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THE JABAL GUYAN ANCIENT GOLD MINE WADI MALAHAH QUADRANGLE (SHEET 18/43D)

KINGDOM OF SAUDI ARABIA

By A. M. Helaby and F. C. W. Dodge

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THE JABAL GUYAN ANCIENT GOLD MINE, WADI MALAHAH QUADRANGLE, SHEET 18/43D, KINGDOM OF SAUDI ARABIA

by

A. M. Helaby and F. C. W. Dodge, 1934-

U. S. Geological Survey
Jiddah, Saudi Arabia

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ABSTRACT

Gold occurs in quartz veins and associated altered country rocks at the Jabal Guyan ancient mine in southern Saudi Arabia. The gold-bearing veins follow northwest-trending fault zones which cut the Precambrian metavolcanic rocks of the area. The veins are brecciated, and gold may have been remobilized during cataclasis. A second generation of unbrecciated, barren quartz cements the earlier quartz and also occurs in north-northeast-trending veins.

Gold values are greater in waste in the mine area than in vein quartz remaining in the ancient workings, and it is believed that considerable gold was extracted from high-grade ore by the ancient miners.

Exploration drilling to determine if veins and alteration zones persist at depth at the Jabal Guyan mine and examination of other ancient mines in the region are recommended.

INTRODUCTION

The Jabal Guyan mine, one of the largest ancient gold mines discovered in southern Saudi Arabia, is about 150 km north of Najran, a large town near the Yemen border. The mine is in the southeast corner of the Wadi Malahah 30-minute quadrangle at lat 18°10'N., and long 43°55'E. (fig. 1).

Najran is easily reached by an asphalt road from Abha, or by commercial airline. The Najran airport is about 30 km east of the town, and numerous truck trails lead northward from the airport in the general direction of Jabal Guyan area. The southernmost 100 km of trails are through flat, sandy plains, whereas the northern 50 km of entry is restricted to two rocky, rugged, major wadis, Wadi Thaar south of the Jabal Guyan mine, or Wadi Talham to the northeast.

Mine workings are in a north-trending 1 by 2 km-sized area (fig. 2). Average altitude of the area is about 1,750 m, and the highest summit is about 1,850 m. Terrain

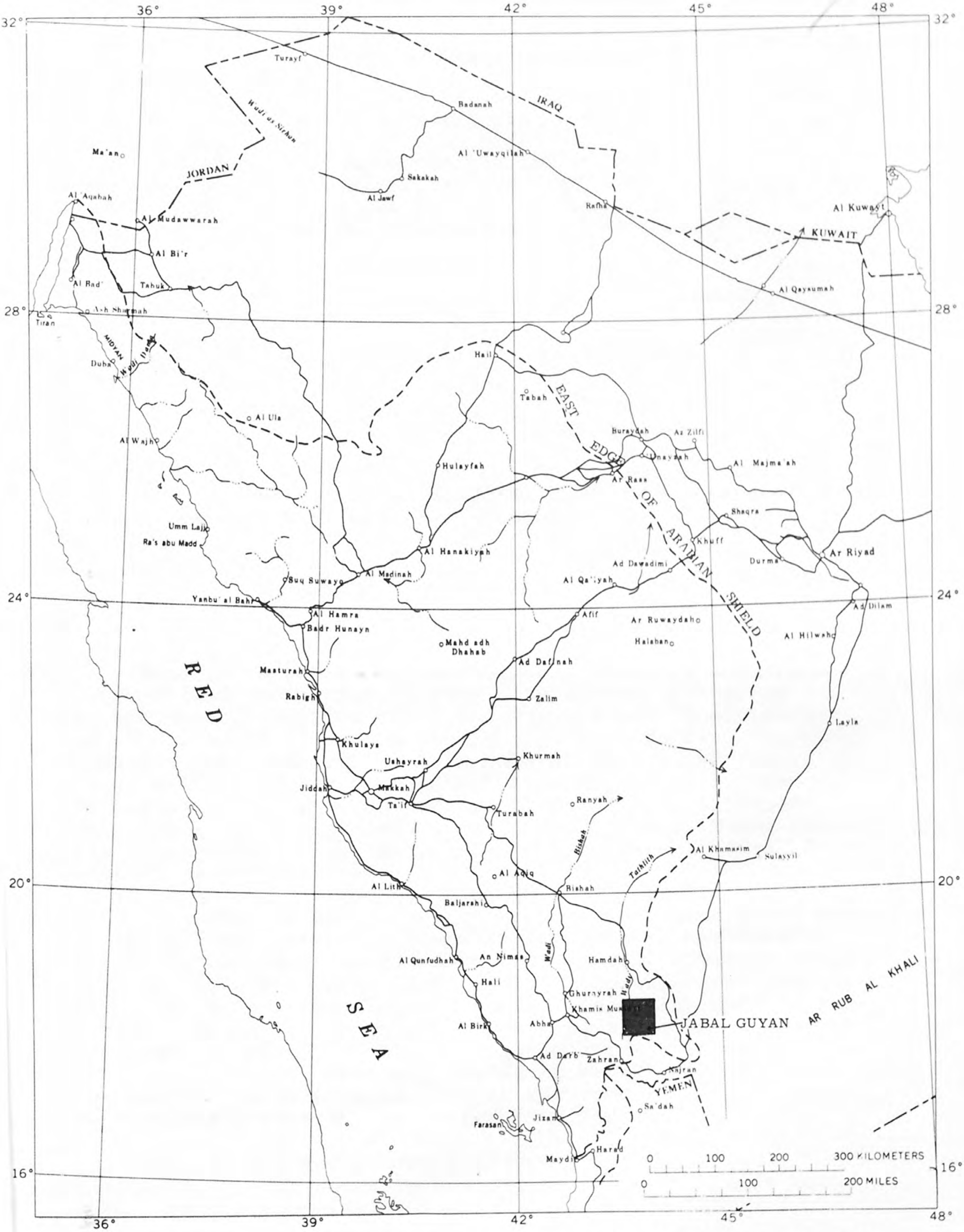


Figure 1.- Index map of western Saudi Arabia showing the location of the Wadi Malahah quadrangle (shaded).

in the vicinity of the mine is rugged and only four-wheeled drive vehicles can reach individual workings.

The Jabal Guyan mine was visited by R. L. Earhart of the U. S. Geological Survey in 1967 and later by Conrad Martin, also of the U. S. Geological Survey. Martin reported that he had visited the mine and suggested further investigation.

The present investigation and preliminary evaluation of the Jabal Guyan mine was carried out in April and May, 1974. The topographic map of the Jabal Guyan area was prepared by F. G. Lavery, topographic section, U. S. Geological Survey-Saudi Arabian Project, and samples were analyzed by atomic absorption techniques in the DGMR-USGS Laboratory, Jiddah, under the direction of W. L. Campbell.

This investigation is one of the series of mineral deposits studies conducted by U. S. Geological Survey, made in accordance with a work agreement with the Ministry of Petroleum and Mineral Resources, Kingdom of Saudi Arabia.

GEOLOGY OF THE JABAL GUYAN AREA

Geologic setting

Massive to schistose metavolcanic rocks of the Precambrian Jiddah Group, cut by felsic hypabyssal dikes and quartz veins, underlie the Jabal Guyan area. Schistosity parallels north to northwesterly regional trends. The metavolcanic rocks are cut by left-lateral faults and shears which follow similar, though not always identical, trends to the schistosity. The general northwesterly attitude and left lateral sense of displacement suggests these faults are components of the Najd wrench fault system (Brown, 1970; Delfour, 1970).

Gold-bearing quartz veins have been injected along some of the northwesterly fault and fracture zones with concomitant alteration of surrounding metavolcanic rocks to sericite schist. Late movements along fault zones fractured this vein quartz. A younger generation of generally northeasterly-trending quartz veins were emplaced and introduced into and cemented the older, highly brecciated veins. The fractures underwent further movement, evidenced by 30°-40° plunging slickensides on vein faces, and at the same time subsidiary left-lateral, east-northeast-trending faults developed.

Mineralized veins were emplaced after major fault displacement, but prior to the cessation of all fault movement. Najd wrench faulting has been dated as Cambrian

(Schmidt and others, 1973, p. 12), thus, the age of mineralization is believed to be Cambrian.

Rock types

Metavolcanic rocks

The metavolcanic country rocks of the Jabal Guyan area range from chloritized and epidotized andesite to greenschist. Alteration accompanying vein emplacement has altered adjacent greenschist to brown-colored, carbonate-rich, sericite schist. Typically, the massive to schistose aphanitic metavolcanic rocks consist principally of fine-grained chlorite, epidote, subhedral laths of chloritized and sericitized plagioclase, and lesser amounts of quartz, carbonate, and opaque to translucent iron oxides and sparse remnants of green hornblende.

Felsic dikes

Dacitic dikes that crop out in the southeast corner of the Jabal Guyan area range from 1 to 10 m in thickness, dip vertically, and trend northwesterly, following the trend of schistosity in the country rocks. Dike rocks consist of medium- to fine-grained anhedral quartz, medium- to fine-grained andesine, and accessory amounts of saussuritized potassium feldspar, carbonate, chlorite, epidote, and opaque iron oxide.

The dikes were most likely emplaced after major fault movement and probably prior to vein injection, however, the age relationship between dikes and veins is uncertain, as contact relations have not been observed.

Quartz veins. Quartz veins, ranging in width from a few cm to over 4 m in width, are conspicuous geologic features in the Jabal Guyan area. One set of veins follows the main fault zone and strikes northwest and dips vertically or steeply southwest. A second set of veins strikes north to northeast and dips gently east to southeast. The northwest-trending veins pinch and swell, whereas the north-northeast-trending veins tend to be more uniform in thickness, although in some cases an entire vein tends to be wedge-shaped. Locally, the north-northeast veins cut the northwest veins.

Two generations of vein quartz have been recognized in the mine area. The old generation of quartz, characterized by its extreme vitreous luster, is colorless or smokey to nearly black; minute inclusions of brown iron oxide and unidentified, dark-colored, translucent material cause the dark coloration. In thin section, this quartz appears to have been intensely pulverized and is highly strained. The young quartz is massive and milky colored. This generation of quartz shows no effects of cataclasis, even though it occurs intimately intermixed with the earlier-formed, pulverized quartz. The old quartz contains disseminated gold and a speckling of brown, earthy, iron oxide grains; the young quartz is generally barren. Northwest-trending veins consist of fractured, old quartz cemented with late-forming quartz. North-northeast-trending veins are generally made up of young, massive, bull quartz.

Mineralization

Gold mineralization is contemporaneous with the oldest generation of quartz. Gold grains are present along fractures in the quartz, and gold may have been remobilized during cataclasis. Pyrite, now completely oxidized, was the only sulfide mineral found in the veins.

Copper mineralization, manifested by the presence of malachite, has been detected in altered metavolcanic rock at one locality, but copper minerals have not been found in quartz.

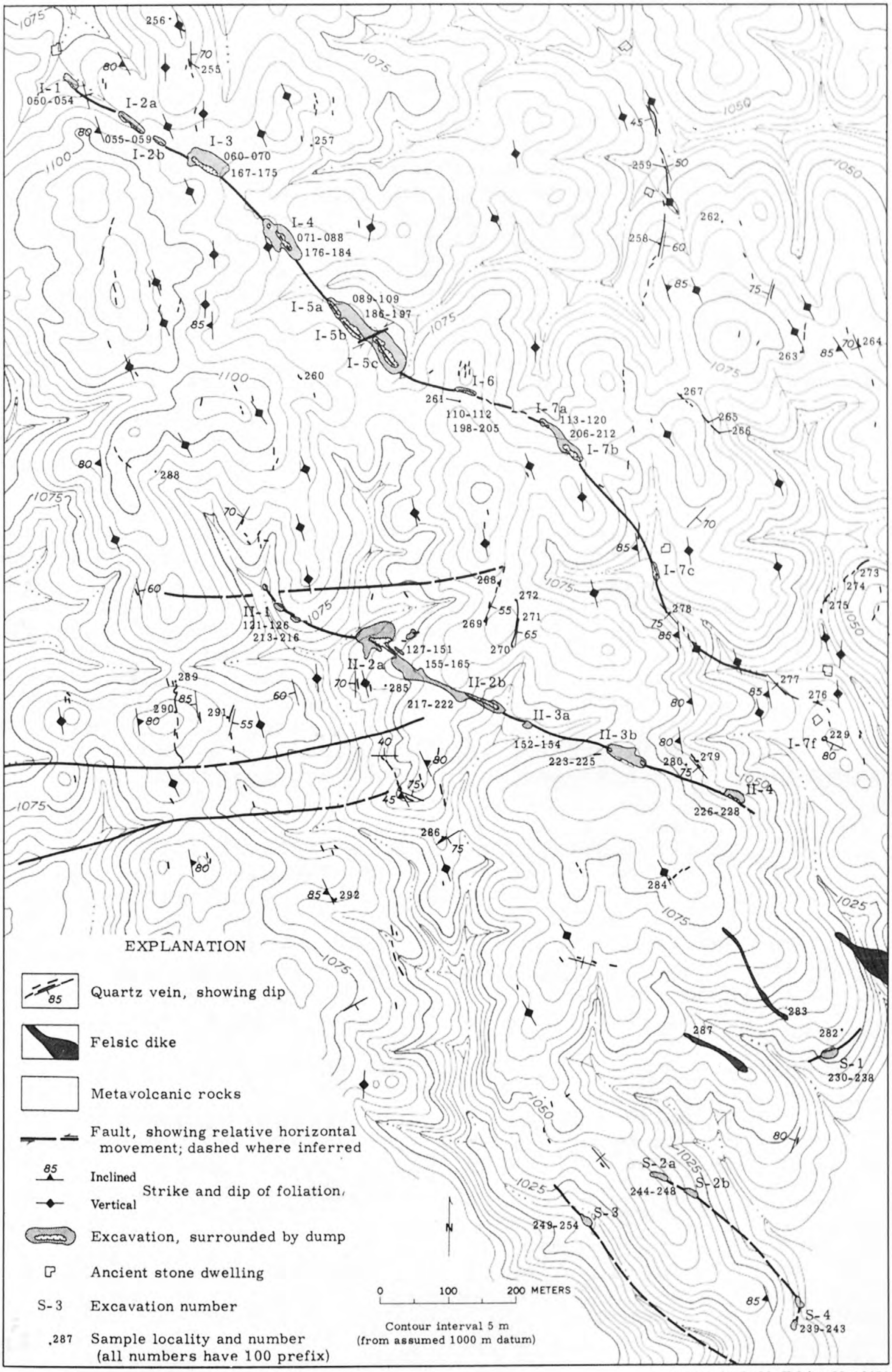
ANCIENT MINE WORKINGS

History

Dates of mining activity at the Jabal Guyan mine are unknown, however, non-Islamic inscriptions on rock faces in the mine area indicate activity in pre-Islamic times. The size and abundance of mine excavations, the large amount of waste material, and the numerous grindstones in the mine area attest to a long period of mining. The large number of grindstones, lack of evidence of appreciable smelting activity, and occurrence of gold in quartz in waste materials indicate the miners were primarily extracting visible gold. Ore crushing and grinding was done at the Jabal Guyan mine by means of operating small hand-held stone grinders back and forth on stone platforms, whereas at other ancient mines in Saudi Arabia, grinding was commonly done by rotating heavy, flat, circular stone discs on lower stone platforms. The difference in grinding technique was probably because the Jabal Guyan ore consisted of highly fractured, easily broken, gold-bearing quartz.

Description of mine workings

The workings of the Jabal Guyan mine consist of over 30 excavations (fig. 2), ranging from small, shallow, barely recognizable prospect-pits to long open cuts, and deep shafts.



Geology by A. M. Helaby, May 1974

Figure 2. - Geologic map of the Jabal Guyan ancient gold mine area.

Present depths of some of the excavations can only be considered minimum depths of the original mining as bottoms of many excavations are filled with fine debris and some of the smaller pits are completely covered. Individual open cuts originally followed quartz veins, however, in many of the workings all vein material has been removed. In some cases, considerable quantities of altered rock adjacent to veins has been excavated. Dumps consist of mixtures of altered metavolcanic rock and vein quartz; gold grains have been recognized in discarded quartz. Grindstones are present on or near some dumps, although major ore crushing areas, while near the excavations, are separated from the dumps. Although gold was the principal metal produced from the mine, one small pit (I-4) may have been mined for copper. Malachite is present in the altered rock of the pit wall, and sparse slag is scattered in the adjacent dump.

Mine workings are concentrated in three groups, generally tending to follow the northwesterly-trending fault and fracture zones. The two northernmost groups of workings, designated the northern and middle belts, are in narrow, chain-like bands. The northern belt is 1.3 km long, nearly twice as long as the middle belt. Large excavations are found in both belts, however, the largest in the middle belt. Size of individual excavations tends to be greatest near the northwest ends of both belts. The third group of workings, the southern group, does not form a well-defined band, and consists of only a few small scattered pits in the southeastern part of the mine area.

Maps of indivudual workings are given in figures 3-6 and approximate dimensions of excavations and dumps are summarized in table 1.

In addition to the Jabal Guyan mine, small ancient workings, generally little more than prospect pits, are scattered throughout the region. Another ancient mine is located about 5 km north of the Jabal Guyan mine.

GEOCHEMICAL STUDY

In order to evaluate the economic potential of the Jabal Guyan mine, 230 samples were collected and analyzed for gold, silver, copper, lead, and zinc. Analytical data are presented in tables 2-9.

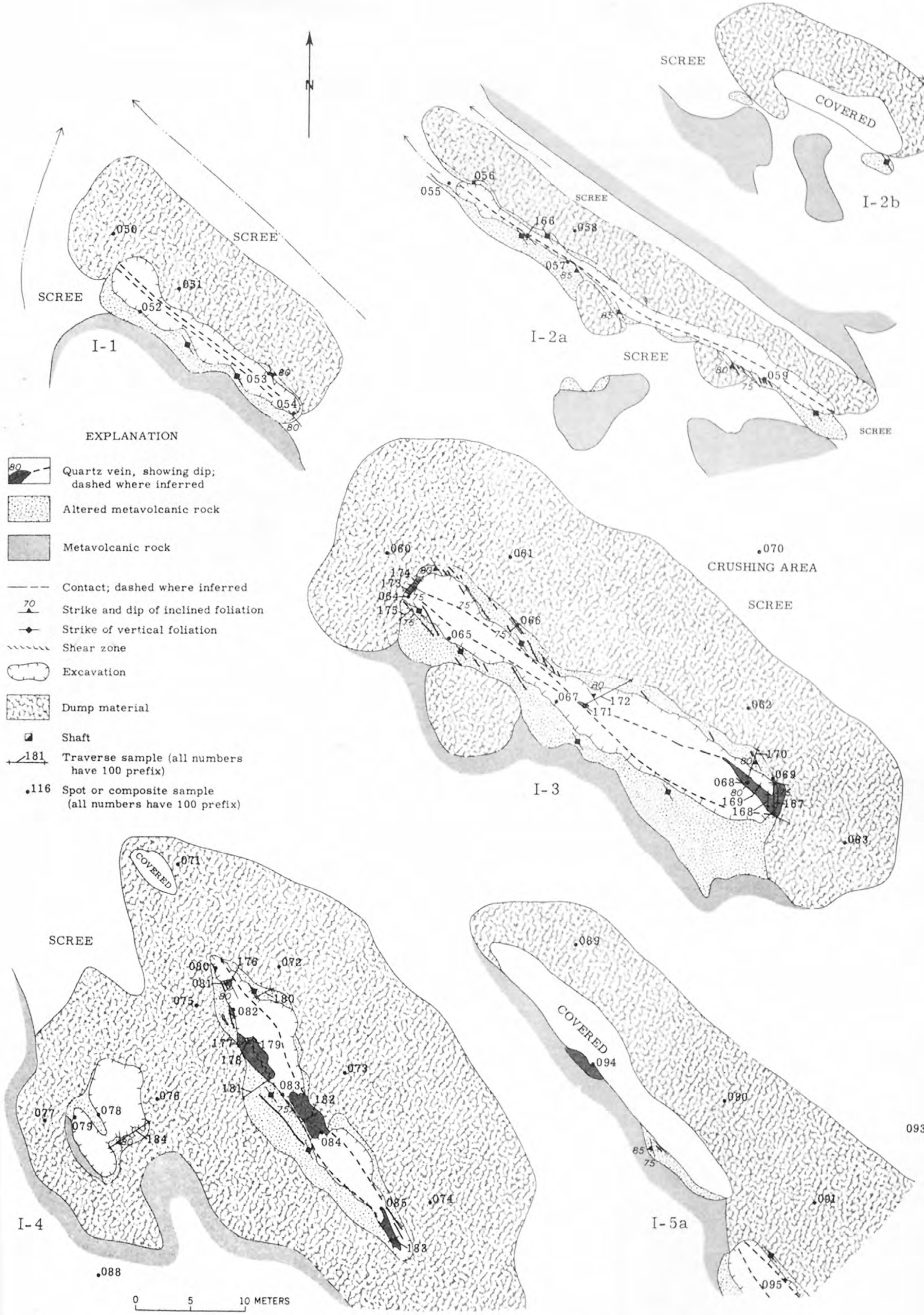


Figure 3.- Geologic maps of excavations I-1, I-2a, I-2b, I-3, I-4, and I-5a showing sample locations. See figure 2 for excavation locations.

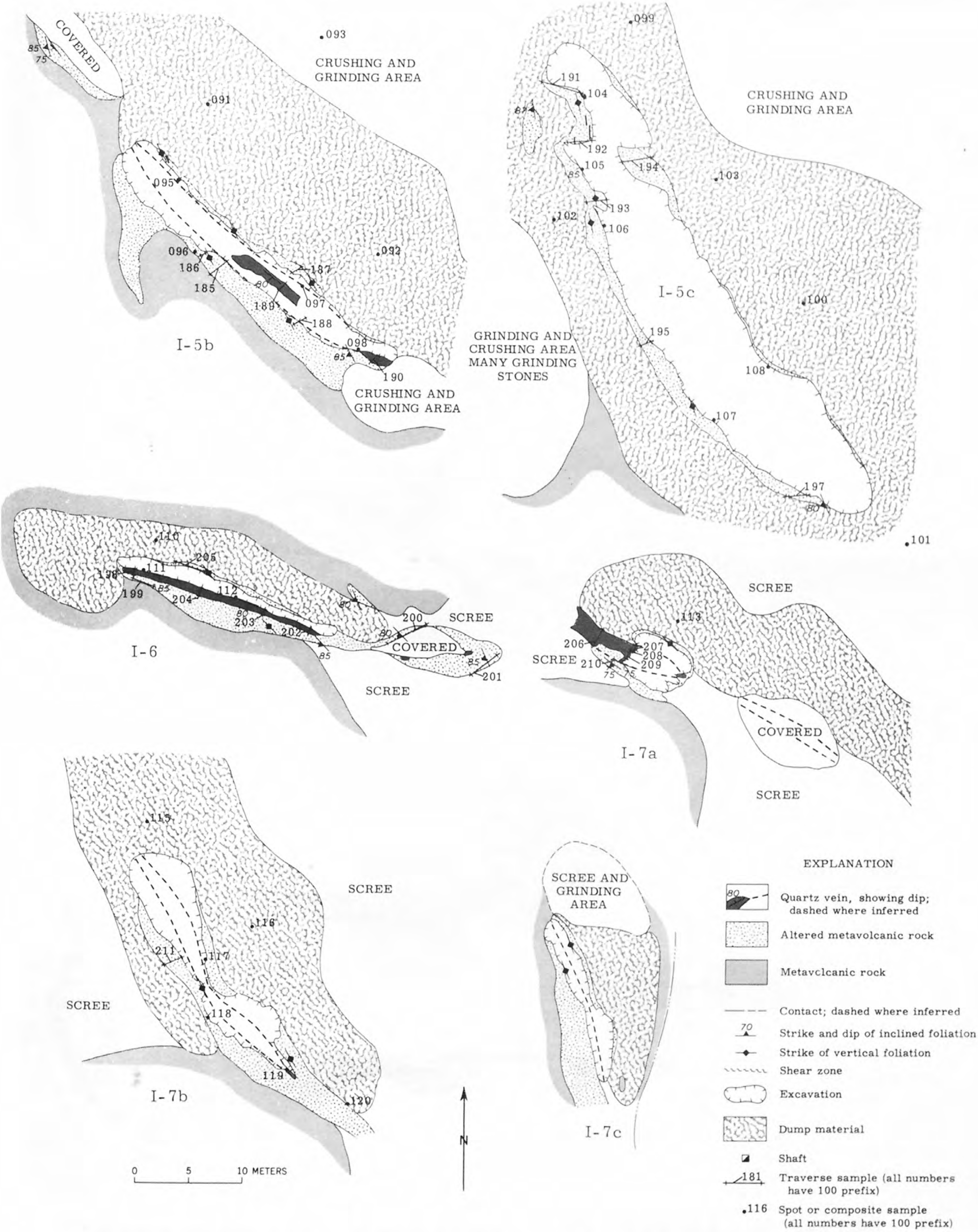


Figure 4. - Geologic maps of excavations I-5b, I-5c, I-6, I-7a, I-7b, and I-7c showing sample locations. See figure 2 for excavation locations.

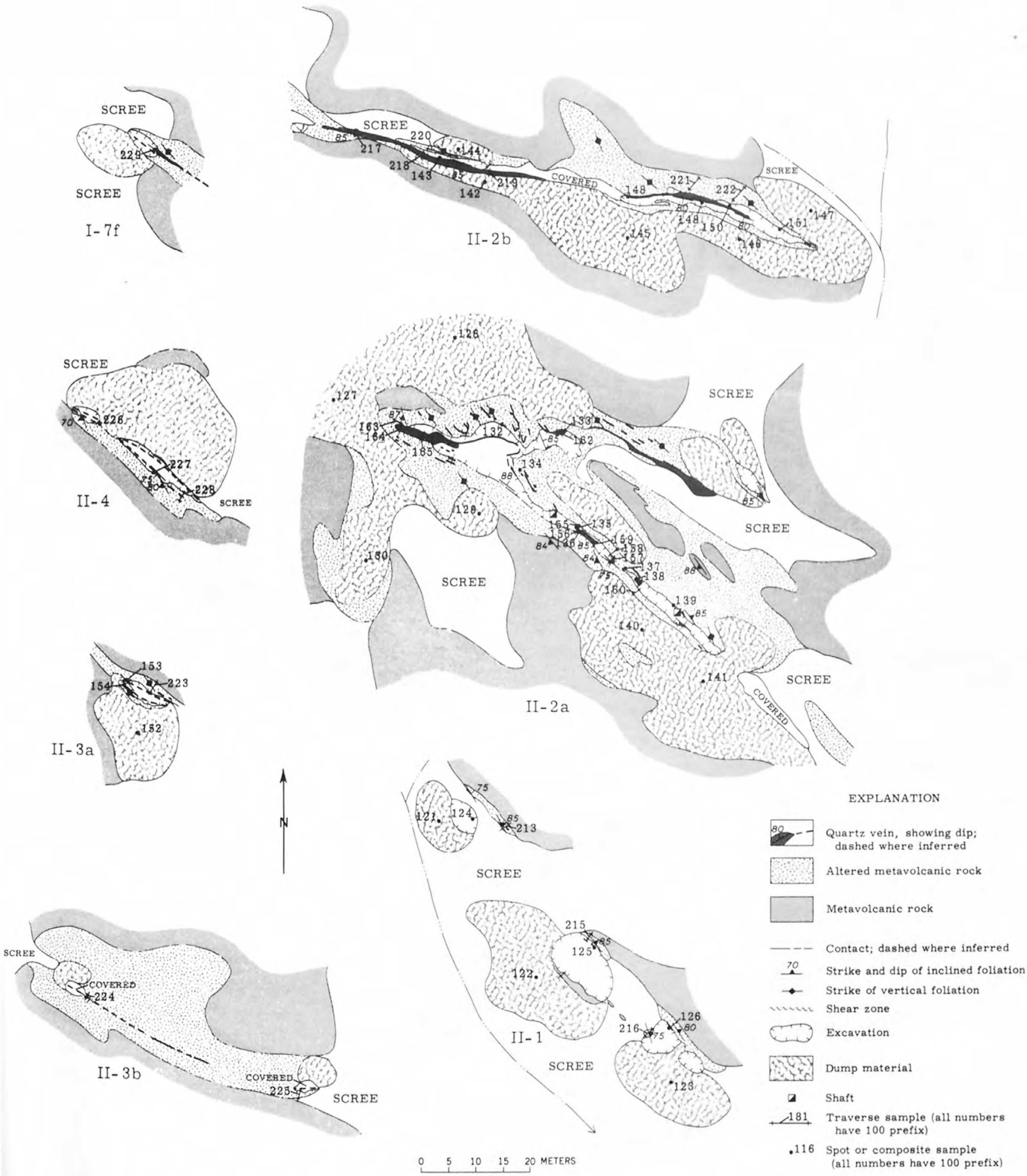


Figure 5. - Geologic maps of excavations I-7f, II-1, II-2a, II-2b, II-3a, II-3b, and II-4 showing sample locations. See figure 2 for excavation locations.

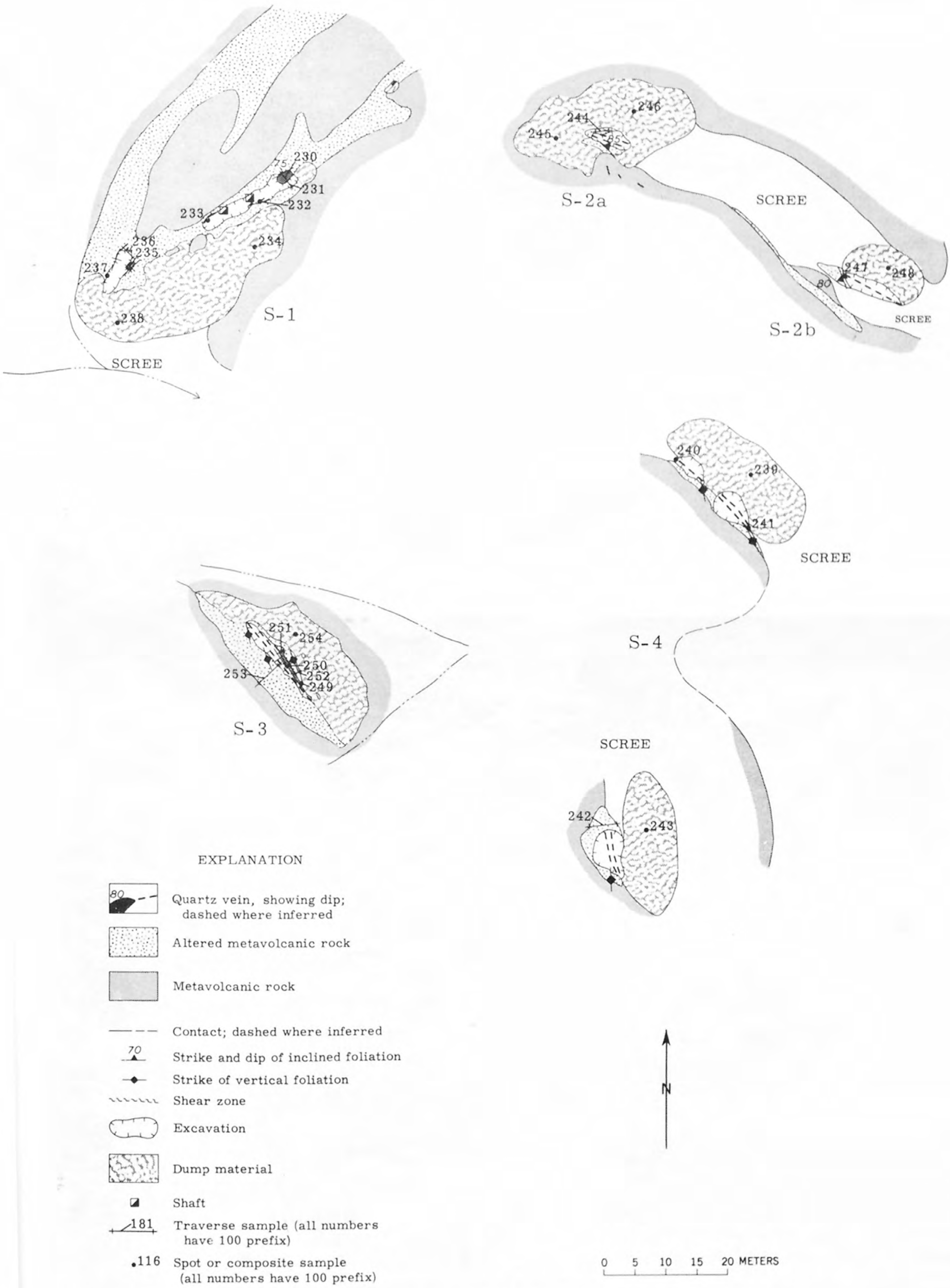


Figure 6.- Geologic maps of excavations S-1, S-2a, S-2b, S-3, and S-4 showing sample locations. See figure 2 for excavation locations.

Table 1. Approximate dimensions of individual workings of the Jabal Guyan ancient mine.

Map designation	Excavation dimensions (m) depth	width	length	Dump dimensions (m) thickness	breadth	length	Remarks
Northern belt							
I-1	.5-1	4	21	.5	7	25	grindstones near dump
I-2 a	.5	1	43	.5	4	50	
b	entirely covered			-	-	-	
I-3	10	2-7	40	1.5	15	60	crushing area nearby
-	entirely covered						malachite in wall of
I-4 -	6	1-6	33	1	8	90	westernmost excavation,
-	.5-1	6	7				slag in adjacent dump.
a	covered	3-4	32				left lateral fault
I-5 b	4	1-4	32	2	10	200	between excavation
c	10	3-10	55				b and c
I-6 -	.5	1	22	.25	4	30	
-	covered	2	7				
a	1.5	4	6				
-	entirely covered			.5	8	80	pits d and e not mapped
I-7 b	2	1-5	25				
c	.5	1.5	15	.25	3	16	
d, e, f	very small pits			minor amount of material			
Middle belt							
a	.5	3.5	6	.25	6	12	
II-1 b	.5	6	15	.5	10	30	
c	2 very small pits			.25	7	22	
a	17	10	20				shaft at northwest end
a	2	1-2	55	1.5	12	110	of open drift; shaft
II-2 a	covered	3	18				tapers to bottom
a	.5	4	8				numerous grindstones
b	0-8	2	55	1	4	95	nearby
a	1.5	2	10	minor amount of material			
b, c	covered, barely recognizable						
II-4	.5	2	24	.5	15	30	

Table 1. Approximate dimensions of individual workings of the Jabal Guyan ancient mine (cont'd.)

Map designation	Excavation dimensions (m)			Dump dimensions (m)			Remarks
	depth	width	length	thickness	breadth	length	
Southern group							
S-1	6 1	2 3	16 9	1	8	30	additional small prospect pit to the northeast
S-2 a, b	very small, shallow pits			.25	8	35	
S-3	3	1	16	.25	7	20	
S-4	very small pit			minor amount of material			adjacent underground shaft

Sampling

Waste materials were generally sampled by collecting uniform, 3 cm diameter chips at 70 cm intervals around the circumference of a 2 m diameter circle (table 2). A few of the composite samples consist only of quartz or only of altered metavolcanic rock, but most are a mixture of the two; one sample is slag. Four samples were taken from crushing areas and the other 53 from dumps adjacent to mine excavations.

"Spot" samples consist of three cm diameter rock chips taken from single 20 cm diameter outcrop areas. Eight vein quartz samples (table 3), 34 quartz veinlets and associated altered rock samples (table 4), and 16 altered rock samples (table 5) were collected in these small areas on mine workings.

Where possible, quartz veins and altered rocks were sampled by collecting "traverse" samples. Small chips were collected at regular intervals along traverses normal to a vein's strike across its entire thickness or at right angles to the schistosity of altered rocks. Traverses are depicted on maps of individual mine workings (figs. 3-22). Fifty vein quartz samples (table 6) and 44 altered rock samples (table 7) from mine excavations, and 19 quartz samples from veins not associated with mine workings (table 8) also were taken.

Unaltered metavolcanic rocks were grab sampled at two locations (table 9).

Results

Gold is present in significant amounts in several samples collected from the Jabal Guyan area. Highest gold values were determined from the compositve waste samples, which average 6.5 ppm Au (0.19 oz/ton). The values on the four waste samples from crushing areas each exceed this value and the four average 37.0 ppm Au (1.08 oz/ton); one of the four samples contains 100.40 ppm Au (2.93 oz/ton). Only one of the 57 composite waste samples contains less than the determinable amount (0.04 ppm) of Au. The metal is present in outcrop samples of both altered rocks and vein quartz collected from mine workings; even though visible gold has been noted in quartz, but not in altered rocks, gold values from the two rock types are not markedly different. Gold values for the 152 outcrop samples from the workings vary considerably. They average 1.5 ppm Au (0.044 oz/ton) and range from below a determinable amount in 11 of the samples to 27.20 ppm Au (0.79 oz/ton) in a "spot" sample of a mixture of quartz and altered rock. Samples of quartz from veins not associated with mine workings have either low reported

Table 2. Atomic absorption analysis of composite waste samples from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Mine pit
100,050	4.16	0.4	9	<10	14	I-1
100,051	0.17	0.7	57	10	64	
100,058	2.88	0.7	92	10	43	I-2a
100,060	1.10	1.0	79	28	350	
100,061	0.35	1.1	51	<10	115	
100,062	12.16	1.0	56	28	86	I-3
100,063	0.30	0.9	87	62	125	
100,070	7.68	1.2	70	20	93	
100,071	2.16	0.8	360	<10	82	
100,072	3.20	1.1	4,600	<10	205	
100,073	0.98	0.5	2,600	<10	98	
100,074	0.15	0.8	135	<10	66	
100,075	2.08	1.2	14,200	<10	168	I-4
100,076	0.04	1.5	8,000	<10	146	
100,077	0.16	2.6	19,000	<10	255	
100,086*	10.96	0.6	2,800	34	130	
100,087**	0.66	1.7	11,800	19	730	
100,089	1.09	1.0	100	20	80	I-5a
100,090	0.48	0.8	245	28	64	
100,091	1.98	1.2	55	42	105	
100,092	0.90	0.6	35	34	35	I-5b
100,093	1.17	0.6	50	34	55	
100,099	12.32	1.3	50	<10	72	
100,100	0.26	0.8	40	20	70	
100,101	0.42	1.0	60	20	100	I-5c
100,102*	100.40	9.7	30	172	60	
100,103	0.52	0.4	6	<10	10	
100,109*	7.94	1.3	60	10	95	
100,110	0.72	0.5	30	<10	73	I-6
100,113	0.13	0.5	45	<10	68	I-7a
100,115	1.55	0.6	20	<10	50	I-7b
100,116	32.80	1.7	57	<10	80	
100,121	2.32	0.6	35	<10	40	
100,122	3.28	1.0	6	<10	17	II-1
100,123	3.04	0.8	13	<10	35	
100,127	5.84	1.1	30	<10	64	
100,128	2.80	1.0	45	28	81	
100,129*	28.80	2.5	50	<10	60	II-2a
100,130	5.84	1.0	57	<10	73	
100,140	9.00	1.2	60	<10	60	
100,141	2.24	0.6	57	<10	40	

Table 2. Atomic absorption analysis of composite waste samples from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Mine pit
100,142	2.96	0.7	105	<10	65	
100,144	2.56	0.4	100	42	45	
100,145	3.28	0.5	56	<10	50	II-2b
100,146	11.84	1.2	45	<10	60	
100,147	6.08	1.0	63	<10	50	
100,152	1.10	0.6	40	<10	65	II-3a
100,234	5.00	0.9	30	<10	42	S-1
100,238	0.28	0.3	22	<10	14	
100,239	0.74	0.4	10	<10	17	S-4
100,243	40.00	3.5	6	<10	<10	
100,244	<0.04	1.2	68	<10	52	
100,245	0.09	0.4	110	<10	19	S-2
100,246	0.14	1.5	39	<10	126	
100,248	0.50	0.4	10	<10	15	
100,254	12.00	1.8	66	<10	72	S-3
100,292	0.13	0.6	11	<10	25	S-5

Footnotes:

* Sample taken from crushing area

** Slag sample.

Table 3. Atomic absorption analysis of vein quartz spot samples from the Jabal Guyan ancient mine (in ppm)

Sample no.	Au	Ag	Cu	Pb	Zn	Mine pit
100,066	0.16	0.2	40	14	15	I-3
100,082	0.32	0.8	25	16	40	I-4
100,111	4.88	0.3	8	<10	11	I-6
100,112	7.56	0.4	55	<10	32	
100,119	0.20	0.6	20	<10	85	I-7b
100,132	0.20	0.1	6	<10	15	II-2a
100,135	8.64	0.4	30	<10	50	
100,143	<0.04	0.1	7	<10	<10	II-2b

Table 4. Atomic absorption analysis of quartz veinlets and altered rock spot samples, from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Mine pit
100,054	0.26	0.7	23	<10	25	I-1
100,055	0.40	1.4	360	<10	66	I-2
100,059	0.13	0.4	31	<10	29	
100,064	0.22	0.2	34	<10	117	
100,065	0.11	1.0	70	34	120	I-3
100,068	0.70	0.2	20	<10	14	
100,080	1.30	0.6	50	34	45	
100,083	6.08	1.0	55	28	68	I-4
100,084	2.80	0.8	70	28	86	
100,085	2.88	1.2	820	28	64	
100,094	0.22	0.4	13	34	27	
100,095	0.50	0.7	340	20	43	
100,096	0.14	1.3	600	20	235	I-5b
100,097	1.71	0.4	25	<10	20	
100,098	0.52	1.0	50	42	35	
100,104	1.52	0.4	30	<10	40	
100,105	0.99	0.6	75	20	77	
100,106	4.96	1.0	45	20	100	I-5c
100,107	0.42	2.9	115	400	210	
100,108	2.56	0.5	30	<10	35	
100,114	0.60	0.7	90	<10	110	I-7a
100,124	7.12	0.6	26	<10	27	
100,125	7.68	0.2	5	<10	11	II-1
100,126	0.04	1.0	10	42	29	
100,131	27.20	2.0	300	<10	81	
100,133	4.08	0.6	170	<10	37	
100,134	4.16	0.6	114	<10	115	II-2a
100,138	1.63	0.2	6	<10	25	
100,139	4.40	0.4	34	<10	35	
100,148	0.35	0.4	21	<10	68	
100,149	1.81	0.4	6	126	60	II-2b
100,150	5.12	0.4	20	<10	30	
100,151	0.35	0.4	37	<10	60	
100,153	1.32	0.2	13	<10	30	II-3a

Table 5. Atomic absorption analysis of altered rock spot samples from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Map location
100,052	0.50	0.8	83	14	150	I-1
100,053	0.24	0.8	67	<10	96	
100,056	1.04	1.3	320	28	93	I-2
100,057	1.54	1.2	37	28	140	
100,067	0.37	0.7	53	<10	110	I-3
100,069	1.40	0.7	80	<10	105	
100,078	0.04	0.8	1160	<10	115	
100,079	0.04	1.0	1140	<10	168	I-4
100,081	1.14	1.7	75	34	105	
100,117	12.32	1.7	2000	42	210	I-7b
100,118	0.08	0.5	65	<10	50	
100,136	0.28	0.4	50	<10	73	II-2a
100,137	3.44	1.2	28	<10	68	
100,154	2.50	0.5	50	<10	66	II-3a
100,240	0.64	0.6	36	<10	38	S-4
100,241	0.92	1.3	84	10	76	

Table 6. Atomic absorption analysis of vein quartz traverse samples from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Traverse length(cm)	Map location
100,156	6.20	0.4	12	<10	10	70	
100,157	6.48	0.7	56	<10	40	20	
100,159	1.30	0.1	20	<10	20	47	
100,160	<0.04	<0.1	<5	<10	<10	100	II-2a
100,162	9.84	0.5	50	<10	10	40	
100,164	0.72	<0.1	6	<10	10	100	
100,165	0.20	<0.1	13	<10	20	200	
100,166	1.54	0.2	25	42	15	20	I-2
100,167	0.18	<0.1	<5	<10	<10	300	
100,168	0.17	<0.1	5	<10	<10	100	
100,169	1.60	<0.1	25	<10	27	70	I-3
100,171	0.28	0.2	23	<10	40	40	
100,173	7.56	0.5	26	<10	35	60	
100,176	0.04	<0.1	12	<10	15	50	
100,177	<0.04	<0.1	<5	<10	<10	80	
100,179	<0.04	<0.1	12	<10	<10	60	I-4
100,182	0.66	0.1	6	<10	<10	100	
100,183	0.22	0.1	16	<10	10	40	
100,189	0.20	<0.1	6	<10	<10	60	I-5b
100,190	0.40	<0.1	<5	<10	<10	100	
100,192	0.17	0.2	13	<10	17	100	I-5c
100,198	<0.04	8.2	95	<10	12	80	
100,202	0.05	1.6	9	<10	<10	30	I-6
100,203	<0.04	0.2	10	<10	<10	90	
100,204	0.05	0.2	6	<10	<10	100	
100,206	0.33	0.2	9	<10	12	150	
100,207	2.60	0.6	7	<10	12	100	I-7a
100,208	10.70	1.8	8	<10	18	15	
100,209	0.14	0.2	9	<10	18	120	
100,217	<0.04	0.4	9	<10	17	120	
100,218	0.07	0.4	7	<10	12	130	II-2b
100,219	0.08	<0.1	<5	<10	<10	100	
100,224	0.70	0.4	11	<10	23	20	II-3b
100,226	0.16	0.9	6	<10	<10	100	II-4
100,227	1.40	0.4	17	<10	30	50	
100,229	0.15	0.3	<5	<10	<10	110	I-7f
100,230	0.16	0.7	6	<10	<10	200	
100,232	0.10	0.4	7	<10	30	20	
100,233	1.26	0.8	30	<10	70	40	S-1
100,235	0.20	2.0	7	<10	<10	100	

Table 6. Atomic absorption analysis of vein quartz traverse samples from the Jabal Guyan ancient mine (in ppm) (cont'd).

Sample no.	Au	Ag	Cu	Pb	Zn	Traverse length (cm)	Map location
100,237	1.90	0.9	125	<10	36	15	
100,249	0.08	0.4	<5	<10	15	20	
100,250	0.06	0.4	5	<10	15	40	S-3
100,251	0.11	0.4	5	<10	12	50	
100,265	0.30	2.3	8	<10	15	100	
100,266	0.71	7.5	14	<10	11	125	prospected
100,267	4.40	<0.1	40	<10	13	50	localities--
100,277	0.05	<0.1	<5	<10	40	40	see fig. 2
100,278	0.12	<0.1	15	<10	40	40	for location
100,284	0.04	2.0	<5	40	<10	100	

Table 7. Atomic absorption analysis of altered rock outcrop traverse samples from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Traverse length(cm)	Map location
100,155	1.14	1.0	120	<10	80	40	
100,158	0.33	1.5	65	28	130	200	II-2a
100,161	1.21	1.2	70	42	60	100	
100,163	3.28	1.3	80	56	80	100	
100,170	4.24	1.0	75	34	125	250	
100,172	0.58	0.8	310	28	75	60	I-3
100,174	1.14	1.0	15	<10	175	60	
100,175	0.54	0.7	230	<10	70	130	
100,178	2.64	0.3	42	<10	50	40	
100,180	0.58	1.1	65	28	107	200	I-4
100,181	0.87	1.2	100	42	86	300	
100,184	0.04	1.4	8400	112	300	400	
100,185	0.28	1.2	56	42	125	200	
100,186	0.30	0.9	53	42	35	40	I-5b
100,187	0.70	0.8	70	42	92	130	
100,188	0.74	0.5	53	28	47	100	
100,191	0.20	1.3	75	19	104	400	
100,193	0.17	1.3	100	114	140	200	
100,194	0.12	0.9	90	19	100	300	I-5c
100,195	0.30	1.5	95	19	112	100	
100,197	0.26	1.2	95	19	150	120	
100,199	0.08	2.0	75	<10	130	200	
100,200	0.05	1.5	13	<10	86	400	I-6
100,201	0.05	1.2	30	<10	175	300	
100,205	0.29	1.6	14	<10	137	300	
100,210	<0.04	1.5	130	<10	130	100	I-7a
100,211	0.05	1.3	60	<10	86	180	I-7b
100,212	0.08	1.5	65	50	110	230	
100,213	0.23	1.8	60	<10	45	150	
100,215	0.08	0.8	47	<10	32	120	II-1
100,216	0.12	0.6	33	<10	52	120	
100,220	0.33	0.9	7	<10	60	500	
100,221	<0.04	1.3	14	<10	100	250	II-2b
100,222	0.26	1.4	140	<10	107	250	
100,223	0.14	1.3	90	<10	107	300	II-3a
100,225	0.16	1.3	7	<10	54	200	II-3c
100,228	0.14	1.6	130	<10	86	120	II-4
100,231	0.10	1.2	14	<10	70	200	S-1
100,236	1.04	0.6	14	<10	32	250	
100,242	0.12	1.2	70	<10	45	300	S-4
100,244	<0.04	1.2	68	<10	52	200	S-2
100,247	0.12	0.9	13	<10	48	50	
100,252	<0.04	0.6	75	<10	100	100	S-3
100,253	0.20	0.8	100	<10	52	250	

Table 8. Atomic absorption analysis of traverse samples of nonprospected vein quartz in Jabal Guyan area (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn	Traverse length
100,255	<0.04	1.4	<5	<10	64	5 m*
100,258	<0.04	1.4	<5	<10	10	80 cm
100,259	<0.04	2.3	17	<10	19	100 "
100,263	<0.04	<0.1	<5	<10	<10	80 "
100,264	<0.04	<0.1	<5	<10	<10	20 "
100,268	0.04	<0.1	<5	<10	<10	100 "
100,269	0.04	<0.1	<5	<10	<10	70 "
100,270	0.60	<0.1	<5	<10	<10	100 "
100,271	<0.04	<0.1	<5	<10	<10	70 "
100,272	<0.04	4.0	<5	<10	<10	70 "
100,273	0.08	3.8	<5	<10	<10	100 "
100,274	0.04	0.8	<5	<10	<10	100 "
100,275	0.04	0.8	<5	<10	46	100 "
100,276	0.30	1.8	<5	<10	50	80 "
100,279	<0.04	<0.1	8	<10	40	60 "
100,286	0.06	<0.1	25	<10	30	100 "
100,289	<0.04	0.4	62	<10	30	300 "
100,290	0.04	4.0	43	<10	30	200 "
100,291	<0.04	1.0	29	<10	40	80 "

* traverse along length instead of across the vein

Note: See figure 2 for sample locations.

Table 9. Atomic absorption analysis of unaltered metavolcanic country rocks from the Jabal Guyan ancient mine (in ppm).

Sample no.	Au	Ag	Cu	Pb	Zn
100,088	0.08	0.8	90	20	100
100,196	<0.02	0.5	95	30	129

gold values or less than one ppm. One of the two analyzed unaltered metavolcanic rock samples contains gold in a minor amount (0.08 ppm).

Copper is present in an amount up to 19,000 ppm Cu (1.9 percent) in dump samples taken near the small pit which may have been mined for the metal. Altered wall rocks selectively collected from the pit contain up to 8,400 ppm Cu (0.84 percent). Visible copper mineralization, restricted to the altered wall rocks of the pit, is sparse and the mineralized area is small. Samples from elsewhere in the mine area vary considerably in copper content but do not contain amounts suggestive of economic concentrations of copper; values do not exceed 600 ppm Cu (0.06 percent). Copper is generally more abundant in altered wall rocks than in adjacent quartz veins; several quartz samples do not contain copper in determinable amounts (5 ppm Cu).

Silver, lead, and zinc are present in samples from the Jabal Guyan area in insufficient amounts to be of potential economic interest. Although generally present in determinable amounts of 0.1 ppm or greater, silver averages only 0.9 ppm (0.026 oz/ton) in all samples, exceeds 3 ppm (0.087 oz/ton) in only 7 samples, and is a maximum of 9.7 ppm (0.28 oz/ton) in a composite waste sample. Lead exceeds the determinable amount of 10 ppm in only 63 (27 percent) of the 230 total analyzed samples, only four samples contain more than 100 ppm Pb, and the metal reaches a maximum of 400 ppm Pb in a "spot" sample of a mixture of quartz and pyrite-bearing altered rock. The maximum value of zinc, 750 ppm, was determined on the copper-rich slag. Generally zinc ranges between 10 and 150 ppm.

DISCUSSION

The gold content of waste material left from mining operations is greater than that of the vein quartz remaining in and near the mine excavations. This suggests that ancient miners selectively mined only the highest grade ore. This ore undoubtedly was hand sorted and the selected ore transported to the crushing areas, where their recovery of gold was poor, judging from the high average gold content of 37 ppm (1.1 ounces per ton) of waste material left at the crushing sites. The high grade material left at the crushing sites indicates that rich ores existed in the veins but the average grade that was mined cannot be determined as there is no way of knowing the volume of higher grade ore that was hand sorted from the total volume that was mined.

Ancient mining ceased at Jabal Guyan, probably for a variety of reasons.

Depth of excavating apparently was limited to about 25 m and in all likelihood mining technology was not advanced enough nor was equipment available to allow deeper mining. Water remains in the deeper workings, thus water could have been a problem. The podiform veins pinch and swell over short distances and the veins cropping out at the surface may not have continued to greater depths.

Massive lower grade quartz was left in place. With depth the fractured quartz and unoxidized adjacent wall rock may have prohibited mining.

It is impossible to accurately determine the amount of gold extracted by the ancient miners but it undoubtedly was considerable.

The podiform quartz veins probably pinch and swell with increasing depth along the northwest-trending fault zones and the associated, gold-bearing altered rocks probably persist at depth. As previously mentioned, gold was apparently remobilized by cataclasis and gold grains occur on fracture faces in quartz. Remobilization of gold could have caused an enrichment in quartz veins and adjacent altered zones at increasing depths.

A considerable amount of gold remains in waste at the Jabal Guyan mine. Volume of waste material totals approximately 9,500 m^3, corresponding to a weight of not less than 24,000 tons. The average gold value for all waste materials is 6.5 ppm (0.185 oz/ton). Thus approximately 4,500 oz of gold, worth $675,000 at a gold price of $150 per oz, are in the waste materials.

RECOMMENDATIONS

Preliminary exploratory drilling is warranted at the Jabal Guyan mine to determine if gold-bearing veins and alteration zones persist and are enriched at depth. If results of preliminary drilling are favorable, further drilling should then be undertaken to evaluate ore reserves.

The workings north of the Jabal Guyan mine merit detailed examination and the entire region should be searched for other ancient mines.

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