to the major northeast-trending set. Most of the zone is covered by talus, and rock is exposed only in small drainages.

Table 2.--Analytical data for sampling in the general Meshaneed area

[Sample localities are shown on plate 1. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
147778	Felsic stock, moderate argillic alteration	0.2	0.5	700	--	Mo-300
147779	Quartz stockwork in hydrothermally altered felsic intrusive	.2	< .5	--	--	Mo-1500
147781	Diorite, medium-grained	.2	.6	--	--	
147782	Sedimentary rocks, hydrothermally altered	.1	.8	--	--	
147791	Quartz stockwork, small	--	< .5	--	--	
147831	Quartz from sorting pile	.2	< .5	--	--	
147832	Quartz, grab, from dump	1.2	3.7	--	--	
147851	Diorite, fine-grained	.5	--	--	--	Ba-700, Mo-5
147859	Felsic intrusive, moderate argillic alteration	.3	.5	700	--	Mo-100
147860	Quartz stockwork, grab sample, float	--	--	--	--	Mo-700
147861	--Do.--	1.3	1.0	--	300	Mo-700
147950	Diorite, extremely altered	< .1	1.7	--	--	Mo-20
147951	Quartz vein with pyrite	.2	1.3	--	--	Mo-50, Bi-700
147952	Felsic intrusive, hydrothermally altered	.1	1.0	--	--	
147966	Quartz vein, sugary texture, with epidote	.1	.1	--	--	Nb-70
147967	Siltatone, hornfelsic	.3	.1	--	--	
147986	Quartz, milky	.1	.1	--	--	Mo-5
147987	Diorite, fresh	.1	.7	--	--	
200014	Quartz with moderate FeO, slight CuO stain, dump, trench 8 m long	2.4	.3	--	700	
200015	Stibnite vein, surface rubble	12.9	5.4	200	>10000	
200016	Basalt, hydrothermally altered, abundant pyrite, 16 m chip sample	2.0	.5	--	700	
200017	Gray quartz, dump	< .1	1.2	--	100	
200018	--Do.--	< .1	.6	--	--	
200019	--Do.--	< .1	1.0	--	--	
200020	--Do.--	< .1	1.3	--	--	
200021	--Do.--	< .1	1.1	--	--	
200022	--Do.--	< .1	.6	--	--	
200023	--Do.--	< .1	1.4	300	--	
200024	--Do.--	< .1	1.3	--	--	
200025	--Do.--	< .1	.9	--	--	W-50
200026	--Do.--	< .1	1.5	--	--	
200027	--Do.--	< .1	2.5	--	100	
200028	--Do.--	< .1	2.0	--	--	
200029	--Do.--	< .1	1.1	--	--	
200030	--Do.--	< .1	1.6	--	--	
200031	--Do.--	.3	1.0	--	--	Bi-20
200032	Quartz vein, 30 m thick, faint FeO stain	.2	1.0	200	3000	
200033	Quartz with stibnite, dump, trench 18 m long	4.0	6.2	1000	3000	
200034	Altered zone in basalt. Abundant hematite after FeS_2	.1	.9	--	--	Mo-20
200035	Quartz with balck calcite, dump, trench 10 m long	< .1	.5	--	--	W-50
200036	Wall rock, hydrothermally altered. Same trench as no. 200035	< .1	.5	--	--	
200037	Quartz with stibnite, dump, trench 10 m long	10.6	5.4	700	>10000	
200038	Wall rock, hydrothermally altered. Same trench as no. 200037	3.6	.9	700	7000	
200039	Calcite-quartz veinlets	.1	1.5	--	500	
200142	Quartz with stibnite, dump, pit 7 m diameter	17.6	1.0	700	>10000	
200143	Quartz with pyrite, dump, trench 12 m long	1.7	.7	700	3000	

Table 2.--Analytical data for sampling in the general Meshaheed area--Continued

Sample No.	Sample description	Atomic absorption analyses Au	Atomic absorption analyses Ag	Emission spectrographic semiquantitative analyses As	Emission spectrographic semiquantitative analyses Sb	Other noteworthy analyses
200144	Diorite, medium-grained	<0.1	<0.5	--	--	
200145	Dike, feldspar porphyry with disseminated pyrite	< .1	.5	--	--	
200146	Quartz vein with pyrite, 40 cm thick	< .1	< .5	--	--	
200147	Quartz with stibnite, brecciated, dump. Trench 20 m long	1.6	< .5	500	>10000	
200148	Diorite, hydrothermally altered	< .1	< .5	--	--	
200253	--Do.--	.7	< .5	1000	--	
200264	Feldspar porphyry moderately hydrothermally altered	.8	.7	--	--	Sn-20
200265	Diorite, moderately hydrothermally altered. Disseminated pyrite	.8	.5	--	--	
200266	Basalt, intensely hydrothermally altered	.8	1.4	--	--	

Gold-stibnite-quartz veins in diorite

Several other limited zones of gold-stibnite-quartz veining were found during our studies of the Meshaheed area. At sample locality 200147 (pl. 1, table 2) a quartz vein bearing abundant stibnite strikes S. 55° E. and is defined by a small ancient trench about 20 m long. The workings are in a small area of hydrothermally altered diorite and the quartz is impregnated with iron oxide and has been brecciated and resealed by quartz. These workings are on the southwest extension of the major gold-stibnite-quartz vein-fracture system (pl. 1), but the strike of the ancient trenches indicates that the quartz veins here are on a second-order fracture set. At sample localities 200142 and 200143 (pl. 1, table 2), small areas of ancient pits and trenches in diorite also contain quartz, stibnite, and gold in much the same manner as those described above. Alignment of trenches, however, are east-west, indicating that these veins are on second-order fractures related to a major west-northwest-trending Najd-type fault. Stibnite in quartz was also found in minor amounts in the large diorite pluton in the northwest corner of the mapped area, but this mineral appears to be much less common in this region.

Gold-quartz veins and veinlets in metasediments and diorite

Several groupings of ancient workings on both east and west sides of the large diorite pluton are given the names Pluton Southeast, Northwest, West, and Southwest for identification purposes (pl. 1, figs. 3 and 4). Nearly all of the workings are in hornfelsed metasedimentary rocks on the periphery of the pluton, and nowhere in this region are veins or veinlets exposed. Minor quartz remains on dumps, but judging from the size of the fragments and the type of mining employed, it seems probable that in much of the area, quartz veinlets were worked for their gold content. For example, Pluton Southeast ancient workings is a series of pits, each approximately 5 m in diameter, closely adjoined, and extending 600 m north-south, and as much as 40 m east-west (fig. 3). Quartz which remains on dumps is coarsely crystalline to vuggy, to saccharoidal, faintly iron stained, in places, clear to transluscent, and locally gray, but ordinarily milky. Calcite is a minor constituent, but pyrite was not observed. Free gold in thin fractures and adjacent to chlorite clots in quartz was found in this area.

The Pluton Southeast ancient workings are entirely in metasediments, but Pluton Northwest trenches are in diorite, and Pluton West and Southwest workings are near, or on, the metasediment-diorite contacts, mostly in metasediments, but partly in diorite (pl. 1, figs. 3 and 4).

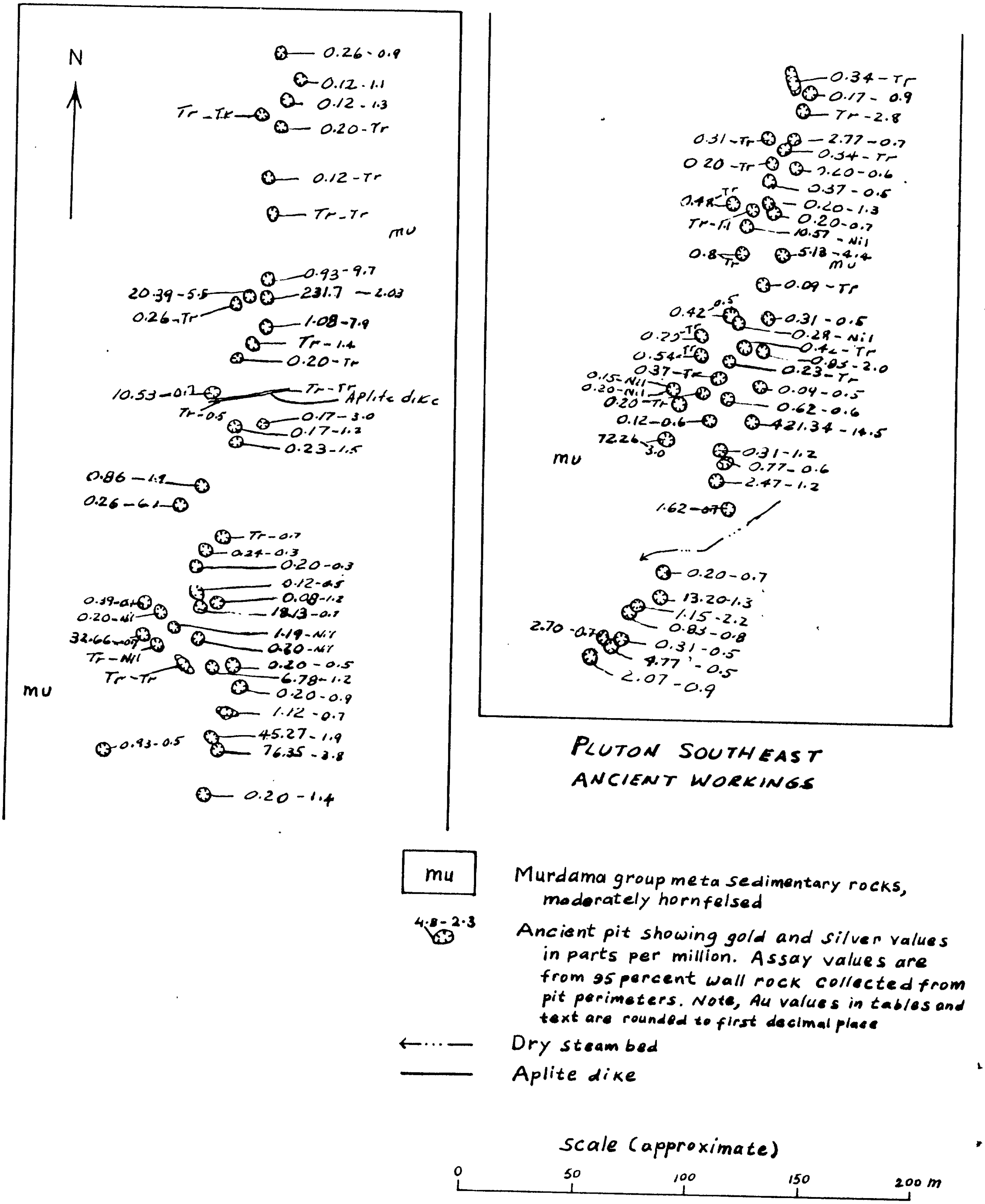
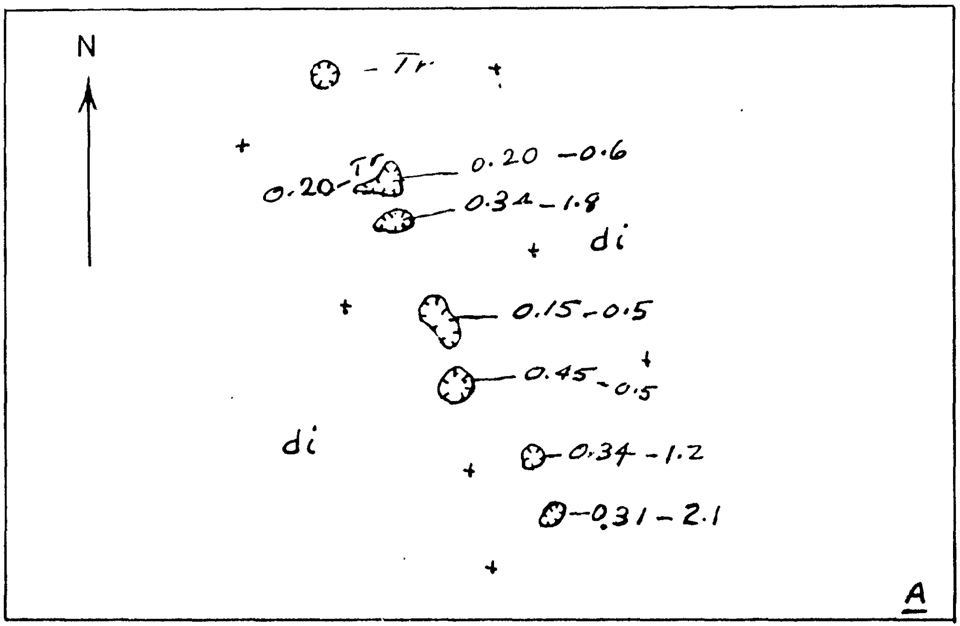


Figure 3.--Inset map showing Pluton Southeast ancient workings and assay values of gold and silver. Inset location is shown on plate 1.



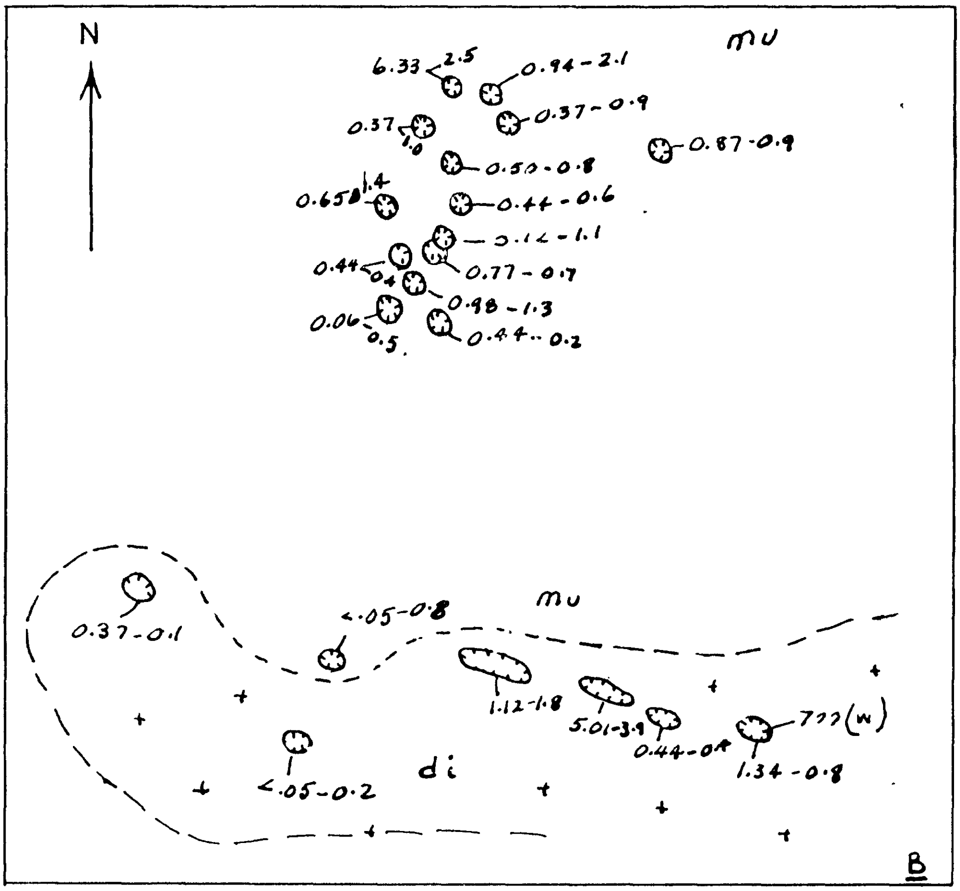
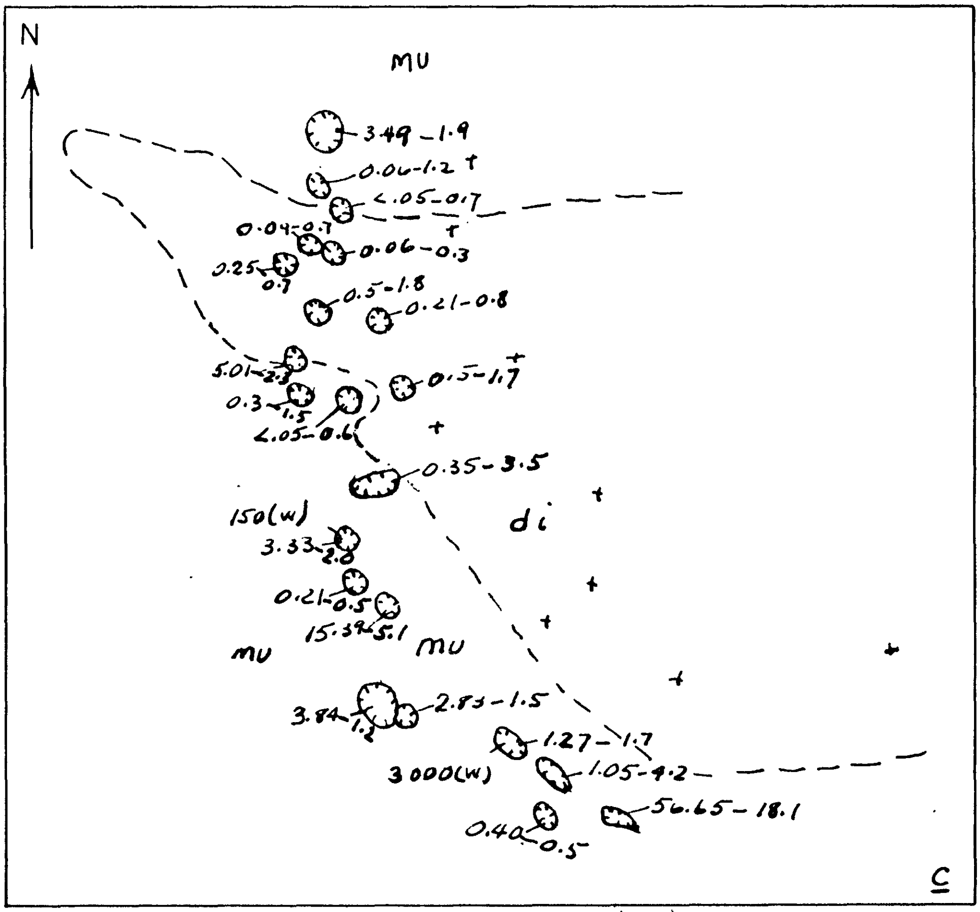


Figure 4.--Inset maps showing Plutons Northwest, West, and Southwest ancient workings and assay values of gold and silver. Inset locations are shown on plate 1.



EXPLANATION

di	Diorite, medium to coarse grained, locally hydrothermally altered
mu	Murdama group meta sedimentary rocks, moderately hornfelsed
– – – –	Contact, approximately located
Gold Silver 7.80 - 5.2	Ancient pit showing gold and silver values in parts per million. Assay values are from 95 percent quartz and 5 percent wall rock collected from pit perimeters. Notable assay values of other elements are also shown. Note, Au values in tables and text are rounded to first decimal place

Scale 1:2000 (Approximate)

0 50 100 150 200 Meters

Figure 4.-- Continued

All the ancient workings were mapped by plane table methods at 1:2000-scale, but because of the lack of outcrops, most show few details of geology (figs. 3 and 4). The mapping shows size and arrangement of the ancient pits. The pits were sampled by collecting quartz from dumps around their perimeters, but it must be noted that many dumps had very sparse quartz. Consequently, it is questionable whether the gold content of this dump material is indicative of the tenor of the ore mined and treated by the ancients. However, no sampling method short of trenching, pitting, or drilling would give better information. Wall rock from dumps was also sampled in places.

Gold and silver values for all sampling in these ancient mining areas are shown in figures 3 and 4. Emission spectrographic data for 30 elements are not given in tables because of the large number of samples involved, but may be obtained from the Rock Analysis Storage System (RASS) files of the USGS in Jiddah. Notable amounts of any element shown in spectrographic analytical data are given in the text.

Summary of analytical data

Pluton Southeast ancient workings.--Sampling gave very erratic results (fig. 3); of 88 samples of quartz material collected from dumps, 66 contained less than 1 ppm gold, but the range of gold content for the remaining samples was 1.1-421.3 ppm. The gold/silver ratio for all 88 samples is 9.2, which probably signifies that free gold is important in this deposit. Very high gold content of a few samples also indicates that the metal is in rich pockets in the quartz, although one sample of altered wall rock assayed 18.1 ppm gold.

Emission spectrographic analytical results show that some elements are erratically high in the following ranges: arsenic 200-300 ppm, copper 200-1000 ppm, antimony 200-2000 ppm, and lead 200-500 ppm. Several samples contained 10-15 ppm tin.

Pluton Northwest ancient workings.--These workings in diorite consist of a series of pits and trenches approximately 140 m long. All quartz samples collected from dumps ran less than 1 ppm gold, and silver values were from Trace to 2.1 ppm (fig. 4). Emission spectrographic analytical data gave the following ranges: arsenic Nil-3000 ppm, and antimony Nil->10,000 ppm. Low values were obtained for copper, lead, and zinc.

Pluton West ancient workings.--This group of ancient workings can be divided into two sets: a north-trending array of pits in metasediments, and a west-trending group which is mainly in diorite (fig. 4). The ranges in dump sample assay values is for gold Trace-6.3 ppm and for silver 0.2-3.9 ppm. The mean gold value is 1.0 ppm and the mean silver value is 1.1 ppm, making the gold/silver ratio 0.91. According to emission spectrographic determinations, nine samples contained arsenic in the 200-700 ppm range, and none of the samples contained detectable antimony.

Pluton Southwest ancient workings.--This set of workings cross the metasediment-diorite contact; 22 samples of quartz from dumps were gathered. The range of values is gold Trace-56.7 ppm and silver 0.5-18.1 ppm. Twelve samples contained less than 1 ppm gold (fig. 4). Mean gold and silver assay values were not calculated because of erratically high values. The gold/silver ratio is 1.8 and emission spectrographic analyses found three samples containing arsenic in the 300-700 ppm range, and two samples containing 150 and 3000 ppm tungsten.

Quartz stockworks in diorite plutons

Three small, moderately hydrothermally altered diorite plutons, named Quartz Hill Nos. 1, 2, and 3, intrude metasediments in the mapped area (pl. 1). All are cut by quartz stockworks, are moderately pyritized, and are mostly covered by quartz vein rubble. Quartz Hill Nos. 2 and 3 are widely separated from Quartz Hill No. 1, but because of their similarity they are described together.

All three plutons were cursorily mapped and sampled in order to determine their relationship with gold-stibnite-quartz veins, and to learn something of their geochemical nature (fig. 2).

Quartz Hill No. 1

Quartz Hill No. 1 consists of a diorite pluton that has been fractured, invaded by quartz stockworks, and completely metasomatized to quartz locally. The remainder of the diorite is slightly to moderately kaolinized, and has undergone varying degrees of pyritization. Apparently several ages of quartz have invaded the diorite, some of which is folded, but there was no attempt to study this during detailed mapping (fig. 2). The main characteristic of the mineralization brought out by mapping and sampling is the distinct nature of the quartz stockwork as opposed to the gold-stibnite-quartz system in the area. Figure 2 shows ancient workings adjacent to, and within, the diorite pluton. These workings are on gold-stibnite-quartz veins which cut the diorite pluton in a northeast direction and are, as indicated on plate 1, part of the northeast-trending system. The quartz veinlet stockwork and larger veins and masses within the pluton contain molybdenite and very low values in precious metals (fig. 2, table 3). In fact, detailed sampling has shown that the higher precious metal values were obtained from quartz on ancient dumps or from diorite with quartz veinlet stockworks on the projection of the northeast-trending quartz vein system. The quartz-molybdenum stockwork and vein system contains molybdenite in flakes as much as 3 mm in diameter, but normally very finely disseminated molybdenite gives the quartz a spotted, blue-gray texture locally. Pyrite is very sparse or is absent from the stockwork.

Table 3 shows analytical data for samples from Quartz Hill No. 1. Quartz from dumps of ancient workings contained relatively high arsenic and antimony in addition to precious metal values; molybdenum values are low or absent in three samples. On the other hand, samples from diorite with quartz veinlets or from quartz veins or veinlets in the stockwork system gave assay results generally high in molybdenum and erratically high in arsenic and antimony. Bismuth in the 20-50 ppm range is a common constituent.

Quartz Hill Nos. 2 and 3

Preliminary mapping and sampling has indicated the similarity of these plutons with Quartz Hill No. 1, the exception being the absence of an associated gold-stibnite-quartz vein system. Both plutons are moderately altered to quartz, sericite, kaolinite, and pyrite, and both contain fracture filling quartz veins and stockworks (fig. 2). Pyrite accompanies the quartz, but molybdenite was not seen.

Fourteen samples of altered diorite, quartz veins, and diorite containing quartz veinlet stockworks were collected at Quartz Hill No. 2 and the analytical data are listed in table 4. It should be noted that samples 200240 through 200245 all contain 0.6 ppm gold according to analytical results, and samples 200246 through 200249 contain 0.8 ppm gold. Because of potential analytical errors in the gold values initially reported to two decimal places, the authors have chosen to round off the gold values to the first decimal place. The authors do not care to interpret these analyses. These data show gold values in the range 0.6-0.8 ppm and silver in the range Nil-<0.5 ppm. Eight samples contained molybdenum in the range 5-50 ppm, and three samples contained bismuth in the range 15-100 ppm.

Thirteen samples of the same type of material were collected at Quartz Hill No. 3 and analytical data are listed in table 5. The authors do not care to interpret reported analytical results for samples 200233 through 200235 which

Table 3.--Analytical data for sampling in the Meshaheed area--Quartz Hill No. 1 quartz-molybdenite stockwork [Sample localities are shown on figure 2-A and plate 1. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
200194	Diorite, argillic alteration	0.1	0.6	--	--	Mo-30
200195	Quartz stockwork	< .1	--	--	--	Mo-70
200196	Diorite, moderately altered	< .1	< .5	--	--	Mo-20
200197	Diorite, mafics completely altered, disseminated pyrite	.6	.6	700	1500	Mo-70
200199	Quartz stockwork	.1	< .5	700	--	Mo-10
200200	Quartz stockwork with dark streaks	2.2	< .5	--	--	Mo,>2000, Bi-20
200201	Granite cut by quartz stockwork	.4	--	--	--	Mo-50
200202	--Do.--	1.0	< .5	--	--	Mo-300, Bi-70
200203	Quartz, dark gray, blue	1.3	< .5	--	--	Mo,>2000
200204	Quartz stockwork	.9	--	--	--	Mo-50
200205	Diorite, altered	.9	< .5	--	--	Mo-20
200206	--Do.--	2.1	< .5	3000	--	Mo-50
200212	Diorite, moderately altered, disseminated pyrite	.9	< .5	--	--	Mo-10
200213	Diorite, moderately altered	.7	--	--	--	Mo-150
200214	Diorite, with a few quartz veinlets	.9	< .5	--	--	Mo-15
200215	Diorite, moderately altered with disseminated pyrite	2.1	.6	1000	--	Mo-150
200216	Diorite, moderately altered with a few quartz stringers	.8	< .5	--	--	Mo-500
200217	Diorite, weathered	1.6	< .5	--	--	Mo-20
200218	Diorite, argillic alteration	.5	< .5	1000	--	Mo-50
200219	Diorite, abundant pyrite and sericite	.8	< .5	1500	--	Mo-70
200220	--Do.--	.9	< .5	--	--	Mo-15
200221	--Do.--	.9	.6	--	--	Mo-10
200222	Diorite, moderately altered no pyrite	.9	.3	--	--	Mo-15
200223	Diorite, intensely altered to sericite with quartz	1.1	.5	--	--	Mo-20
200224	Diorite, intensely altered to sericite with sparse pyrite	1.1	< .5	--	--	Mo-10
200225	Diorite, moderately altered	.9	< .5	--	--	Mo-7

Table 4.--Analytical data for sampling in the Meshaheed area--Quartz Hill No. 2

[Sample localities are shown on figure 2-B and plate 1. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
200239	Diorite, moderately altered to quartz and sericite. Limonite disseminated	0.8	<0.5	--	--	Mo-5
200240	Diorite, moderately altered with quartz stringers	.6	< .5	--	--	Bi-100, Mo-10
200241	Diorite, intensely sericitized	.6	< .5	--	--	Mo-7
200242	Aplite dike?, moderately altered to quartz, sericite, minor epidote. Moderate disseminated FeO	.6	< .5	--	--	Mo-5
200243	Diorite, fine-grained, chilled margin?, moderately sericitized and pyritized	.6	< .5	--	--	
200244	Diorite, quartz-sericite alteration with disseminated FeO	.6	< .5	--	--	
200245	Diorite, intensely sericitized with disseminated FeO	.6	.5	--	--	Ba-1000, Mo-50
200246	Quartz, massive, white	.8	< .5	--	--	Mo-5, Bi-15
200247	Diorite, sericitized. Disseminated FeO	.8	< .5	--	--	
200248	--Do.--	.8	< .5	--	--	Mo-20
200249	--Do.--	.8	< .5	--	--	Mo-15
200250	Quartz, blue-gray, 30 cm thick	.7	--	--	--	
200251	Diorite, sericite, clay alteration	.7	--	--	--	
200252	Diorite, sericite, clay alteration, disseminated FeO	.7	--	--	--	Bi-15

Table 5.--Analytical data for sampling in the Meshaheed area--Quartz Hill No. 3
[Sample localities are shown on figure 2-C and plate 1. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
200226	Quartz vein with pyrite	0.9	<0.5	--	--	
200227	Diorite, moderately altered	.8	< .5	--	--	
200228	Rhyolite dike, silicified, sparse disseminated pyrite	.8	< .5	--	--	
220229	Quartz vein, white	.7	< .5	300	--	
220230	--Do.--	.6	< .5	--	--	
200231	--Do.--	.8	< .5	--	--	
200232	Diorite with moderate sericite and disseminated pyrite	.6	.7	--	--	Mo-15
200233	Diorite, intensely sericitized	.6	< .5	--	--	Mo-7
200234	Diorite, silicified with disseminated pyrite	.6	< .5	--	--	Mo-7
200235	Diorite, silicified with limonite after pyrite	.6	< .5	--	--	Mo-5
200236	Quartz, 20 cm thick vein, minor FeO	.8	47.0	--	--	Bi-70, Pb-150
200237	Diorite, moderately sericitized	.8	< .5	--	--	Mo-7
200238	--Do.--	.8	< .5	--	--	Mo-10

have listed gold values of 0.6 ppm and samples 200236 through 200238 which have listed gold values of 0.8 ppm. According to the tabulated data, all samples contained gold in the range 0.6-0.9 ppm, and all except two samples contained less than 0.5 ppm silver; a sample of pyritized diorite contained 0.7 ppm and a moderately iron-stained quartz vein sample contained 47.0 ppm silver. This sample also contained 70 ppm bismuth and 150 ppm lead. Six samples contained molybdenum in the range 5-15 ppm. One sample of quartz vein contained 300 ppm arsenic, otherwise, arsenic and antimony are noticeably absent from the area.

Geochemistry of hydrothermally altered zones in metasediments

Twenty-three rock-chip samples were collected from altered areas in metasediments in order to determine the geochemical characteristics of the hydrothermal system which affected the area (pl. 1, table 6). All samples had low gold and silver contents and emission spectrographic analyses detected molybdenum in the 5-10 ppm range in eight samples. Otherwise, no unusual amount of any element was found.

Asha North ancient workings

The ancient workings at Asha North (pl. 1, table 2) consist of a line of trenches 120 m long, trending N. 55° W. Quartz on dumps is iron stained and milky white. The veins are evidently in metasediments, but are now covered by mining debris. Analytical results for two grab samples of quartz (147831, 147832) from dumps ran 0.2 and 1.2 ppm gold and Trace and 3.7 ppm silver. Assay values were low in all other metals.

STATISTICAL STUDIES OF ANALYTICAL DATA

Mapping in the Meshaheed area has indicated that at least two periods of mineral deposition are evident in the zone; namely the formation of the gold-stibnite-quartz veins and the molybdenite-quartz stockwork at Quartz Hill No. 1. Analyses from samples at Quartz Hill Nos. 2 and 3, and in hydrothermally altered metasediments gave erratically low molybdenum values, and for this reason both of the zones were suspected of being contemporaneous with the molybdenite-quartz stockwork at Quartz Hill No. 1. In order to study this aspect further all sampling in the Meshaheed area was grouped into four classes: (1) Meshaheed area northeast-striking gold-stibnite-quartz veins; (2) Quartz Hill No. 1 molybdenite-quartz; (3) Quartz Hill Nos. 2 and 3; and (4) hydrothermally altered metasediments. Tables A1-A4 in the

Table 6.--Analytical data for sampling in the Meshaheed area--hydrothermally altered metasediments
[Sample localities are shown on plate 1. Values in parts per million (ppm). Detection limits for semiquantitative emission spectrographic analyses are: arsenic (As) 200 ppm, antimony (Sb) 100 ppm; > = greater than; < = less than; -- = not detected]

Sample No.	Sample description	Atomic absorption analyses		Emission spectrographic semiquantitative analyses		Other noteworthy analyses
		Au	Ag	As	Sb	
147792	Sedimentary rocks, hydrothermally altered	--	0.6	--	--	
147827	--Do.--	<0.1	.7	--	--	
147828	--Do.--	< .1	.5	--	--	
147829	--Do.--	< .1	< .5	--	--	
147830	--Do.--	.1	3.5	--	--	Zn-140
147968	--Do.--	.1	.4	--	--	
147969	--Do.--	.2	1.1	--	--	
147970	--Do.--	.1	.4	--	--	
147971	--Do.--	.1	1.2	--	--	
147972	--Do.--	.1	.5	--	--	
147973	--Do.--	.1	1.0	--	--	
147974	--Do.--	< .1	2.2	--	--	
147975	--Do.--	.1	.3	--	--	
147976	--Do.--	.1	.3	--	--	Mo-7
147977	--Do.--	.1	.3	--	--	Mo-7
147978	--Do.--	.1	.1	--	--	
147979	--Do.--	.1	.4	--	--	Mo-10
147980	--Do.--	.1	.4	--	--	Mo-5
147981	--Do.--	.1	.4	--	--	
147982	--Do.--	.1	.4	--	--	Mo-5
147983	--Do.--	.1	.4	--	--	Mo-7
147984	--Do.--	.1	.3	--	--	
147985	--Do.--	.1	.6	--	--	Mo-7

appendix are correlation matrices for the metals analyzed for among the four sample classes.

The Meshaheed vein system contains arsenic and antimony in 28 pairs, whereas, samples from the remaining groups contain no detectable amounts of these metals. The correlation of gold with other elements was not particularly helpful when considering trends among data groups; only a moderate correlation with antimony stands out as unique. Silver correlates moderately well with copper, lead and antimony in the Meshaheed vein system group, whereas, only silver and copper were moderately correlative in altered metasediment samples.

Probably molybdenum is the most useful element in comparing different groups, since it is present in varying amounts in all data sets and appears to correlate differently among them. Molybdenum is moderately correlative with arsenic, barium, antimony, and zirconium in the Meshaheed vein system samples. Quartz Hill No. 1 samples show moderate negative correlations of molybdenum with iron, magnesium, calcium, manganese, copper, and strontium; samples from Quartz Hill Nos. 2 and 3 and from altered metasediments show moderate to high positive correlation between molybdenum and iron, magnesium, calcium, manganese, and copper. Copper correlates moderately well with lead, antimony, zirconium, and silver in Meshaheed veins only, again, making the vein system unique from other sampled areas.

These studies indicate that the Meshaheed gold-stibnite-quartz vein system was derived from a different stage of mineral deposition than that of the quartz-molybdenite stockwork at Quartz Hill No. 1. The correlation coefficients of various elements at Quartz Hill Nos. 2 and 3 are unlike those of Quartz Hill No. 1, but resemble those of the altered metasediments suggesting that there may have been several periods and types of metallization in the entire area.

REGIONAL GEOCHEMISTRY

A program of wadi sediment sampling has been completed by the USGS in a large area of the northern Arabian Shield, which includes the Meshaheed area. This program, conducted by R. M. Samater, included gathering wadi sediments on a density of approximately one sample per square kilometer and saving the panned fraction minus magnetic material for emission spectrographic analysis. Analytical data for all samples collected within the Jabal Habashi quadrangle, 26F, were given to the USGS, Denver, Colorado for statistical analysis, and results of this work identified the Meshaheed area as anomalous in some metals. Specifically, using R-mode factor analysis, an area southeast and adjacent to Meshaheed is anomalous in lead, copper, boron, and tin (Allen and others, 1984). In addition, single-element analyses indicate significant concentrations of lead, copper, boron, tin, iron, and molybdenum.

GEOPHYSICAL STUDIES

Preliminary geophysical studies made at Meshaheed by Flanigan and Zablocki (1984) consisted of audio-magneto-telluric and telluric-electric methods, which measure the relative resistivities of subsurface materials; the resistivity is a function of the clay therein. These geophysical methods were being tested for the first time in Arabian Shield rocks, and one traverse nearly east-west across the hydrothermally altered intrusive basalt at Meshaheed extended approximately 7.5 km (pl. 1). A large anomalous low-resistivity zone was found to be about 2 km in width and to extend to depths in excess of several kilometers. Flanigan and Zablocki pointed out that (1) this zone coincides with the surface extent of the exposed altered sub-volcanic basalt (ba on pl. 1); (2) the most electrically conductive part coincides exactly with the location of the exposed, highly altered plagioclase porphyry felsic intrusive (pp on pl. 1); (3) the low resistivities are caused by the relatively higher content of clay minerals in altered rocks in contrast to the unaltered igneous or metasedimentary rocks in the surrounding area. The telluric-electric method also revealed a zone of extremely low resistivity in an area about 1 km east of the intrusive basalt. Concerning this, Flanigan and Zablocki indicate the possibility that this area is underlain by similar, if not more intensely altered rocks.

GEOLOGIC HISTORY

Although some data are absent and time relationships have not been established concerning certain geological events, the sequence of geological activities that lead to mineralization at Meshaheed probably occurred in the following order: The initial phase was folding of metasediments and the formation of northeast-trending faults, probably concurrent with the intrusion of basalt. Continued movement on northeast-trending faults fractured the basalt and opened channelways in metasediments. Subsequent northwest-trending Najd-type faults formed, and diorite intruded both fault sets to form cupolas. Hydrothermal systems, perhaps a subsequent phase of dioritic or granitic intrusive activity, then deposited molybdenite-quartz stockworks in Quartz Hill No. 1 and later deposited quartz stockworks in Quartz Hill Nos. 2 and 3. Large areas of metasediments were moderately hydrothermally altered along fault systems at this time. The final phase of hydrothermal activity was the alteration of basalt and diorite and deposition of gold-quartz-stibnite in fractures.

DISCUSSION

Any discussion of the genesis of molybdenite or gold mineralization at Meshaheed must take into account the presence of nearby granite at Jabal Qut'n. This mineralization is similar in many respects to base and precious metal deposits spacially associated with the granite plutons, Jabal Silsilah and Baid al Jimalah, which are relatively near the Meshaheed area (fig. 5). Although the Meshaheed area is 10 km north of the Jabal Qut'n granite pluton, the belt of alteration extending north from the jabal into the Meshaheed area may be related to Meshaheed mineralization (see plate 1). In addition, the presence of molybdenum in widely spaced stockworks in small diorite plutons and also in the altered metasediments appears to be significant since it points to a condition where similar hydrothermal systems were active in this large area.

The Jabal Qut'n granite, studied by Stuckless and others (in press), is weakly to strongly peraluminous and highly radioactive. They suggest a similarity with the Baid al Jimalah granite (fig. 5), which is associated with tungsten, tin, and base metals. At the Baid al Jimalah deposit, wolframite-bearing quartz veins in a small greisenized granite are located 2 km northwest of lead-zinc-silver veins in a volcanoclastic conglomerate. Element zoning in the rocks of the prospect area suggests that there was a decreasing pressure-temperature gradient southeastward from the Baid al Jimalah tungsten-bearing granite outcrop to the east prospect lead-zinc-silver area at the time of hydrothermal activity (Lofts, 1982, p. 180). According to Lofts, the lead-zinc-silver veins of the east prospect area are cogenetic with the veins of the west prospect.

Radiometric dating by Stacey and Stoeser (1982) using U/Pb ratios in zircon from Baid al Jimalah and by Hedge (written commun., 1983) using K/Ar and Rb/Sr dating methods for Jabal Qut'n place the ages of both granites at 575 Ma, thus, they are similar in both composition and age.

Little work has been done at Jabal Qut'n, but the granite may be anomalous in tin content. Samater sampled stream sediments in and around the jabal and found tin values as high as 500 ppm, and Smith collected a sample of fluorite-bearing granite that contained 30 ppm tin.

The nearby fluorite-bearing peraluminous granite at Jabal Silsilah is associated with tin and tungsten deposits and is part of a ring complex of mainly peralkaline granites (see fig. 5). In the Shiaila area, just north of the ring complex, is a group of gold-stibnite-quartz veins in metasediments. Unfortunately, the gold deposits have not been

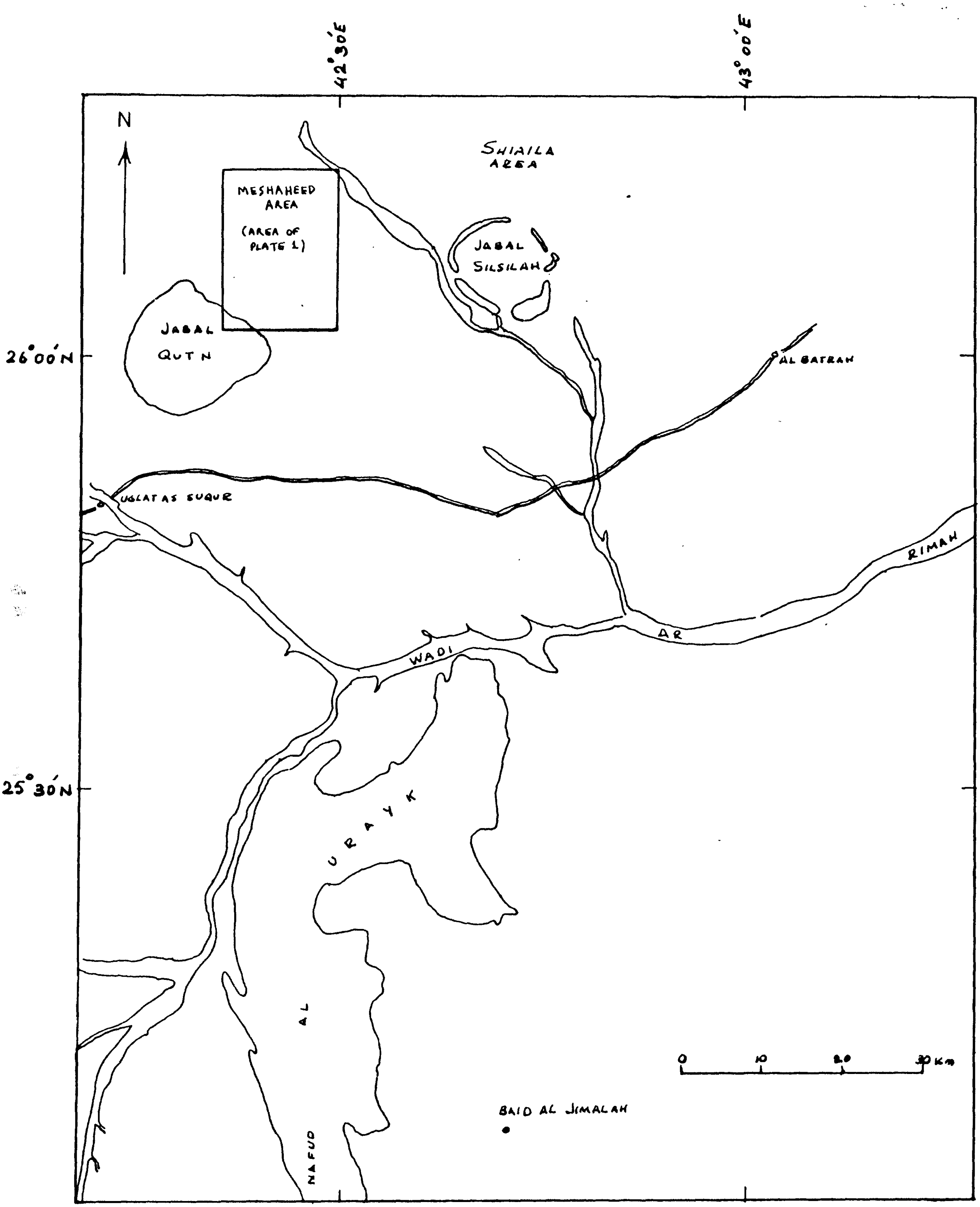


Figure 5.--Index map showing locations of Meshaheed area, Jabal Qut'n, Jabal Silsilah, and Baid al Jimalah.

studied in detail to date, but studies of the peraluminous granite and associated tin tungsten deposits (du Bray, 1984) indicate that this region may fit a geochemical pattern similar to Baid al Jimalah and Jabal Qut'n-Meshaheed.

RECOMMENDATIONS

Further work in much of the area is recommended to include a more thorough study of all of the mineralized zones known to date, and other studies of a more general nature. Specifically, in a zone immediately southeast of Meshaheed, rock-chip sampling for geochemical studies may reveal the source of the geochemical anomalies in stream sediments. Sampling could be done on a grid system and more detailed mapping carried out at the same time. Trenching and detailed sampling should be done where gold veins are obscured; this would require many trenches over much of the Meshaheed study area. The intrusive basalt should be mapped in detail, and rock-chip samples should be gathered for geochemical studies; trenching in this zone would be advisable because of cover. All three hydrothermally altered diorite intrusive bodies (Quartz Hill Nos. 1, 2, and 3) with stockworks should be mapped and sampled in more detail, with special emphasis on the sequence of deposition relationships with gold-stibnite-quartz veins, and the elements in the deposits. If possible, more extensive geophysical studies including electric-telluric and audio-magnetotelluric methods could be employed to better define the subsurface geometry of the hydrothermally altered rocks. In conjunction with this, a detailed mapping and sampling program should be made in the region of the telluric-electric resistivity low which is about 1 km east of the basalt intrusive. No detailed studies have been made in this area to date. In addition, induced potential geophysical surveys would be useful where disseminated sulfides are present, especially in the sub-volcanic basalt.

The juncture of two fracture systems at Quartz Hill No. 1 evidently provided access for the intrusion of the small diorite cupola (pl. 1), and continued movement allowed for fracturing of diorite and the deposition of quartz and molybdenite in openings. Subsequent movement along northeast fractures apparently gave access to gold-stibnite-quartz deposition to the extent that the most intensive gold deposition in the fracture system is found within this zone. Consequently, junctures of fracture systems appear to have influenced greater gold deposition. Therefore, it is suggested that a close examination of the area for this type of feature may lead to additional discoveries. Much of the region is covered by recent alluvium and such structural relations may be obscured, but low-level aerial photography, and careful mapping may delineate fracture systems which project into covered zones.

DATA STORAGE

Petrographic descriptions, sample locations, thin sections, and results of chemical analyses are stored in data-file USGS-DF-04-9 (Smith and Samater, 1984) in the Jiddah office of the U.S. Geological Survey Saudi Arabian Mission.

Data on mineral occurrences in the Meshaheed area have been updated and entered for the following MODS numbers:

1266	Meshaheed	Au	Updated	3/83
3275	Asha North	Au	New input	3/83
3672	No's 2 and 3	Au	New input	3/83

REFERENCES CITED

Allen, M. S., Tidball, R. R., and Samater, R. M., 1984, Interpretation of geochemical data from panned concentrates of wadi sediments using R-mode factor analysis, Jabal Habashi quadrangle (26F), Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 84-

du Bray, E. A., 1984, Geology and discovery of the Silsilah tin deposit, Kingdom of Saudi Arabia: U.S. Geological Survey Open-File Report 84-

Flanigan, V. J., and Zablocki, C. J., 1984, An evaluation of the applicability of the telluric-electric and audiomagnetotelluric methods to mineral assessment on the Arabian Shield, Kingdom of Saudi Arabia: Available from Saudi Arabian Deputy Ministry for Mimeral Resources Data-File USGS-DF-04-17..

Lofts, P. G., 1983, A preliminary evaluation of the Baid al Jimalah tungsten prospect: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report RF-OF-02-21, 223 p.

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.

Smith, C. W., and Samater, R. M., Supporting data for preliminary report on the gold deposits at Meshaheed, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resourses Data-File USGS-DF-04-17.

Stacey, J. S., and Stoeser, D. B., 1983, Distribution of oceanic and continental leads in the Arabian-Nubian Shield: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-55, 36 p.; also, 1984, Contributions to Mineralogy and Petrology, v. 84, p. 91-105.

Stuckless, J. S., Van Trump, G., Jr., Bunker, C. M., and Bush, C. A., 1982, Preliminary report on the geochemistry and uranium favorability of the post-orogenic granites of the northeastern Arabian Shield, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-02-38, 45 p.; also in press, Proc., Pan-African Crustal Evolution in Arabia and northeast Africa, IGCP Project 164.

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

APPENDIX

The following tables show correlation analyses (matrices) for metal pairs among four sample classes: (1) Meshaheed area northeast-striking gold-stibnite-quartz veins, (2) Quartz Hill No. 1 molybdenite-quartz, (3) Quartz Hill Nos. 2 and 3, and (4) hydrothermally altered metasediments. Atomic absorption analytical data were used for gold and silver, and semiquantitative spectrographic data for the remaining elements. The emission spectrographic method is limited in application to statistical analysis because of the high detection limits for many elements. Nevertheless, despite the absence of information regarding certain elements, the method is considered useful provided that trends or patterns within groups are noted.

The matrices indicate correlation coefficients for the various metal pairs (above the diagonal) and the number of samples upon which the calculations are based (below the diagonal). Numbers along the diagonal are the standard deviations of the variables for unqualified values (those between the lower and upper limits of detection). If either of the elements in a sample was not detected, then the sample was dropped from the calculation. In cases where there were no valid metal pairs or where one of the elements had no variance, the tables show a series of asterisks.

Appendix A1.--Correlation analysis for Meshaheed area northeast-striking gold-stibnite-quartz veins

	Fe	Mg	Ca	Ti	Mn	As	B	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sb	Sc	Sr	V	Y	Zr	Au	Ag
Fe	0.3438	0.7308	0.3180	0.7664	0.5373	0.2758	0.1068	0.5788	0.5424	0.2873	0.1954	-0.0364	0.6944	-0.0548	0.2730	0.5850	-0.0354	0.8331	0.2902	0.3872	0.0335	-0.0437
Mg	184	.5122	.5193	.7760	.6047	.1512	.2246	.5245	.5984	.0940	.1119	-.0218	.5339	-.1340	-.0539	.5167	.1740	.7371	.3137	.4285	.1290	.0100
Ca	182	174	.5992	.2444	.6337	.0082	.0727	-.0722	.1129	.0431	-.0038	-.2701	.0774	.1322	-.1435	-.4802	-.0568	.1735	-.4623	-.2619	.0586	-.1158
Ti	187	181	177	.5116	.5363	.2097	.1397	.6366	.6253	.1370	.1106	-.0920	.6392	-.1600	.1316	.6688	.1409	.8076	.3567	.5704	.0106	-.1721
Mn	190	184	180	186	.4484	-.0052	-.0179	.1690	.2522	.2051	.0751	-.3542	.4382	.1145	-.1615	-.2358	.0821	.4844	.0330	-.1389	.0948	-.0937
As	74	69	73	74	73	.2901	.1662	.1842	.1824	.2167	.2833	.3039	.1875	.3034	.4687	.6898	-.0733	.2512	.3890	-.0309	.0474	.0931
B	165	157	159	160	163	72	.2440	.0600	.3618	-.1930	.0764	.1644	-.0258	-.1242	-.0559	.2763	.0267	.0763	.1138	.1804	.0592	.0206
Ba	129	126	119	129	129	49	112	.4176	.1851	.1357	.0605	.3369	.5163	.0724	.3206	.4739	.2148	.5828	.2016	.6885	-.0492	.1416
Co	24	23	22	24	24	11	19	22	.2080	-.0834	-.0820	.0216	.6247	-.4825	-.0720	.7077	.5546	.5736	.3070	.3668	-.3629	-.3407
Cr	192	184	182	187	190	74	165	129	24	.2631	.1753	-.0794	.3963	.2710	.4028	.2910	-.1284	.1619	.3264	-.0901	.0162	.1586
Cu	186	180	176	183	185	73	160	127	24	186	.4084	-.1145	.2155	.6166	.2381	.1755	-.1969	.1326	.0909	.2535	.1092	.4202
Mo	33	30	33	31	33	16	29	25	8	33	33	.3818	.0172	-.0071	.4047	-.2443	.1130	.0310	-.9212	.2326	-.0816	-.0408
Ni	179	174	169	176	179	68	155	128	24	179	175	33	.2184	-.0245	.2769	.6145	.1259	.6149	.3742	.3316	.0258	.0022
Pb	75	71	71	74	75	42	67	52	12	75	75	20	69	.3998	.2276	-.1138	-.3838	-.0680	-.0505	.0677	-.0288	.3303
Sb	51	49	49	50	50	28	45	33	8	51	50	18	47	26	.6280	.9000	.0191	.1999	.8255	.6143	.3267	.4366
Sc	25	25	20	25	25	5	16	22	12	25	25	5	22	9	8	.2145	.2344	.5700	.7205	.6027	-.0248	-.2532
Sr	64	64	55	64	64	25	47	58	14	64	64	12	61	27	16	21	.2294	.0396	.3525	.4816	-.0299	-.0125
V	167	164	157	165	167	60	141	125	20	167	164	29	158	64	41	25	64	.3124	.2747	.3917	-.0059	.0297
Y	27	27	17	27	27	4	16	25	12	27	27	4	25	9	7	20	24	27	.1480	.3036	.1032	.0022
Zr	47	47	39	47	47	17	42	45	13	47	47	11	47	17	11	16	30	47	18	.4070	-.2112	-.2191
Au	153	146	147	148	151	70	140	99	14	153	147	26	142	68	44	10	39	130	11	30	35.5795	.2852
Ag	15f	152	148	153	157	65	133	104	22	158	154	31	146	68	43	25	61	139	27	42	126	9.5175

Appendix A2.--Correlation analysis for Quartz Hill No. 1 molybdenite-quartz

	Fe	Mg	Ca	Ti	Mn	B	Ba	Co	Cr	Cu	Mo	Ni	Sr	V	Zr	Au
Fe	0.3266	0.6620	0.5936	0.7253	0.6206	0.4809	0.7904	0.3442	-0.2003	0.7169	-0.3721	0.0211	0.3948	0.6072	0.7348	-0.1372
Mg	30	.4448	.7964	.6496	.3160	.1764	.5499	.3900	- .1550	.2528	- .3541	.3224	.3732	.4663	.1440	- .1999
Ca	32	30	.4042	.6221	.5766	.2426	.6280	.3868	- .1877	.3198	- .3809	.3804	.1657	.3717	.1756	- .3400
Ti	32	30	32	.4845	.4848	.5878	.7499	.1730	- .0846	.4491	- .1881	.0840	.3442	.8080	.4518	- .3266
Mn	32	30	32	32	.4134	.2777	.4298	.3649	.1323	.3245	- .3470	.2844	.0133	.5039	.3028	- .3535
B	28	26	28	28	28	.2397	.4216	- .0233	.2552	.2436	.3060	.2141	.2986	.8057	.6175	- .3792
Ba	28	28	28	28	28	25	.4028	.1902	.1944	.3653	- .1649	.1504	.2225	.4181	.6910	- .0574
Co	14	12	14	14	14	12	11	.0908	- .2086	.2200	.1215	.4905	.1587	.3061	.2411	- .0371
Cr	32	30	32	32	32	28	28	14	.2788	- .4787	.2876	.2484	.4871	.2956	.3088	- .3925
Cu	31	29	31	31	31	28	27	14	31	.2952	- .2899	- .0699	- .2352	.1938	.3522	.2223
Mo	28	28	28	28	28	26	26	10	28	27	.6237	.3281	.1454	.0343	.2382	- .1682
Ni	28	26	28	28	28	24	24	14	28	27	24	.2305	.0700	.3282	.1939	- .3025
Sr	12	12	12	12	12	10	12	8	12	12	10	12	.1290	.2844	.1771	.1571
V	28	28	28	28	28	24	27	10	28	27	26	24	12	.2496	.4869	- .2735
Zr	28	27	28	28	28	26	27	12	28	28	25	24	12	26	.2205	- .2931
Au-T	28	26	28	28	28	26	25	11	28	28	25	24	10	25	26	.5679

Appendix A3.--Correlation analysis for Quartz Hill Nos. 2 and 3

	Fe	Mg	Ca	Ti	Mn	B	Ba	Cr	Cu	Mo	Ni	Pb	Sr	V	Zr	Au
Fe	0.4529	0.8139	0.6782	0.8575	0.6702	-0.2399	0.7971	0.0532	0.7535	0.5278	0.1247	-0.2586	0.5803	0.7671	0.4914	-0.0076
Mg	25	.5233	.6408	.9017	.5798	-.4146	.8701	-.0483	.7894	.5706	-.0140	-.0378	.4680	.7092	.6814	-.1826
Ca	27	25	.4778	.7297	.7852	-.0893	.8119	.4189	.5778	.7405	.1894	-.4241	.5491	.6652	.2178	.0158
Ti	27	25	27	.7383	.7041	-.3318	.8593	.1023	.7845	.5546	.1435	-.3946	.6647	.8532	.6577	-.0326
Mn	26	25	26	26	.4229	-.1368	.6413	.2863	.6823	.4651	.0669	-.3036	.4588	.7926	.1707	.2146
B	17	17	17	17	17	.2405	-.3106	.1212	-.3434	-.1774	.4138	.1109	.3231	-.1410	.0694	.4361
Ba	26	25	26	26	25	17	.4100	.1477	.7135	.7229	.0132	.0708	.6171	.6911	.6008	-.2014
Cr	27	25	27	27	26	17	26	.2641	.1748	.4571	.2237	-.0633	.3948	.2068	.0722	-.1114
Cu	23	22	23	23	23	16	22	23	.2788	.5254	-.0334	-.2136	.1454	.7394	.4608	.0289
Mo	16	16	16	16	16	12	16	16	15	.2781	.4624	.6337	.1773	.5997	.1279	-.0578
Ni	22	21	22	22	22	14	21	22	20	15	.0911	-.1948	.3501	.0571	.3756	-.0167
Pb	14	13	14	14	14	7	13	14	13	9	12	.3098	-.3339	.2644	-.1170	.3483
Sr	16	16	16	16	16	11	16	16	15	10	13	11	.1782	.5690	.5612	-.0728
V	21	21	21	21	21	16	21	21	19	15	17	12	15	.3208	.4302	.1499
Zr	19	19	19	19	19	13	19	19	18	13	16	13	16	18	.1785	-.1501
Au-T	27	25	27	27	26	17	26	27	23	16	22	14	16	21	19	.0858

Appendix A4.—Correlation analysis for hydrothermally altered metasediments

	Fe	Mg	Ca	Ti	Mn	B	Ba	Be	Co	Cr	Cu	La	Mo	Ni	Pb	Sc	Sr	V	Y	Zr	Au	Ag
Fe	0.2579	0.7587	-0.4173	0.9335	-0.2424	0.2317	0.7112	****	0.5246	0.3080	0.9046	0.2169	0.6099	0.8516	0.5263	0.7993	-0.7067	0.9173	0.4605	0.7989	-0.0906	0.1627
Mg	27	.4508	-.2438	.7491	.0910	-.1731	.4696	****	.6228	.3191	.6875	.1002	.4201	.7151	-.0084	.2799	-.4165	.7692	.2859	.5501	-.0441	.0425
Ca	27	27	.6077	-.3770	.7099	-.3298	-.4988	****	-.1698	-.1079	-.3583	.3705	.2444	-.4866	-.3897	-.4606	.4095	-.4019	-.5877	-.6528	.1144	.4153
Ti	27	27	27	.3749	-.2698	.2536	.7942	****	.3023	.3224	.8896	.3489	.6080	.8630	.2579	.5983	-.6321	.8890	.4615	.8718	.1061	.1789
Mn	27	27	27	27	.4056	-.6494	-.5029	****	.1960	-.0038	-.2707	-.0752	.3049	-.2259	-.4112	-.3647	.0351	-.3149	-.4054	-.5273	-.0309	.3326
B	21	21	21	21	21	.3302	.6991	****	-.1742	.0808	.2190	-.2872	.2832	.2113	.5240	.4694	-.0765	.3406	.4499	.4706	-.4778	.1284
Ba	27	27	27	27	27	21	.3024	****	-.1992	.0714	.6865	-.0392	.4073	.7378	.4601	.2956	-.5034	.6721	.6766	.8747	.2259	.0080
Be	11	11	11	11	11	11	11	.000	****	****	****	****	****	****	****	****	****	****	****	****	****	****
Co	19	19	19	19	19	16	19	6	.2101	.4838	.1424	-.1469	.1372	.4683	.2969	.3096	-.5805	.1898	.0236	.1995	-.2453	-.0197
Cr	27	27	27	27	27	21	27	11	19	.2131	.2903	.2180	.3778	.2441	.1565	.1170	-.0605	.2960	-.0190	.2731	.1914	-.0400
Cu	27	27	27	27	27	21	27	11	19	27	.2904	.3372	.6313	.7729	.3318	.6900	-.5281	.8641	.4467	.7225	.0146	.2650
La	12	12	12	12	12	11	12	7	9	12	12	.0907	-.5772	.0690	.0085	.2294	****	.2544	-.2137	.0374	-.0081	.6371
Mo	11	11	11	11	11	10	11	7	7	11	11	6	.1761	.6496	.2783	.6156	****	.4860	.3230	.4451	.1356	.4434
Ni	26	26	26	26	25	20	26	10	19	26	26	11	11	.2369	.2899	.4242	-.6392	.7921	.5114	.8256	.1540	.0102
Pb	19	19	19	19	19	17	19	9	16	19	19	11	10	19	.1870	.2963	-.3289	.3987	.6321	.3869	-.1126	.1037
Sc	23	23	23	23	23	20	23	10	19	23	23	11	10	23	19	.1375	-.5899	.8139	.4585	.4724	-.7442	.0906
Sr	13	13	13	13	13	8	13	3	9	13	13	3	1	12	6	10	.2967	-.6276	-.5686	-.4510	-.0242	-.1359
V	27	27	27	27	27	21	27	11	19	27	27	12	11	26	19	23	13	.3975	.5430	.7260	-.0946	.2017
Y	23	23	23	23	23	19	23	9	18	23	23	10	11	23	18	21	9	23	.1561	.6955	-.2758	.1330
Zr	26	26	26	26	26	21	26	11	19	26	26	12	10	25	19	23	13	26	22	.2834	.0580	-.1922
Au	22	22	22	22	22	16	22	8	16	22	22	12	8	21	16	18	10	22	19	21	.0568	-.1101
Ag	26	26	26	26	26	20	26	10	18	26	26	12	10	25	18	22	12	26	22	25	22	.7222