U. S. GEOLOGICAL SURVEY

MINERALIZATION IN THE UYAIJAH-THAABAN AREA, WEST-CENTRAL PART OF THE UYAIJAH RING STRUCTURE KINGDOM OF SAUDI ARABIA

by

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U. S. Geological Survey
Jiddah, Saudi Arabia

1975

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ABSTRACT

Anomalous amounts of tungsten, molybdenum, and bismuth were found previously in surficial debris collected from the Uyaijah-Thaaban area in the west-central part of the Precambrian Al Uyaijah ring structure. The area is mostly underlain by quartz monzonite. Countless quartz veins ranging from a knife edge to more than 3 m in thickness cut the quartz monzonite; many of these veins contain molybdenite. Detailed mapping and intensive sampling of the molybdenite-bearing quartz veins indicate that their grade and quantity are probably inadequate to permit present-day mining; however, they represent a potential future resource. The tungsten of the area appears to be negligible.

INTRODUCTION

In the course of geochemical exploration in western Saudi Arabia, U. S. Geological Survey geologists discovered areas of anomalous values of molybdenum, tungsten, and bismuth in panned concentrates of surficial debris collected from the Al Kushaymiyah and Jabal al Hawshah quadrangles (Whitlow, 1966a, b). Because of these findings, the Buhairan-Abu Khurg and Uyaijah-Thaaban areas were proposed for further, more intensive study. Although tungsten mineralization is sparse in the Buhairan-Abu Khurg area, significant molybdenum mineralization is present in the Uyaijah-Thaaban area. This report documents the results of an investigation of the latter area.

LOCATION, GEOGRAPHY, AND ACCESS

The Uyaijah-Thaaban area is about 200 km south of Ad Dawadami (fig. 1), approximately at lat 22°45'N. and long 44°30'E. In its longest direction the rectangular-shaped area extends 12.5 km N.72°E. It occupies 60 sq km of a roughly 1000 sq km region known locally as Al Areyef, a region of numerous, isolated, steeply-rising inselbergs and surrounding near-flat wadis and pediments. Quarat al Uyaijah and Jabal Thaaban, from which the area is named, are the two most prominent inselbergs in the area, rising 100 and 170 m respectively from their plain-like surroundings. Elevations in the area range from 898 m in the northeast corner to 1103 m at the summit of Jabal Thaaban. The area is in a remote part of Arabia; nearest permanent settlements of significant size are the towns of Sabha and Sanam, 55 and 100 km respectively northeast. Access is limited to truck tracks through largely uninhabited areas from Zalim or Ad Dawadami on the Taif-Ar Riyad road and airborne entry.

PREVIOUS STUDIES

Whitlow (1966a, b) noted unusual abundances of tungsten and molybdenum in panned concentrates collected during a survey of mineral potential of the Al Kushaymiyah and Jabal al Hawshah 1:100,000 quadrangles. He (Whitlow, 1966c) recommended an exploration program for mineral deposits in an approximately 1000 sq km tract that coincides closely with the Al Areyef region.

Whitlow's recommendation for further exploration was supported by Theobald (1970) who compiled values of tungsten, molybdenum, and tin in heavy mineral concentrates derived from surficial sediments collected

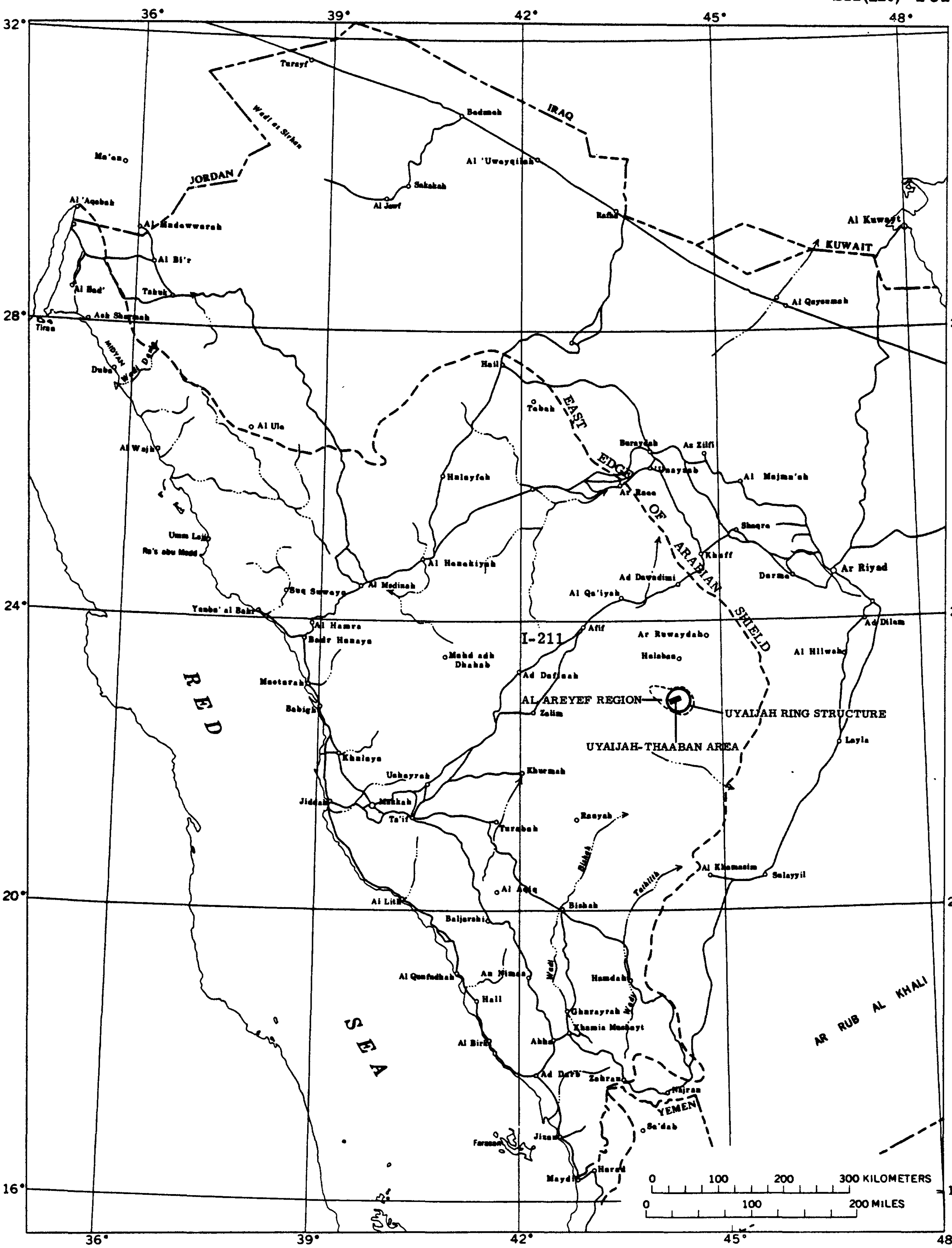

Figure 1.- Index map of western Saudi Arabia showing the location of the Al Areyef region, the Uyaijah ring structure, and the Uyaijah-Thaaban area. I-211 identifies the area covered by the scale 1:500,000 geologic map of the southern Najd quadrangle (Jackson and others, 1962).

from throughout much of western Saudi Arabia. Based on his compilation, Theobald singled out the Al Areyef region* as the one region in the Arabian Shield that shows anomalous concentrations of the three elements. Theobald (1970) postulated that the region had close geologic and geochemical similarities with well known areas of molybdenum deposits in Colorado and New Mexico, U.S.A., and suggested that exploration of the region should be undertaken to search for a stockwork molybdenum deposit.

Following Theobald's (1970) study, Theobald and Allcott (1973) mapped the distribution of rock types in the Uyaijah ring structure of the Al Areyef region at a scale of 1:50,000 and systematically collected and analyzed panned sediment samples in the area occupied by the ring structure. In conjunction with this investigation, Flanigan and Andreasen (1973) conducted regional airborne magnetic and gamma radiation surveys. Based on results of their study, Theobald and Allcott recommended that the Uyaijah-Thaaban and Buhairan-Abu Khurg areas be explored further. Dodge (1973) examined the latter area and concluded that no exploitable mineral deposits exist in it.

PRESENT INVESTIGATION AND ACKNOWLEDGEMENTS

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

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* Theobald (1970) and subsequent investigators have referred to this region as the "Al Kushaymiyah area", taking the name from a prominent jabal in the western part of the region. "Al Kushaymiyah" is a geographic name not well known to local bedouin, who refer to the region as "Al Areyef". We have dropped usage of Theobald's designation of this specific region as "Al Kushaymiyah" in favor of the more widely recognized name "Al Areyef".

Prior to beginning systematic fieldwork, a 2-day reconnaissance of the region was made in August 1972 in order to plan succeeding work. Twelve weeks were spent in the field investigation of the Uyaijah-Thaaban area during the period between December 1972 and April 1973.

A special topographic map, prepared at a scale of 1:10,000 by cartographers of the U. S. Geological Survey, served as a base for geologic mapping and sampling (plate 1). A total of 239 samples were collected and analyzed. Favorable rocks were extensively examined at night with a portable short-wave ultraviolet lamp to search for fluorescent tungsten minerals.

Topographic maps of selected mineralized areas were prepared at 1:1,000-scale by K. S. McLean and F. G. Lavery. These maps served as a base for mapping distribution of quartz veins and for further sampling (plates 2, 3, and 4).

Geochemical sampling guided by geologic precepts has been an integral part of this investigation, both during the preliminary exploration and evaluation phases. Spectrographic and chemical analyses were made in USGS/DGMR laboratories in Jiddah, Saudi Arabia. I. M. Naqvi performed the spectrographic determinations. Chemical analyses were made under the direction of W. L. Campbell. Tungsten and molybdenum were routinely determined by colorimetric methods by Ibrahim Baradja and Q. S. Osman. Bismuth, copper, gold, lead, manganese, silver, and zinc were determined by A. A. Masud and Abdulmohsin Abuzinadah.

In addition to chemical and spectrographic analysis, laboratory study consisted of thin-section petrographic examination, modal analysis of sawed and stained plutonic rocks, specific gravity determination of igneous rocks, and separation of various mineral phases from samples of vein quartz.

Lester North and Ibrahim Abuttahir calculated statistics on, and plotted distribution of elements in vein quartz samples at the College of Petroleum and Minerals Computer Center, Dhahran.

GEOLOGIC SETTING

The Uyaijah-Thaaban area occupies a part of the west-central Uyaijah ring structure (fig. 2). The ring structure consists of a circular dike 15 to 20 km in diameter and associated sill-like bodies of the quartz monzonite of Abu Khurg, which have been intruded into a large, pre-existing granodiorite to quartz monzonite batholith, the granodiorite of Al Areyef, and pre-existing metamorphic rocks. Prior to emplacement of the quartz monzonite of Abu Khurg, a stock and dike offshoots of quartz monzonite, herein named the quartz monzonite of Jabal Thaaban, invaded the batholith, forming the present core of the ring structure. The entire assemblage of intrusive rocks is part of a major Precambrian magmatic sequence of calc-alkaline plutonic rocks abundant in the northeast portion of the Arabian Shield (Greenwood and Brown, 1972).

Subsequent to emplacement of the ring dike, the entire structure was broken by faults. Rocks in the southeast quadrant of the ring structure were horizontally offset approximately three-quarters of a kilometer by a northwest-trending, left-lateral fault, which may be part of the Najd fault system. No single fault trace can be

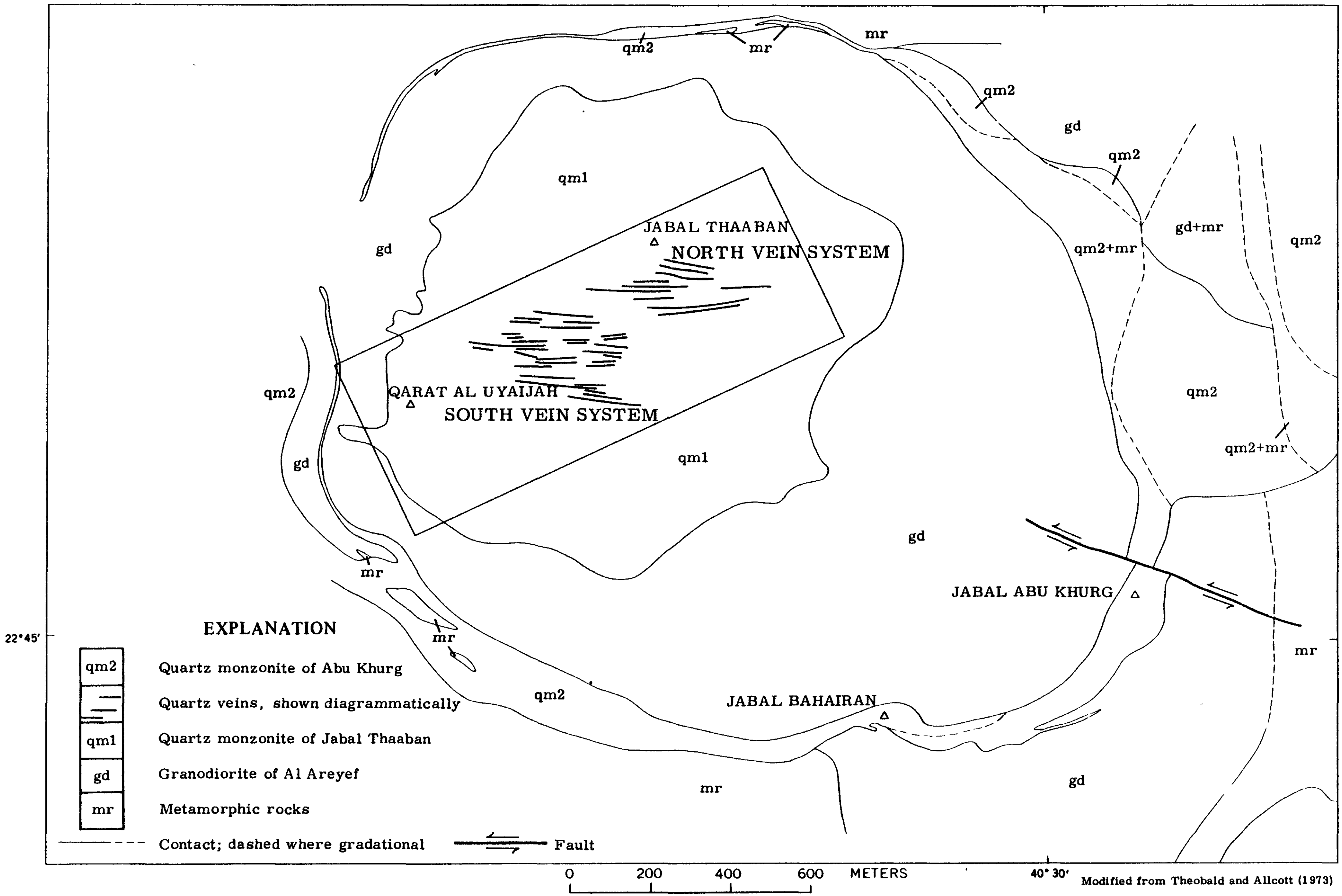

Figure 2. - Geologic sketch map of the Uyaijah ring structure.

followed into the Uyaijah-Thaaban area, and horizontal offset cannot be demonstrated in the area. Nevertheless, prior to or contemporaneous with the major episode of faulting, rocks in the area contiguous to numerous recognizable shear zones that parallel the Najd system were altered and invaded by quartz veins.

After the period of alteration, veining and faulting, and presumably after a period of uplift, east-west to northwest trending hypabyssal dikes, and later a second set of parallel quartz veins, were injected into rocks of the ring structure. Finally, the entire structure was further uplifted and unroofed.

ROCKS IN THE UYAIJAH-THAABAN AREA

The greater part of the Uyaijah-Thaaban area is underlain by the core-forming quartz monzonite of Jabal Thaaban (plate 1). Although neither the oldest or youngest major units of the ring structure, the metamorphic rocks and the quartz monzonite of Abu Khurg are represented(with the possible exception of a 2-m wide quartz monzonite dike in the central part of the area), meager amounts of the granodiorite of Al Areyef crop out along the west side of the area. A multitude of veins and diverse types of dikes; a fraction of a centimeter to a few meters wide, cut the quartz monzonite of Jabal Thaaban in an abundance far greater than in granitic rocks elsewhere in the region.

About one-half of the Uyaijah-Thaaban area is masked by a thin veneer of surficial debris consisting of wadi sediments, eolian dune sands, poorly sorted pediment materials, and talus.

Granodiorite of Al Areyef

The oldest rock unit in the Uyaijah-Thaaban area is the granodiorite of Al Areyef. Although it forms a batholith covering at least 180 sq km, it underlies only a small expanse along the western margin of the Uyaijah-Thaaban area.

Within the area, the granodiorite varies little in composition and has the same general appearance in each outcrop. Color index of a modally analyzed sample (fig. 3) is 10. Euhedral tabular microcline phenocrysts up to 3 cm long are a conspicuous feature. Quartz, plagioclase (andesine), biotite, hornblende, sphene, apatite, epidote, and magnetite are other minerals present. Minor element content (table 1) is similar to minor element contents reported in the Buhairan-Abu Khurg area (Dodge, 1973).

Table 1. Minor element content and location of a sample of granodiorite of Al Areyef (sample no. 72510).

Lat (N)	Long (E)	ppm								
		W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
22°46'58"	44°21'08"	<20	5	N	.2	<1	<25	55	25	310

N = Looked for, not detected

Oriented phenocrysts or lenticular mafic inclusions define a prominent foliation in the granodiorite. In the Uyaijah-Thaaban area, strike of the foliation is variable, but it generally trends near north-south and dips vertically.

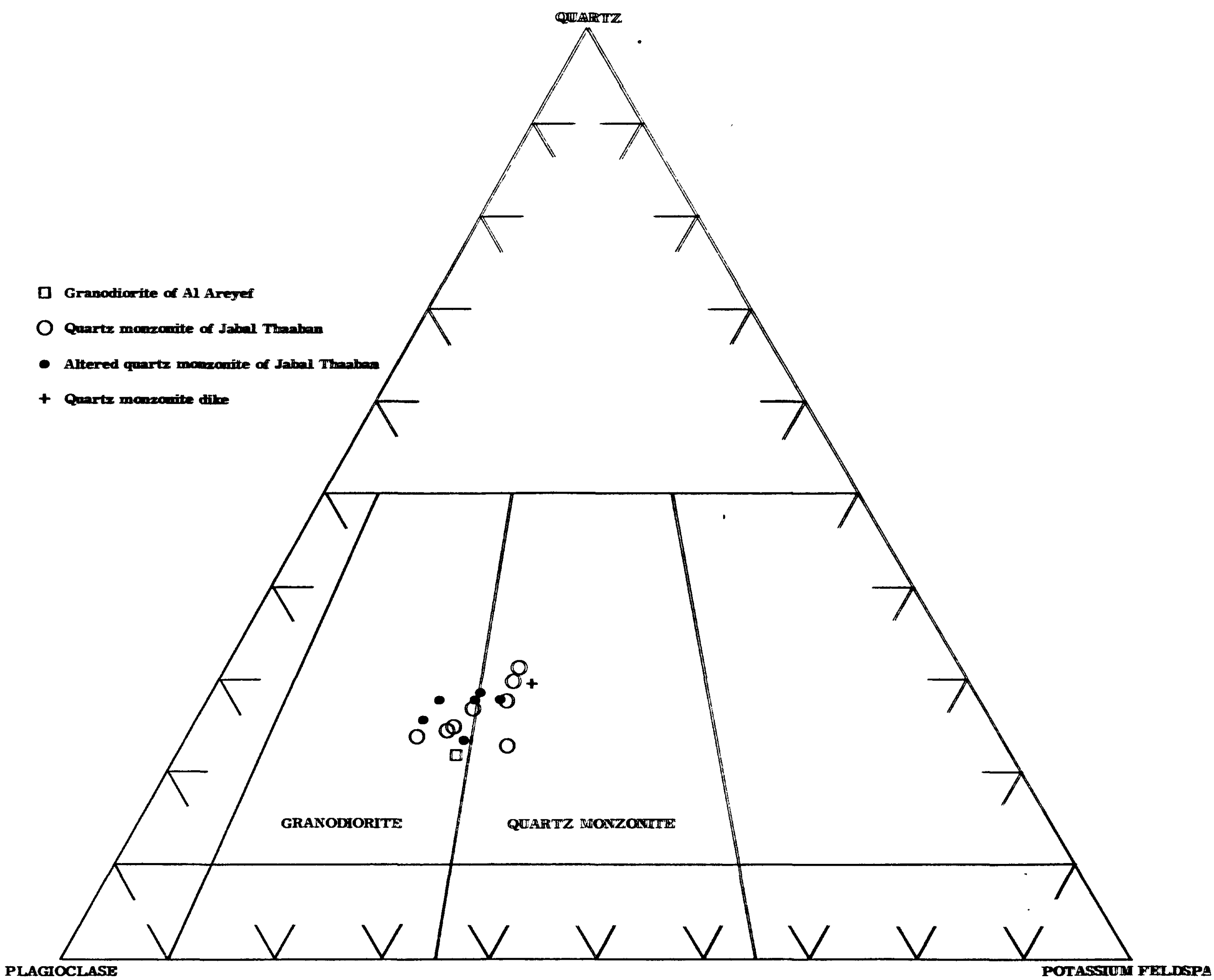

Figure 3.- Modal plot of granitic rocks of the Uyaijah-Thaaban area.

Quartz monzonite of Jabal Thaaban

The quartz monzonite of Jabal Thaaban, herein named after one of the most prominent landmarks of the region, is well exposed in the Uyaijah-Thaaban area. The quartz monzonite forms a roughly circular core in the Uyaijah ring structure, underlying approximately 35 sq km.

Intrusive relations between the quartz monzonite of Jabal Thaaban and the granodiorite of Al Areyef are clearly displayed along the southwestern boundary of the area; blocks of the granodiorite are commonly included in the quartz monzonite near the contact between the two rock units, and small dikes of the quartz monzonite have been injected into the granodiorite.

The quartz monzonite of Jabal Thaaban is a light- to medium-gray, medium-grained, hypidiomorphic granular, seriate rock. Compositionally, it is a quartz monzonite, and contains a little more plagioclase than either quartz or potassium feldspar (fig. 3). Content of mafic minerals ranges from 4 to 8 percent. Both quartz and plagioclase occur in a wide range of grain sizes. Jaggedly bounded anhedral grains of quartz commonly display undulose or patchy extinction. Plagioclase occurs in polysynthetically-twinned, concentrically zoned subhedral to euhedral grains with an average composition of calcic oligoclase. Potassium feldspar is in large, commonly grid-twinned anhedral grains, sporadically associated with myrmekite. Small, ragged flakes of olive-brown biotite are disseminated throughout the rock. Minor accessories include opaque grains, epidote minerals, apatite, zircon, white mica, and rarely sphene.

Foliation in the quartz monzonite is absent or defined very weakly by alignment of biotite grains. Joints are widely spaced and are preferentially oriented. They are responsible for the marked N. 70°W. physiographic trend of the Uyaijah-Thaaban area.

Pervasive alteration of the quartz monzonite is widespread; most rocks show minor alteration effects, including varying degrees of sericitization of plagioclase, small, sericite-filled fractures, and sericitic coatings of grain boundaries. The most intensely altered rocks occur in a crudely defined, 3-km wide, N.70°W. trending belt, through the central part of the area. From a distance, exposure of altered rocks appear dark brown, whereas relatively unaltered counterparts are white or light gray. The altered rocks themselves are pink. In contrast to other areas, joints in highly altered rocks are closely spaced; however, they generally follow the dominant joint trend manifest elsewhere in the quartz monzonite. Although altered rocks underlie broad expanses, particularly north of Jabal Dagma, they also occur in narrow bands 1 cm to 1 m wide, alternating with relatively unaltered rocks. The alternation is commonest along the southern edge of the alteration belt, midway between Jabal Dagma and Qarat al Uyaijah, but it is present elsewhere also. Jabal Dagma is a 100-m high inselberg which, even though it occurs in the middle of the alteration belt, consists entirely of relatively unaltered rocks.

Altered rocks are typically enriched in muscovite; biotite is absent or chloritized, opaque minerals are oxidized, and plagioclase feldspar and rarely potassium feldspar are sericitized. Minor amounts of oxidized pyrite, carbonate, and epidote are present in some altered rocks. Development of clay minerals or potassium feldspar enrichment are not alteration features (fig. 3); in fact, some potassium feldspar may have been removed during alteration. The alteration cannot be easily placed in the hydrothermal alteration classification scheme proposed by Creasy (1966), for enrichment of muscovite and chlorite, both in the absence of clay minerals, are characteristic of his potassic and propylitic alterations, respectively. Nevertheless, on the basis of mineralogical changes, particularly the development of muscovite, the alteration would be considered the muscovitic type of Burnham's (1962) phyllic facies. This places an upper temperature limit of 620°C. at 1,000 bars water pressure on the alteration, a limit only slightly below magmatic crystallization temperatures.

A slight decrease of specific gravity is a consequence of alteration; six samples of relatively unaltered quartz monzonite average 2.61, and range from 2.59 to 2.63 in specific gravity, whereas 14 samples of altered rock average 2.58 and range from 2.54 to 2.61.

Minor element contents of six relatively unaltered and 28 altered samples of the quartz monzonite are presented in table 2. In general, the minor element contents are not greatly different between the altered and unaltered rocks. One sample of altered quartz monzonite (sample no. 72,612) contains much greater amounts of Bi, Pb, Ag, and Au, and slightly greater amounts of Cu and Mo than most other samples of the quartz monzonite. The sample was taken from a 5 to 20 cm wide alteration zone alongside a narrow quartz veinlet; elsewhere the same narrow zone is along joints barren of quartz. In many of the other samples, some of the elements, particularly Mo, Au, and Ag are present in amounts somewhat, though not significantly higher than

Table 2. Minor element contents and locations of samples of quartz monzonite of Jabal Thaaban

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
UNALTERED											
72,504	22°49'33"	44°27'06"	<10	5	.03	.2	10	<25	40	<5	150
72,512	22°47'56"	44°21'49"	<10	<5	N	N	<1	<25	40	<5	135
72,515	22°47'10"	44°21'53"	<10	<5	N	N	<1	<25	35	<5	150
72,517	22°47'15"	44°22'40"	<10	<5	N	.2	<1	<25	50	<5	180
72,535	22°49'40"	44°24'16"	N	N	.10	<.2	135	25	45	11	160
72,621	22°48'40"	44°24'21"	N	10	.08	.3	8	40	55	13	152
ALTERED											
72,505	22°48'52"	44°26'55"	<20	5	N	.2	N	N	15	<5	150
72,508	22°49'27"	44°26'30"	<20	5	N	N	N	N	<10	<5	75
72,514	22°48'01"	44°29'09"	<20	<5	N	N	10	<25	<10	<5	30
72,521	22°48'56"	44°22'34"	<20	<5	N	N	<1	<25	<10	<5	100
72,540	22°49'44"	44°24'54"	<20	60	<.04	<.2	10	25	15	25	60
72,544	22°49'39"	44°24'57"	<20	<5	.10	<.2	15	40	35	14	185
72,547	22°49'38"	44°25'08"	50	<5	.06	<.2	50	40	40	11	170
72,549	22°49'37"	44°25'10"	<20	<5	.18	.3	10	75	85	25	110
72,554	22°49'32"	44°24'43"	<20	5	.12	<.2	10	100	35	11	70
72,557	22°49'34"	44°24'53"	N	N	.12	<.2	8	80	12	11	45
72,560	22°49'33"	44°24'23"	<20	30	.12	<.2	15	50	12	11	70
72,567	22°49'21"	44°25'15"	N	N	.16	<.2	8	25	20	N	80
72,570	22°49'20"	44°25'03"	N	N	.14	<.2	40	25	25	N	100
72,574	22°49'21"	44°24'33"	<20	<5	.14	<.2	10	25	9	14	100
72,577	22°49'22"	44°24'38"	N	N	.18	N	10	25	50	8	220
72,579	22°49'21"	44°24'00"	N	N	.18	N	30	25	22	8	190
72,583	22°49'27"	44°23'38"	N	N	.18	N	25	110	15	N	160
72,590	22°49'13"	44°25'39"	N	10	.14	N	20	N	10	28	45
72,597	22°48'30"	44°25'35"	N	N	.14	<.2	15	N	45	20	210
72,598	22°48'14"	44°25'11"	<20	5	.14	N	10	N	35	13	170
72,603	22°48'07"	44°23'48"	<20	5	.14	8.8	35	N	30	5	35
72,604	22°48'08"	44°23'50"	N	N	.14	6.9	40	N	40	13	130
72,612	22°48'24"	44°25'56"	H	80	.60	58.5	65	300	<10	1980	<5
72,617	22°48'27"	44°24'02"	N	<5	.11	.3	20	40	73	25	152
72,623	22°48'44"	44°25'36"	N	10	N	.6	10	80	45	13	195
72,687	22°48'46"	44°22'31"	60	80	.09	N	35	140	90	7	25
72,707	22°48'17"	44°22'48"	<20	10	.07	.2	200	35	50	7	15
72,717	22°49'07"	44°24'47"	N	<5	.03	N	25	35	85	15	365

N = Looked for, not detected. H = Interference in analysis.

average amounts reported by Turekian and Wedepohl (1961) for high calcium granites of the earth's crust.

Steeply dipping aplitic and pegmatitic dikes that are a few centimeters to more than a meter wide and as much as a few hundred meters long cut the quartz monzonite of Jabal Thaaban, but were emplaced prior to alteration. In general, these dikes are of little quantitative importance and are not shown on the geologic map. Aplites predominate, but commonly aplitic and pegmatitic textures are present in the same dike. Mostly likely, these dikes are late-stage products related to consolidation of the quartz monzonite of Jabal Thaaban magma.

A prominent 2-m wide vertical dike of muscovite quartz monzonite trends N.60°W. and crops out on south-facing slopes of Dagma. The dike is not vastly different in content of felsic minerals (fig. 3) or in content of minor elements (table 3) from the quartz monzonite of Jabal Thaaban. Theobald and Allcott (1973, p. 25) have correlated the granitic rocks of dikes near the center of the Uyaijah ring structure with rocks of the ring-dike itself, the quartz monzonite of Abu Khurg, and have suggested that this indicated that rocks of the

Table 3. Minor element content and location of a sample of a quartz monzonite dikes. (Sample no. 72624)

Lat. (N)	Long. (E)	ppm								
		W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
22°48'45"	44°24'38"	N	<5	N	.2	20	50	15	10	130

N - Looked for, not detected.

ring-dike formed a shallow cupola beneath this area. Evidence does not confirm or discredit the contention that the quartz monzonite dikes are in fact correlative with rocks of the ring-dike, or that they were derived from a shallow source. Equally likely, the quartz monzonite dikes may be merely late-stage magmatic differentiates of the quartz monzonite of Jabal Thaaban.

Quartz veins and mineralization

Quartz veins that are a fraction of a centimeter to over 2 m wide and in some places as much as several hundred meters long cut the quartz monzonite of Jabal Thaaban (fig. 4). The veins are abundant in the central portion of the Uyaijah-Thaaban area in two zones approximately 3 km long and 1 km wide, separated by Jabal Dagma; to the west of the jabal the zones appear to merge; however, exposures are relatively poor in this area. Individual veins, as well as the vein zones themselves, have a general N.70°W. trend following the dominant joint pattern in the quartz monzonite. Generally veins are steep dipping or vertical, although shallow dipping veins are present locally.

Although the two zones of quartz veins are in altered rocks, the alteration and injection of veins were not contemporaneous in all instances. The most intensely altered quartz monzonite, roughly 600 m north of Jabal Dagma, contains only a relatively few small veins, some of which cut bands of altered rocks. On the other hand, away from the main areas of alteration, some veins are bounded by intensely altered rocks. Apparently pre-existing jointing was the dominant control of both alteration and vein trends, but as recognized by Theobald and Allcott (1973, p. 27) altering solutions and silica-rich

Narrow gash-like veins cutting quartz monzonite of Jabal Thaaban. Alteration of the quartz monzonite is confined to narrow bands which may or may not enclose the veins.

Single quartz vein cutting altered quartz monzonite of Jabal Thaaban.

Figure 4.- Typical steeply-dipping molybdenite-bearing quartz veins in the Uyaijah-Thaaban area (photographs by T. H. Kiilsgaard).

solutions evolved at least partially independently, with alteration preceding vein formation.

Two discrete generations of quartz veins are present in the Uyaijah-Thaaban area. The older veins are cut by hypabyssal mafic dikes, whereas the younger veins cut the dikes. As some individual veins cannot be differentiated, no age distinction of veins has been shown on plate 1. In addition, composite veins consisting of both generations of quartz have been recognized. One of these composite veins is described in a succeeding section on evaluation of mineralized areas.

Of the two generations of quartz veins, the older are by far the most abundant. Commonly they are in en echelon swarms of thin, gash-like veins, extending for tens of meters. The larger, more persistent older veins pinch and swell along their strike length for hundreds of meters. Downdip plunging slickensides on vein walls are common, indicating vertical movement along fractures subsequent to vein emplacement. Gouge is associated with veins at a few localities. The quartz in the veins is generally massive and milky or translucent, although reddish, iron-stained quartz is also present. Some of the quartz is granulated. Large, euhedral to anhedral, salmon-colored potassium feldspar crystals and fine, colorless to pale-green muscovite flakes are present in some veins.

Mineralization consists of disseminated sulfide minerals, ubiquitous oxidation products, and rare scheelite. Although most of the veins have been highly oxidized, commonly fresh pyrite cubes and hexagonal plates of molybdenite are present. Bismuthinite, chalcopyrite, and galena are rare. Boxworks as large as 2 cm along an edge are common in the veins. Limonite fills many of the boxworks. Iron oxide coatings are present along fractured vein surfaces. Segregations of specular hematite, probably the result of oxidation of pyrite are present in a few of the older veins. Molybdenite crystals are commonly encircled by a thin ring of powellite, undoubtedly an oxidation product of the sulfide, suggesting that conditions of oxidation were acidic (Mikhailov, 1964). In addition, powellite occurs as film-like coatings and in disseminated grains in the veins. It rarely occurs along fractures in host rocks adjacent to the veins indicating that molybdenum has probably not migrated far during the oxidation process. Although molybdenite crystals as large as 5 mm across have been noted, the mineral has apparently not oxidized as readily as has pyrite, for boxworks of molybdenite derivation are not present. Nevertheless some molybdenum occurs in oxide coatings and in earthy oxidation products (table 4). Chalcopyrite, which is much less common than either pyrite or molybdenite, is generally altered to malachite. Other sulfide minerals, only rarely present, have not altered to any specific recognizable oxide minerals; however, Bi, Pb, and Zn have been determined in fairly large contents in cryptocrystalline oxidation products (table 4). Sulfur coatings are present along fractures and near oxidized sulfide minerals in some of the veins. Scheelite is a rare constituent of some of the veins at a few localities.

Younger quartz veins which cut mafic dikes comprise only a small fraction of the veins in the Uyaijah-Thaaban area. The younger veins tend to extend for tens to hundreds of meters with fairly constant widths. Breccia fragments of host rocks, particularly of the mafic

Table 4. Semiquantitative spectrographic analyses of materials concentrated from vein quartz samples

	72,523 oxide coating	72,530 oxide coating	72,573 oxidation product	72,573 hematite	72,562 hematite	72,606 pyrite	72,606 chalco-pyrite	72,606 molyb-denite	72,721 molyb-denite	72,531 bismuth-inite	72,670 bismuth-inite
PERCENT											
Fe	7	7	.7	>20	>20	>20	>20	.5	.5	L	.1
Mg	.1	.15	-	.05	.05	-	-	-	-	-	L
Ca	.5	1.5	-	.15	L	-	-	-	-	-	.7
Ti	.02	.015	-	.003	.002	-	-	-	-	-	.005
PARTS PER MILLION (PPM)											
Mn	200	150	-	30	N	-	-	-	-	-	10
Ag	.5	1.5	5,000	30	70	50	500	50	70	20	300
As	N	N	N	N	N	500	N	-	-	-	N
Au	N	N	-	N	N	-	-	-	-	-	N
B	N	N	-	N	N	-	-	-	-	-	15
Ba	70	50	-	N	N	-	-	-	-	-	50
Be	1	2	-	N	N	-	-	-	-	-	1
Bi	70	30	>1,000	300	200	200	70	100	100	>1,000	>1,000
Cd	N	N	-	N	N	-	-	-	-	-	N
Co	10	L	-	N	N	-	-	-	-	-	N
Cr	N	N	-	N	N	-	-	-	-	-	N
Cu	1,500	300	>20,000	1,000	30	2,000	>20,000	300	100	200	3,000
La	N	N	-	N	N	-	-	-	-	-	L
Mo	>2,000	700	1,000	30	150	70	30	>2,000	>2,000	5	200
Nb	N	N	-	L	L	-	-	-	-	-	N
Ni	10	15	-	5	5	-	-	-	-	-	10
Pb	70	50	>20,000	70	50	30	10	30	50	2,000	20,000
Sb	N	N	N	N	N	N	N	-	-	-	500
Sc	N	N	-	N	N	-	-	-	-	-	N
Sn	N	N	-	N	N	-	-	-	-	-	N
Sr	N	N	-	N	N	-	-	-	-	-	150
V	50	70	-	50	70	-	-	-	-	-	20
W	N	N	-	N	50	-	-	-	-	-	N
Y	N	N	-	N	N	-	-	-	-	-	N
Zn	N	N	300	N	N	700	1,500	-	-	-	200
Zr	N	N	-	N	N	-	-	-	-	-	N

N = Looked for, not detected. L = Detected, but below level of determination.

dikes at localities where the dikes are cut by the veins, are a feature of the younger veins. The veins themselves consist principally of massive milky quartz; however, comb and banded structures are common locally. These features are rarely present in the older quartz veins. At a few localities, black, radiating, prismatic crystals of replaced tourmaline are present. Tourmaline has been altered to fine radiating mica and to carbonate. Analysis of a vein sample containing replaced tourmaline (table 5) indicates no appreciable amount of boron remaining after replacement. Mineralization is generally sparse, although trace amounts of sulfide minerals have been noted in some of the younger veins.

Table 5. Semiquantitative spectrographic analysis of a sample from a young quartz vein (sample number 72,599)

Element	Weight concentration	Element	Weight concentration
Fe	.5 percent	La	100 ppm
Mg	.1 "	Mo	<10 "
Ca	.6 "	Nb	<50 "
Ti	<.005 "	Ni	<10 "
Mn	70 ppm	Pb	<50 "
Ag	<2 "	Sb	<500 "
As	<1,000 "	Sc	<10 "
B	<100 "	Sn	<50 "
Ba	20 "	Sr	<200 "
Be	50 "		
Bi	50 "	V	<20 "
Cd	<500 "	W	50 "
Co	10 "	Y	<20 "
Cr	500 "	Zn	500 "
Cu	30 "	Zr	<10 "

Geochemical data from fault gouge associated with the older quartz veins at some localities indicate no significant metal concentrations (table 6).

Table 6. Minor element contents and locations of samples of fault gouge

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
72,520	22°48'35"	44°21'45"	<20	<5	N	N	N	<25	10	<5	50
72,580	22°49'21"	44°24'00"	N	N	.18	<.2	8	N	8	8	25
72,665	22°49'08"	44°23'48"	N	10	.12	N	35	26	20	20	10

N = Looked for, not detected.

Analysis of 190 vein quartz samples are shown in table 7. Arithmetic means to the nearest two places of eight of the elements are given at the end of the table. For analyses in which the element is present in amounts below the limit of determination, a zero value has been assigned. Upper limits are given for all the elements, but the lower limit for each one does not exceed the determinability limit.

Variation of contents of determined elements in the vein quartz samples, except for tungsten, are depicted by histogram (fig. 5). Of the eight elements, contents of copper show the most scatter and gold the least. Both molybdenum and bismuth, which Theobald and Allcott (1973) found in anomalously large amounts in panned concentrates of unconsolidated debris collected in the Uyaijah-Thaaban area,

Table 7. Minor element contents and locations of samples of vein quartz

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
72,500	22°49'04"	44°25'08"	<20	10	N	.7	N	N	<5	25	<5
72,501	22°49'04"	44°25'09"	<20	90	N	1.2	N	175	<5	1,200	50
72,502	22°49'04"	44°25'12"	<20	5	.04	1.3	890	65	10	140	40
72,503	22°49'05"	44°25'04"	<20	5	N	N	150	N	10	<5	<5
72,513	22°48'01"	44°22'09"	<20	10	.18	.7	<1	<25	<5	250	<5
72,518	22°48'24"	44°22'04"	<20	10	N	.8	<1	<25	<5	100	N
72,522	22°48'56"	44°22'34"	<20	5	N	<.2	N	<25	<5	50	40
72,523	22°49'24"	44°23'07"	H	440	N	2.1	1,050	<25	<5	<5	<5
72,524	22°49'18"	44°23'20"	<20	180	N	.6	140	75	<5	35	<5
72,525	22°49'17"	44°23'20"	<20	100	N	8.3	10	50	<5	400	<5
72,526	22°49'16"	44°23'25"	<20	20	.03	3	10	75	<5	500	<5
72,527	22°49'15"	44°23'26"	<20	10	N	7.9	<1	<25	<5	60	<5
72,528	22°49'13"	44°23'27"	H	1,000	N	.8	75	50	<5	90	<5
72,529	22°49'09"	44°23'37"	<20	100	N	.6	260	<25	<5	50	<5
72,530	22°47'52"	44°23'51"	<20	225	N	3.6	90	75	10	410	<5
72,531	22°48'07"	44°23'44"	H	550	.03	26.5	75	375	10	3,650	25
72,533	22°48'14"	44°23'32"	<20	40	.03	N	N	N	<5	285	<5
72,536	22°49'42"	44°24'40"	N	20	.18	<.2	10	25	5	33	25
72,537	22°49'43"	44°24'40"	H	210	.14	13	500	275	8	423	25
72,539	22°49'44"	44°24'54"	N	30	<.02	<.2	8	25	7	25	15
72,541	22°49'51"	44°25'13"	N	30	.06	<.2	40	25	<5	25	35
72,542	22°49'40"	44°25'03"	N	10	.10	2.3	5	25	<5	11	20
72,543	22°49'39"	44°24'57"	N	40	.10	1.3	20	50	<5	14	45
72,545	22°49'33"	44°25'02"	N	<5	.10	1.1	8	25	8	14	60
72,546	22°49'38"	44°25'09"	N	<5	.06	<.2	N	N	<5	11	15
72,548	22°49'37"	44°25'10"	N	5	.12	<.2	8	25	7	11	35
72,550	22°49'44"	44°25'41"	20	115	.18	.8	10	30	10	21	40
72,551	22°49'36"	44°25'02"	N	5	.18	1.1	10	50	6	500	20
72,552	22°49'35"	44°24'39"	N	5	.18	1	8	95	8	430	50
72,553	22°49'32"	44°24'43"	N	15	.18	1.3	30	40	5	50	20
72,555	22°49'35"	44°24'53"	N	5	.12	.3	5	30	7	6	35
72,556	22°49'34"	44°24'53"	N	N	.12	1	10	30	9	6	30
72,558	22°49'32"	44°24'58"	N	15	.12	1.7	8	75	8	50	45
72,561	22°49'31"	44°24'38"	N	5	.12	.3	8	N	<5	11	50
72,562	22°49'28"	44°25'05"	N	150	.14	5	20	45	7	285	20
72,563	22°49'24"	44°25'10"	H	10	.10	.2	40	N	12	N	30
72,564	22°49'26"	44°25'16"	N	5	.14	1	50	30	<5	8	25
72,565	22°49'26"	44°25'25"	N	<5	.14	.2	8	30	7	11	35
72,566	22°49'21"	44°25'20"	20	20	.14	1.7	8	25	<5	50	15
72,568	22°49'21"	44°25'10"	N	115	.18	15	25	250	8	1,740	30
72,569	22°49'20"	44°25'03"	N	5	.18	<.2	5	N	8	55	40
72,571	22°49'19"	44°24'55"	N	15	.16	<.2	15	25	7	30	35
72,572	22°49'20"	44°24'35"	H	115	.18	14	35	180	7	610	30
72,573	22°49'21"	44°24'33"	H	115	.26	120	1,873	750	7	14,200	70
72,575	22°49'21"	44°24'33"	N	<5	.10	<.2	10	N	<5	8	35
72,578	22°49'19"	44°24'53"	N	15	.18	.7	15	25	6	14	40
72,581	22°49'24"	44°23'47"	N	N	.18	N	10	N	<5	6	50
72,582	22°49'27"	44°23'38"	N	5	.18	1.5	50	125	<5	33	45
72,584	22°49'24"	44°25'37"	N	15	.10	1	25	95	60	25	40
72,585	22°49'21"	44°26'00"	N	10	.10	.2	8	N	<5	15	15

Table 7. Minor element contents and locations of samples of vein quartz (cont'd.)

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
72,586	22°49'18"	44°26'02"	N	<5	.12	.2	8	N	15	15	110
72,587	22°49'11"	44°26'02"	50	60	.14	5.6	25	235	8	3,750	30
72,588	22°49'10"	44°25'46"	50	15	.14	11	8	35	<5	25	35
72,589	22°49'12"	44°25'39"	N	575	.14	<.2	20	N	7	28	35
72,591	22°49'13"	44°25'28"	N	10	.14	.9	400	35	10	35	15
72,592	22°49'02"	44°25'51"	N	5	.14	1.1	30	N	<5	13	25
72,593	22°49'02"	44°25'43"	N	115	.14	.3	45	N	<5	15	25
72,594	22°49'04"	44°25'44"	N	5	.14	<.2	140	N	<5	15	20
72,595	22°49'04"	44°25'41"	N	5	.14	<.2	1,400	80	15	13	35
72,596	22°48'39"	44°25'34"	N	N	.14	N	90	N	7	13	25
72,599	22°47'53"	44°24'32"	N	N	.14	N	10	N	5	20	110
72,600	22°47'54"	44°24'14"	N	N	.14	N	100	N	12	20	35
72,601	22°47'56"	44°24'04"	N	N	.14	12	25	N	5	13	15
72,602	22°48'07"	44°23'48"	N	5	.14	2.7	10	N	30	38	15
72,605	22°48'09"	44°23'51"	N	5	.14	16	35	N	25	1,250	25
72,606	22°48'19"	44°24'07"	H	1,000	.14	18	325	N	10	610	15
72,607	22°48'19"	44°24'07"	H	150	.14	1.6	135	N	10	130	25
72,608	22°48'19"	44°24'08"	N	100	.14	1.3	45	N	20	48	25
72,609	22°48'19"	44°24'08"	N	5	.14	.2	145	N	15	10	25
72,610	22°48'19"	44°24'08"	H	150	.06	.7	8	40	5	38	15
72,611	22°48'24"	44°23'56"	N	10	.09	N	38	100	165	20	118
72,613	22°48'25"	44°23'52"	H	60	.18	22.5	6	175	45	970	13
72,614	22°48'25"	44°24'15"	N	10	.09	2.9	1,500	N	20	35	22
72,615	22°48'27"	44°24'14"	N	40	.11	55.5	270	360	10	2,380	18
72,616	22°48'27"	44°24'02"	N	10	.11	33.5	33	205	25	2,260	28
72,618	22°48'24"	44°24'02"	N	10	.11	.3	18	40	<5	25	22
72,619	22°48'31"	44°24'12"	H	200	.06	.9	28	150	140	25	60
72,620	22°48'33"	44°24'18"	H	60	.08	4.3	605	40	<5	13	22
72,622	22°48'41"	44°24'30"	H	40	.08	.7	1,000	40	25	13	64
72,625	22°48'24"	44°24'33"	N	10	N	.9	50	40	<5	20	212
72,626	22°48'39"	44°24'05"	H	120	N	9.8	800	150	<5	1,660	28
72,627	22°48'35"	44°23'56"	H	80	N	N	8	40	<5	25	9
72,628	22°48'41"	44°23'55"	H	90	.08	3	1,400	40	15	25	9
72,630	22°48'43"	44°23'43"	H	200	.08	8.1	2,788	40	20	25	28
72,631	22°48'38"	44°23'37"	H	80	N	3.4	55	120	20	430	30
72,632	22°48'37"	44°23'33"	H	150	N	81.5	230	720	<5	5,000	18
72,633	22°48'37"	44°23'26"	H	120	N	113	100	590	<5	3,750	22
72,634	22°48'35"	44°23'26"	H	120	N	.3	8	N	10	50	22
72,635	22°48'35"	44°23'25"	H	150	.09	3	40	N	<5	50	28
72,636	22°48'35"	44°23'53"	H	150	.12	.5	28	N	15	118	32
72,637	22°48'31"	44°23'39"	N	20	N	1.1	10	N	20	10	100
72,638	22°48'27"	44°23'36"	H	120	N	.9	280	N	20	60	28
72,639	22°48'27"	44°23'35"	N	20	N	.7	65	205	45	38	590
72,640	22°48'28"	44°23'34"	H	150	.09	3	175	70	10	205	42
72,641	22°48'29"	44°23'32"	H	150	.09	.4	25	40	<5	13	22
72,642	22°48'30"	44°23'27"	H	80	.09	.7	20	80	<5	118	9
72,643	22°48'32"	44°23'25"	H	170	N	.5	45	50	10	35	42
72,644	22°48'34"	44°23'20"	H	150	N	.2	70	30	<5	20	22
72,645	22°48'35"	44°23'18"	H	150	N	.2	160	30	<5	20	52
72,646	22°48'36"	44°23'15"	H	150	N	4.8	6,000	30	<5	20	22

Table 7. Minor element contents and locations of samples of vein quartz (cont'd.)

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
72,647	22°48'37"	44°23'14"	H	120	N	1.7	725	N	<5	20	70
72,648	22°48'38"	44°23'13"	H	130	N	1.6	270	325	525	20	64
72,649	22°48'39"	44°23'11"	H	200	N	<.2	100	50	10	20	22
72,650	22°48'40"	44°23'10"	<20	20	N	.9	175	50	45	20	38
72,651	22°48'40"	44°23'10"	<20	10	.09	N	88	N	30	20	70
72,652	22°48'39"	44°23'16"	H	200	.09	6.5	1,500	40	<5	20	22
72,653	22°48'39"	44°23'19"	H	150	.09	1.5	283	40	10	110	58
72,654	22°48'44"	44°23'16"	H	150	.09	1.2	85	50	<5	50	80
72,655	22°48'54"	44°23'10"	N	40	.08	1.6	175	35	30	25	25
72,656	22°48'53"	44°23'15"	H	350	.08	.2	25	N	20	25	24
72,657	22°48'53"	44°23'15"	50	20	.07	N	375	N	45	25	60
72,658	22°49'05"	44°23'12"	H	300	.10	6.0	20	<25	85	75	25
72,659	22°48'51"	44°23'21"	H	80	.07	N	20	<25	N	20	20
72,660	22°48'51"	44°23'20"	H	350	.08	8.6	20	25	20	20	30
72,661	22°48'50"	44°23'23"	N	60	.08	1.5	20	<25	N	20	50
72,662	22°48'56"	44°23'44"	H	200	.08	.6	25	<25	N	20	20
72,663	22°48'55"	44°23'42"	H	175	.08	3	10	<25	N	20	15
72,664	22°49'08"	44°23'48"	H	200	.09	.6	295	<25	N	20	24
72,666	22°49'05"	44°23'29"	N	20	.09	1	12	26	15	45	24
72,667	22°49'10"	44°23'19"	H	175	.07	.5	15	65	160	20	10
72,669	22°49'05"	44°23'13"	H	350	.07	.6	35	<25	N	330	10
72,670	22°48'58"	44°22'56"	H	150	.08	.3	N	100	N	330	10
72,671	22°48'56"	44°22'54"	H	175	.07	N	15	40	N	21	15
72,672	22°48'53"	44°22'57"	H	350	.07	.2	15	<25	N	20	10
72,673	22°48'32"	44°23'13"	H	200	.07	6	38	<25	N	20	25
72,674	22°48'32"	44°23'11"	N	320	.07	<.2	125	32	15	20	35
72,675	22°48'20"	44°23'26"	H	150	.02	N	65	26	175	16	25
72,676	22°48'19"	44°23'25"	H	200	.04	.5	10	26	15	103	25
72,677	22°48'17"	44°23'23"	H	150	.04	N	10	<25	N	20	24
72,678	22°48'52"	44°22'45"	H	100	.04	1.2	95	113	N	18	22
72,679	22°48'51"	44°22'48"	N	10	.08	N	15	40	N	20	15
72,680	22°48'50"	44°22'50"	H	200	.07	1.5	60	40	N	550	18
72,681	22°48'48"	44°22'35"	20	10	.06	N	10	40	N	10	88
72,682	22°48'46"	44°22'42"	H	400	.06	.2	25	40	N	100	20
72,683	22°48'44"	44°22'53"	H	150	.06	.7	10	50	N	15	25
72,684	22°48'46"	44°22'53"	H	150	.06	.2	10	90	N	8	20
72,685	22°48'40"	44°22'33"	H	300	.07	2.1	25	40	N	350	20
72,686	22°48'46"	44°22'31"	H	550	.09	4.5	15	40	50	1,250	20
72,688	22°48'42"	44°22'46"	20	150	.07	1.7	40	40	N	N	23
72,689	22°48'40"	44°22'47"	H	200	.07	.2	60	50	N	N	27
72,690	22°48'36"	44°22'50"	N	60	.09	N	15	50	N	7	40
72,691	22°48'36"	44°22'56"	H	175	.07	2.1	125	50	N	7	22
72,692	22°48'38"	44°22'56"	H	80	.09	.5	60	50	N	N	20
72,693	22°48'38"	44°23'01"	N	60	.08	1	35	50	N	N	40
72,694	22°48'34"	44°23'00"	H	150	.08	8.6	12	130	N	N	50
72,695	22°48'33"	44°22'50"	H	350	.06	.3	30	<25	76	N	50
72,696	22°48'32"	44°22'51"	N	100	.04	.3	25	<25	N	N	22
72,697	22°48'40"	44°23'01"	N	40	.06	.2	20	30	N	N	39
72,698	22°48'36"	44°23'05"	H	275	.04	.2	140	30	20	N	70
72,699	22°48'34"	44°23'05"	N	80	.04	.2	15	30	75	N	40

Table 7. Minor element contents and locations of samples of vein quartz (cont'd.)

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
72,700	22°49'05"	44°24'23"	N	30	.04	.2	10	30	90	N	66
72,701	22°48'33"	44°22'56"	H	350	.04	.5	65	30	15	N	55
72,702	22°48'32"	44°23'00"	N	30	.04	77	45	30	N	N	40
72,703	22°48'32"	44°23'05"	N	80	.04	1.5	15	30	N	N	75
72,704	22°48'28"	44°23'16"	N	20	.04	1.8	135	30	N	8	10
72,705	22°48'26"	44°23'08"	H	150	.04	50	115	<25	15	8	85
72,706	22°48'17"	44°22'48"	H	140	.04	13	40	<25	20	7	70
72,708	22°48'33"	44°23'06"	H	200	.04	12	35	<25	50	7	40
72,709	22°48'28"	44°23'18"	H	200	.06	5.6	25	<25	20	7	39
72,710	22°48'28"	44°23'22"	H	200	.07	17.5	40	<25	N	300	70
72,711	22°48'27"	44°23'19"	H	200	.14	10	15	<25	N	195	70
72,712	22°48'24"	44°23'20"	H	150	.18	.7	65	<25	60	15	50
72,714	22°48'21"	44°23'27"	H	200	.04	N	20	<25	N	15	39
72,715	22°48'28"	44°23'21"	N	40	.04	N	10	<25	N	15	50
72,716	22°48'54"	44°25'16"	N	<5	.02	N	20	<25	N	15	25
72,718	22°49'07"	44°24'43"	N	40	.02	.5	20	<25	N	15	50
72,719	22°49'02"	44°24'41"	N	10	.07	N	10	<25	30	10	40
72,720	22°49'59"	44°24'51"	N	10	.07	N	10	<25	N	370	50
72,721	22°49'02"	44°24'38"	H	150	.07	N	30	<25	75	15	20
72,722	22°48'52"	44°24'45"	H	150	N	N	<1	<25	<5	15	20
72,723	22°48'54"	44°24'37"	<20	10	N	11.8	<1	68	<5	390	50
72,724	22°48'56"	44°24'34"	H	250	N	5.8	N	125	<5	N	30
72,725	22°48'57"	44°24'34"	H	250	N	1.5	<1	36	<5	N	37
72,726	22°48'56"	44°24'39"	H	300	N	1.2	N	28	<5	290	20
72,727	22°48'58"	44°24'42"	H	20	N	1.2	400	28	<5	N	20
72,728	22°49'10"	44°24'38"	H	20	N	N	35	28	<5	15	27
72,729	22°49'14"	44°24'30"	<20	10	N	N	35	28	<5	15	62
72,730	22°49'14"	44°24'31"	H	40	N	1.6	282	232	<5	N	55
72,731	22°49'14"	44°24'40"	<20	150	N	.6	38	28	<5	N	17
72,732	22°49'11"	44°24'40"	H	100	N	36	<1	68	<5	610	20
72,733	22°49'16"	44°24'49"	<20	120	N	N	52	<25	<5	N	40
72,734	22°49'10"	44°24'47"	<20	10	N	N	N	<25	<5	15	31
72,735	22°49'15"	44°24'56"	H	500	N	2.4	2,438	<25	7	30	26
72,736	22°49'15"	44°24'57"	<20	300	N	1.2	2	<25	<5	N	15
72,737	22°48'39"	44°22'16"	<20	60	N	N	<1	<25	<5	N	44
72,738	22°48'42"	44°22'12"	<20	40	N	12.9	2	195	<5	2,260	20
72,739	22°48'16"	44°22'41"	<20	600	N	.3	<1	<25	<5	28	52
72,740	22°48'14"	44°22'53"	<20	600	N	N	88	<25	<5	15	36
72,741	22°48'20"	44°22'48"	H	150	N	.5	<1	36	<5	28	22
72,742	22°48'23"	44°22'46"	H	120	N	1.2	38	<25	<5	28	32
72,743	22°48'16"	44°23'07"	H	300	N	.3	62	<25	<5	15	15
% detnd.	-	-	3	94	73	77	90	59	45	87	93
range	-	-	N-50	N-1,000	N-.26	N-120	N-6,000	N-750	N-525	N-14,200	N-590
mean	-	-	-	130	.07	5.4	180	55	15	300	37

N = looked for, not detected
H = interference in analysis
% detnd. = percent of samples in which element was present in determinable amounts

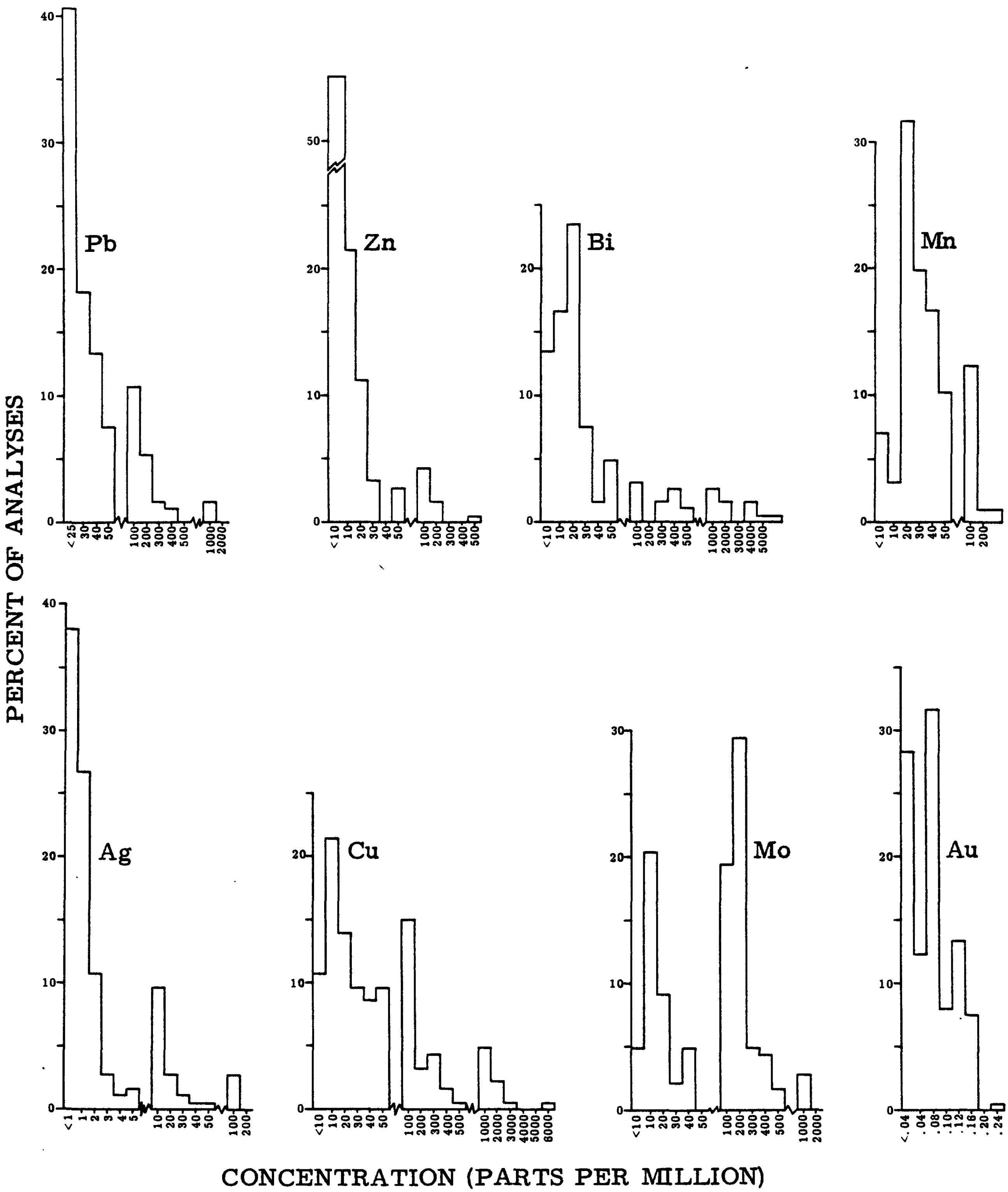

Figure 5.- Histograms of analyses of 190 vein quartz samples from the Uyaijah-Thaaban area.

are present in significant amounts in a number of the samples of vein quartz. Both metals vary widely in content in the veins. Distribution of contents of the two elements in the quartz veins are depicted in fig. 6. The plots clearly show that molybdenum and bismuth are present in greatest amounts in the zone of the Uyaijah-Thaaban area where the veins are most abundant.

Linear correlation coefficients, measures of statistical interrelations of element pairs in the vein quartz samples, are given in table 8. Molybdenum does not have an apparent correlation with any of the other elements; however, there is a significant relationship between bismuth and silver and a somewhat lesser correlation between bismuth and lead. Silver and lead also have a close relationship.

Table 8. Correlation coefficients and numbers of pairs of elements in 190 vein quartz samples from the Uyaijah-Thaaban area.

	Mo	Ag	Cu	Pb	Zn	Bi	Mn
Mo		-0.021	-0.058	-0.042	-0.010	0.016	-0.051
Ag	142		-0.011	0.584	-0.090	0.778	-0.034
Cu	168	138		0.005	-0.009	-0.025	-0.041
Pb	135	110	134		-0.008	0.473	-0.027
Zn	97	76	100	78		-0.082	0.247
Bi	154	125	155	118	38		-0.019
Mn	166	135	170	134	101	154	

Correlation coefficients are presented above the diagonal line, and number of samples on which the correlation is based, that is the number of samples in which the two elements were both present in determinable amounts, is given below.

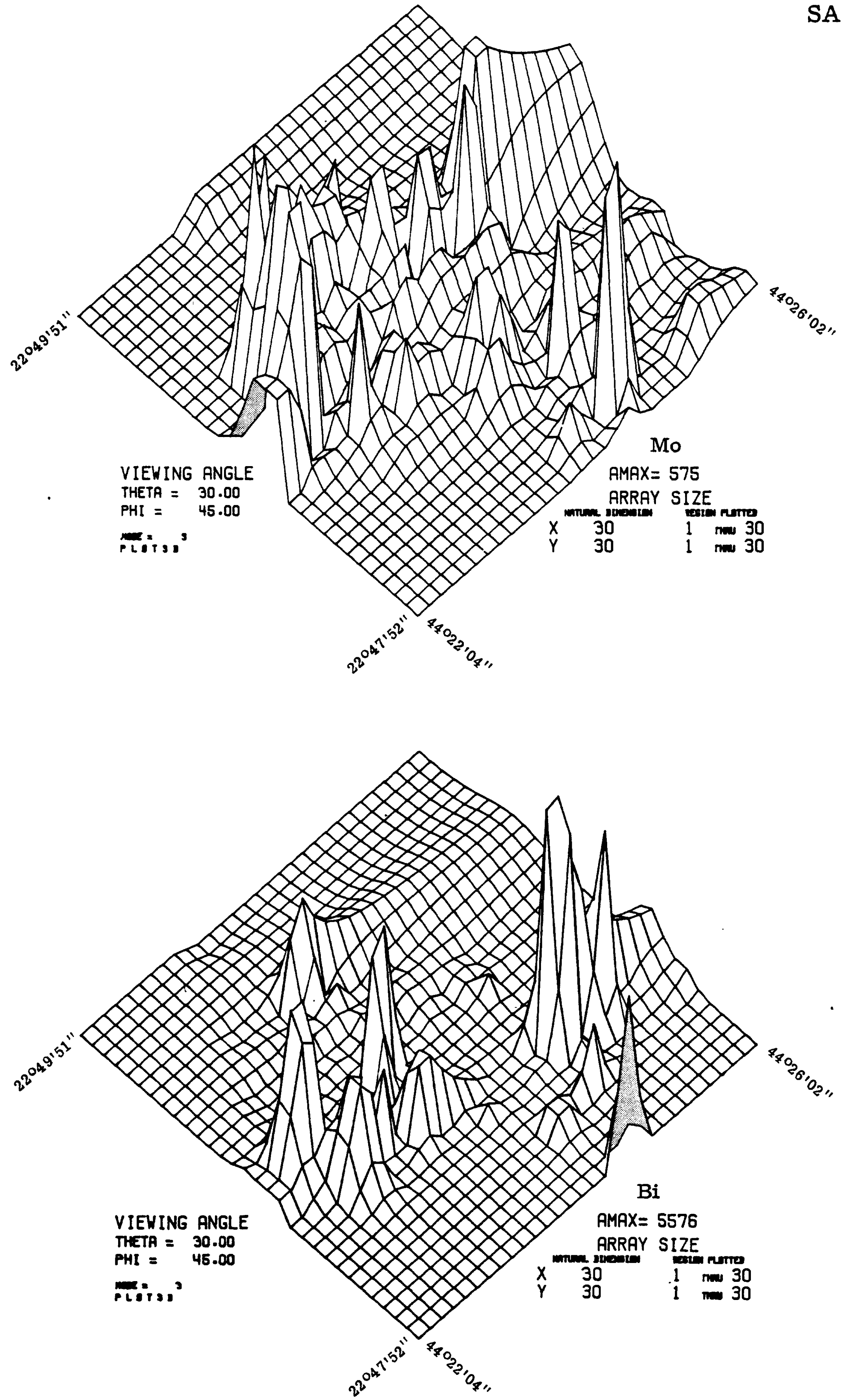

Figure 6.- Perspective diagrams showing distribution of Mo and Bi in quartz vein samples. Peak heights are proportional to abundance of element.

These interrelationships are at least in part attributable to the presence of appreciable amounts of lead and silver in bismuthinite (table 4). Surprisingly, lead and zinc are not significantly related.

Hypabyssal dike rocks

Steep-dipping northwest- to east-west-trending felsic and mafic hypabyssal dikes are intrusive into plutonic rocks in the Uyaijah-Thaaban area. Only minor effects of baking or alteration by the dikes on surrounding rocks are apparent. Although the dikes follow the same structural trends as do the quartz veins, there is no evidence of movement along dike surfaces. The two types of dikes are not in contact in the Uyaijah-Thaaban area; however, a few kilometers to the southeast in the Buhairan-Abu Khurg area the felsic dikes can be clearly seen to have preceded their mafic counterparts (Dodge, 1973).

A 2- to 3-m wide felsic dike on the northern slopes of Jabal Thaaban forms the apex of a narrow 30-m high ridge that extends from the jabal to the eastern edge of the Uyaijah-Thaaban area. The dike consists of fairly uniform, massive, pinkish-brown, porphyritic rock. Medium-grained phenocrysts of euhedral to subhedral embayed quartz, elongate tabular, euhedral to subhedral, unzoned plagioclase of sodic andesine composition, and euhedral to subhedral perthitic alkali feldspar make up 15 to 20 percent of the rock. The groundmass consists of a fine-grained to microcrystalline mixture of anhedral quartz, plagioclase, alkali feldspar, green hornblende, and opaque grains. Compositionally the felsic dike is a dacite.

Numerous 10-cm to 2-m wide mafic dikes are present in the Uyaijah-Thaaban area. Rocks of these dikes range widely compositionally.

Specific gravities, a measure of composition, of eight samples range from 2.73 to 2.90 and average 2.81. An almost identical range and average was determined on similar rocks from the Buhairan-Abu Khurg area. One-millimeter long laths of plagioclase, the most abundant constituent of the rocks, range from sodic andesine to sodic labradorite. Other than plagioclase, opaque grains, and in some samples minor amounts of quartz, primary constituents have been altered beyond recognition. Alteration products include chlorite, carbonate, epidote, and sericite. One-millimeter sized vesicules, which are common in all the samples from mafic dikes, are filled with micro- to cryptocrystalline chlorite or zeolite. Based on specific gravities and plagioclase compositions, rocks of the mafic dikes are considered to range from andesites to basalts.

Minor element contents of hypabyssal dike rocks are given in table 9.

Table 9. Minor elements contents and locations of samples of hypabyssa dike rocks.

Sample no.	Lat. (N)	Long. (E)	ppm								
			W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
					Mafic dike rocks						
72,507	22°49'23"	44°26'28"	<20	5	N	1	<1	65	140	60	700
72,511	22°48'14"	44°21'10"	<20	5	N	.9	25	50	125	<5	635
72,516	22°47'07"	44°22'38"	<20	10	N	1	50	50	90	70	875
72,519	22°48'35"	44°21'45"	<20	5	N	.8	30	50	140	40	800
72,538	22°49'44"	44°25'01"	N	10	.14	.7	60	45	150	30	425
72,576	22°49'23"	44°24'32"	N	N	.18	<.2	65	75	450	60	930
72,629	22°48'41"	44°23'39"	N	<5	.08	1.2	60	70	185	60	940
72,668	22°49'08"	44°23'12"	20	10	.08	.7	2	42	145	20	885
					Felsic dike rocks						
72,509	22°49'55"	44°26'45"	<20	5	N	.2	<1	<25	25	<5	150
72,534	22°50'05"	44°25'20"	N	N	.12	<.2	15	25	950	11	150

N = Looked for, not detected

The contents of lead and bismuth in mafic dike samples from the Uyaijah-Thaaban area are anomalously high relative to contents in basaltic rocks of the earth's crust reported by Turekian and Wedepohl (1961), but the content of other elements generally does not differ notably from normal values for such mafic rocks.

EVALUATION OF MINERAL POTENTIAL

The highest molybdenum values are in samples of vein quartz collected from two zones in the central portion of the Uyaijah-Thaaban area, which are approximately 3 km long and 1 km wide. Quartz veins are most abundant in these zones, thus three small subareas were selected for closer examination in order to assess the economic potential of the mineralized area.

Subarea I (plate 2) is a rectangular area of roughly 240,000 sq m, 2 km S.70°W. of Jabal Dagma and is bounded by lat 22°48'19" and 39" N. and long 44°23'19" and 32"E. About 1 percent of the exposed rock in the area is vein quartz. Vein width ranges from less than a centimeter to three meters. Although the veins rather consistently strike N.70°W., dips vary erratically. All the veins within subarea I are of the older generation of quartz, except for a 1-m wide younger vein 23 m south of the southeast corner of the subarea.

Results from subarea I samples taken on traverses across the strike of the quartz veins--referred to hereafter as profile sampling--are presented in table 10. Molybdenum values are significantly higher across veins than across intervals of the host quartz monzonite.

The overall average molybdenum content of all the sampled profiles of subarea I, weighted according to profile length, is only 80 parts per million.

Table 10. Molybdenum contents of composite samples from profile sampling, subarea I

Profile-number & trend	Sample no.	Mo (ppm)	Number localities sampled	Length of sample (meters)	Desc.	Length of profile (meters)	Mo content (ppm) of profile
	82,043	500	5	2.70	V		
I N10E	82,044	20	5	1.70	(a)p	4.62	330
	82,045	700	3	0.22	V		
II N10E	82,046	80	8	14.00	P (u,a)	15.20	130
	82,047	700	5	1.20	V		
	82,048	60	10	38.00	P (u,a)		
III S-N	82,049	10	5	32.20	(u)p	70.75	40
	82,050	400	5	0.55	V		
IV N35E	82,051	80	6	5.60	P (u,a)	5.60	80
V S-N	82,052	100	7	11.70	P (a)	11.70	100
VI N20E	82,053	140	5	0.95	V	0.95	140
	82,054	120	5	3.00	(u)p		
	82,055	400	5	0.60	V		
	82,056	10	5	3.90	(u)		
VII N10W	82,057	10	5	1.90	(a)	36.65	20
	82,058	10	5	18.65	(u)		
	82,059	20	5	8.60	(u,a)p		
VIII N5W	82,060	10	7	7.25	P (a)	7.79	60
	82,061	700	5	0.54	V		
	82,062	30	5	0.60	V		
	82,063	20	4	0.40	(a)		
	82,064	40	4	0.27	V		
	82,065	20	5	6.40	(u,a)p		
IX N35E	82,066	150	4	0.35	V	20.30	20
	82,067	15	4	1.50	(a)p		
	82,068	120	4	0.44	V		
	82,069	10	5	10.10	(u,a)p		
	82,070	130	4	0.24	V		
X N25E	82,071	150	8	19.40	P (u,a)	19.40	150
XI N7E	82,072	200	8	14.60	P (u,a)	14.60	200
XII N20W	82,073	80	10	30.00	P (u,a)	30.00	80
XIII S-N	82,074	1,600	5	0.80	V	0.80	1,600

Description of sampled interval:

V = quartz vein.
P = quartz vein(s) present in sampled interval.
(u) = sampled interval is in unaltered quartz monzonite.
(a) = sampled interval is in altered quartz monzonite.
(u,a) = both unaltered and altered quartz monzonite are present in sampled interval.
p = quartz stringers (generally <5 cm wide) are present in sampled interval.

Subarea II (plate 3), a nearly square area covering 160,000 sq m bounded by lats 22°48'29" and 22°48'42"N. and longs 44°22'52" and 44°23'08"E. is about 2.5 km S.75°W. of Jabal Dagma, in the same mineralized zone as subarea I. Veins in the subarea strike approximately N.60°W. and dip generally south. Zones of thin, gash-like, en echelon veins are common. As in subarea I, veins range from less than 1 cm to 3 m in width. Less than 1 percent of the exposed rock in the subarea is vein quartz. A 150-m long composite vein of both the older and younger generations of quartz crops out near the center of the subarea. All other veins in the subarea are of the older quartz generation.

Molybdenum contents of sampled profiles of subarea II (table 11) are similar to those of subarea I; the weighted profile averages in the two areas are identical, 30 ppm. Contents of eight elements in the composite vein are given in table 12. The close correspondence of the various elements in the two generations of quartz may simply be due to incorporation of older material by the younger veins.

Subarea III (plate 4) is a roughly circular 64,000 sq m area, the center of which is at lat 22°49'15"N. and long 44°24'40"E. It is three-quarters of a kilometer N.60°E. of Jabal Dagma in the northern zone of quartz veins. Only a fraction of a percent of the exposed rock in the subarea is vein quartz. The veins tend to strike N.55°W. and dip vertically or to the northeast. Vein width ranges from a few centimeters to 2 m. All of the veins consist of the older generation of quartz.

Much of subarea III is covered with rubble, consequently profile sampling normal to vein trends was impractical; however, several veins

Table 11. Molybdenum contents of composite samples from profile sampling, subarea II

Profile-number & trend	Sample no.	Mo (ppm)	Number localities sampled	Length of sample (meters)	Desc.	Length of profile (meters)	Mo content (ppm) of profile
	82,016	150	5	3.40	V		
	82,017	20	5	1.30	(a)		
	-	-	-	1.93	unexposed		
	82,018	10	5	14.95	(u,a)p		
	82,019	30	5	0.05	V		
I N10E	82,020	40	5	4.10	(u,a)	65.89[2]	60
	82,021	600	5	0.13	V		
	82,022	100	5	20.35	(u,a)p		
	82,023	500	5	0.44	V		
	82,024	70	5	1.43	(u,a)		
	82,025	20	5	0.64	(a)p		
	82,026	20	10	19.10	(u,a)p		
II S-N	82,027	30	6	4.85	P (a)	9.85	20
	82,028	10	6	5.00	(u)		
	82,029	50	9	17.00	P (a,u)		
	82,030	10	3	0.80	(a)		
III N35E	82,031	10	4	3.20	(u)p	24.60	50
	82,032	120	4	1.60	P (a)		
	82,033	40	5	2.00	(u)		
IV N40E	82,034[1]	150	5	1.10	V	1.10	150
	82,035	20	5	2.35	V		
V S-N	82,036	40	6	10.65	(u)p	13.01	30
	82,037	80	3	0.01	V		
	82,038	1,300	5	0.70	V		
	82,039	10	5	13.00	(u,a)p		
VI N35E	82,040	750	5	5.10	P (a)	56.80	140
	82,041	150	5	20.40	(u,a)p		
	82,042	10	7	17.60	(a)p		

[1]Cu content = 35.5 ppm
[2]Exposed length of profile

Description of sampled interval:

V = quartz vein.
P = quartz vein(s) present in sampled interval.
(u) = sampled interval is in unaltered quartz monzonite.
(a) = sampled interval is in altered quartz monzonite.
(u,a) = both unaltered and altered quartz monzonite are present in sampled interval.
p = quartz stringers (generally <5 cm wide) are present in sampled interval.

Table 12. Analyses of samples from composite quartz vein, subarea II (values in ppm).

Sample no.	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn	Relative age
82,075	30	.09	.3	45	15	15	12	36	Young
82,076	250	.14	.3	28	15	5	43	50	Old
82,077	800	.14	N	25	15	23	12	46	Young
82,078	625	.14	N	20	15	10	12	15	Old
82,079	275	.14	5.0	740	75	10	30	25	Old
82,080	150	.14	.6	20	146	30	13	29	Young
82,081	250	.14	4.8	70	25	15	25	18	Old
82,082	300	.14	2.0	740	25	20	<5	33	Old
82,083	1,500	.14	1.2	45	65	10	21	36	Young
82,084	90	.14	1.8	500	15	20	<5	30	Old
82,085	40	.11	1.0	430	15	N	<5	36	Young
82,086	20	.11	1.0	33	15	N	<5	45	Young
82,087	625	.07	1.2	295	15	8	<5	38	Old
82,088	20	.11	.6	48	15	8	<5	48	Young
82,089	20	.09	.6	15	15	<5	<5	29	Old
82,090	40	.09	.3	30	65	10	<5	34	Old
82,091	20	.11	.6	20	10	<5	<5	29	Young

were sampled along their entire exposed lengths and the host quartz monzonite was sampled. Molybdenum contents of the vein samples are similar to the contents of their counterparts in subareas I and II, but the element is present in amounts below its determinability level in all the samples of the quartz monzonite (table 13).

Present-day exploitation of molybdenum from the Uyaijah-Thaaban area is probably not economically feasible. Molybdenum values from 30 samples representing 146 localities along quartz veins in the three subareas average 430 ppm, which is far below ore grade. Even the richest vein sample (no.82,074) does not approach ore grade. Although the most relief seen on any single quartz vein is only about 25 m,

Table 13. Molybdenum contents of composite samples, subarea III.

Sample no.	Mo (ppm)	Description
82,000	20	Quartz vein; 6-1/2 m length, 65 cm width.
82,001	80	" " ;64 m length, 10-80 (av. 20) cm width.
82,002	50	" " ;20-1/2 m length, approx. 75 cm width; poorly exposed.
82,003	60	" " ;71 m length, 10-90 (av. 45) cm width.
82,004	1,500	" " ;46 m length, 5-50 (av. 30) cm width.
82,005	40	" " ;25 m length, 15-80 (av. 30) cm width.
82,006	100	" " ;14 m length, 5-200 (av. 20) cm width.
82,007	60	" " ;17 m length, 40 cm width.
82,008	20	" " ;14 m length, 5-150 (av. 15) cm width; poorly exposed.
82,009	<10	Quartz monzonite; weathered, slightly altered.
82,010	<10	" " ; " , unaltered.
82,011	<10	" " ; " , slightly altered.
82,012	<10	" " ; " , slightly altered.
82,013	<10	" " ; highly altered
82,014	<10	" " ; " "
82,015	<10	" " ; " "

Each sample consisted of five equal sized chips. Veins were sampled at equally spaced intervals along entire exposed vein length; quartz monzonite was sampled in the center of and at quadrants around a 2-m diameter circle.

nothing was seen along the vein that would indicate any increase in molybdenite content with depth. Likewise, no mineralogical changes were seen along the veins in the hundreds of meters of combined strike length that indicate significant increases in molybdenite content at any particular localities. As no marked changes in molybdenum grade in the veins is foreseen near the surface, there would be little gained from further exploration by diamond drilling. The veins, by themselves, are too narrow and too low in grade to mine profitably. Further, they are too far apart, too lean, and constitute too small a volume of quartz to be considered for any block-carving or high volume mining method.

Samples of altered and unaltered quartz monzonite including some small quartz stringers, between the veins average 55 ppm molybdenum. Even the quartz stringers between veins are low in molybdenum. The samples indicate clearly that molybdenite is not disseminated in any quantity between the veins. As the veins themselves are low in molybdenum value and in size, it would not be feasible to mine them and the intervening country rock by open pit methods.

The highest content of molybdenum in any of the analyzed materials from the subareas is 1,600 ppm, corresponding to 0.27% MoS_2. In comparison, ore from the Climax, Colorado, molybdenum deposit, a large tonnage, low grade deposit, grades only slightly less than 0.4 percent MoS_2 (Wallace and others, 1968). While the grade and the quantity of the molybdenite-bearing quartz veins relative to the total amount of exposed rock of the area are inadequate to permit present-day mining, the veins represent a potential future resource, should the price of molybdenum rise appreciably. In view of the low molybdenum contents of the host quartz monzonite, future mining would of necessity be selective, being restricted to the larger, higher grade quartz veins.

Theobald and Allcott (1973) found anomalus contents of tungsten, as well as molybdenum and bismuth in panned concentrates of unconsolidated debris collected from the Uyaijah-Thaaban area. They outlined an area 2 km southeast of Jabal Thaaban in which tungsten content was particularly high in their heavy-mineral concentrates. We collected debris in this area at 200 m intervals along two parallel traverses located 400 m apart through two broad separate wadis. In addition, debris was sampled at two localities in areas where mineralization was known to be absent in order to determine a background value of tungsten. Results of analysis of -10, +30 mesh, panned, nonmagnetic concentrates of the debris (table 14) did not confirm Theobald and Allcott's previously found tungsten anomaly. Only one of the 15 concentrates contained tungsten in detectable amounts, and subsequent analysis of splits of this concentrate did not yield tungsten in detectable quantities. Furthermore, the tungsten content of analyzed rocks of the Uyaijah-Thaaban area does not exceed 50 ppm, and the element was found to generally be present in amounts less than the 20 ppm determinability level (tables 1-3, 6, 7, 9--admittedly the element could not be determined in several of the samples because of interference). Lamping of numerous localities in the Uyaijah-Thaaban area indicated that while the tungsten mineral, scheelite, is present in some quartz veins it is present only in sparse amounts. These minor amounts of scheelite apparently were adequate to provide the tungsten of Theobald and Allcott's geochemical anomaly. We consider the tungsten potential of the Uyaijah-Thaaban area to be negligible.

Table 14. Bismuth, molybdenum, and tungsten contents (in ppm) of panned sediment concentrates.

Traverse number	Sample no.	Bi	Mo	W
I	72,750	20	2	N
	72,751	15	5	N
	72,752	<10	3	N
	72,753	200	5	N
	72,754	<10	5	N
	72,755	N	<2	N
	72,756	N	<2	N
	72,757	<10	2	N*
	72,758	<10	5	N
II	72,759	N	10	N
	72,760	N	2	N
	72,761	<10	N	N
	72,762	<10	3	N
	72,763	<10	<2	N
	72,764	<10	5	N
Background samples	72,765	N	7	N
	72,766	N	5	N

N = looked for, not detected; detectibility level for W is 100 ppm.

* W contents of separate splits of the material originally ground for analysis are 200,500, and 200 ppm; W was not detected in three analysed splits of the material which re-remained after the original split.

Analyses by I. M. Naqvi using six-step semiquantitative emission spectrographic methods similar to those described by Myers and others (1961).

CONCLUSIONS

Areas of mineralization found in the Uyaijah-Thaaban area are believed to adequately account for previously discovered sediment anomalies. Although the grade of mineralized rock is inadequate to permit present-day mining and further exploratory work would not be practicable at the present time, the quartz veins represent a potential future resource of molybdenum.

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