U. S. GEOLOGICAL SURVEY

SAUDI ARABIAN PROJECT REPORT NO. 163

GEOLOGY AND EVALUATION OF TUNGSTEN ANOMALIES BUHAIRAN-ABU KHURG AREA, SOUTHEASTERN PART OF THE UYAIJAH RING STRUCTURE, KINGDOM OF SAUDI ARABIA

by

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73-60

U. S. Geological Survey
Jiddah, Saudi Arabia
1973

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ABSTRACT

Previous geochemical exploration has indicated areas in the Precambrian Al Uyaijah ring structure for further investigation. This report encompasses the results of geologic and geochemical investigations made in a 40 square kilometer area located on the southeast perimeter of the ring structure, an area where previous geochemical exploration revealed anomalous tungsten and molybdenum values.

Igneous rocks exposed in the area include batholithic plutonic rocks, intrusive rocks of the ring dike, hypabyssal dike rocks, and late epithermal quartz veins; remnants of metamorphosed, pre-batholithic rocks are also exposed. About two-thirds of the area is covered with a veneer of surficial debris. Structural patterns of the area are dominated by the ring structure.

The principal mineralization consists of powellite and scheelite in high-temperature, quartz-rich veinlets and pods and in contact metamorphic rocks. Although the areas of metallization account for the previously discovered sediment geochemical anomalies, mineralization is sparse, and no currently valuable mineral deposits are known or thought to be present in the area.

INTRODUCTION

Anomalous values of tungsten and molybdenum in concentrates derived from unconsolidated debris collected from the Al Kushaymiyah and Jabal Al Hawshah 30-minute quadrangles, southern Najd, have been discovered and reported in the course of geologic investigations by members of the U. S. Geological Survey. Based on results of these studies, two areas in the Al Uyaijah ring structure, termed the "Uyaijah-Thaaban" and the "Buhairan-Abu Khurg" areas, were selected for further study. A reconnaissance examination of the two areas indicated that even though both are within the same major geologic structure, geologic environments are different, and thus the two areas have been evaluated independently. This report describes the results of the investigation of the Buhairan-Abu Khurg area undertaken to determine sources of the anomalous metal concentrations in the sediment samples, to define controls of mineralization, and to evaluate the economic potential of any mineral deposits of the area.

The Buhairan-Abu Khurg area is located in the northeast quarter of the Southern Najd 1:500,000 quadrangle (Jackson and others, 1962), about 200 kilometers south of Ad Dawadimi. The area is rectangular, about 12.5 kilometers long and 4.5 kilometers wide with a trend of N.40°E. in the longest direction. Topographically, the area is dominated by an arcuate chain of inselbergs which commonly rise over 200 meters from a broad, nearly flat, pediment surface. Jabals Buhairan and Abu Khurg are the two highest most prominent inselbergs.

PREVIOUS STUDIES

Unusually large amounts of tungsten and molybdenum were noted by Whitlow (1966a, b) in some panned concentrates collected during searches for areas likely to contain economic mineral deposits in the Jabal Al Hawshah and Al Kushaymiyah quadrangles. In addition to general suggestions made in his two previous reports for field work to determine the presence and distribution of tungsten minerals in the quadrangles, Whitlow (1966c) specifically recommended that further mineral exploration in a region of approximately 1,000 square kilometers, bounded by 22°43' and 22°57'N. latitude and 44°07' and 44°43'E. longitude be given a high priority.

Theobald (1970) amassed and summarized values of tungsten, molybdenum, and tin determined on heavy mineral concentrates from wadi sediments collected from throughout much of the Arabian shield. In this report, Theobald postulated that the Kushaymiyah area, the general area Whitlow had previously recommended for further exploration, had close similarities with well-known areas of ore deposits in Colorado and New Mexico, U.S.A., and suggested that a study of the area should be undertaken in search of a stockwork molybdenite deposit. Later Theobald and Allcott (1973) mapped the Uyaijah ring structure of the Kushaymiyah area and systematically collected and analyzed panned sediment samples from the area. In conjunction with this study, Flanigan and Andreasen (1973) carried out regional airborne gamma radiation and magnetic surveys. Theobald and Allcott recommended further exploratory work in the Uyaijah-Thaaban and the Buhairan-Abu Khurg areas.

PRESENT INVESTIGATION AND ACKNOWLEDGEMENTS

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

Prior to beginning systematic field work, a two-day reconnaissance of the region was made in August 1972 in order to plan succeeding work. A total of five weeks was spent geologically mapping and geochemically sampling the Buhairan-Abu Khurg area during October and November, 1972. Throughout this period I was assisted by W. I. Assumali. A. M. Helaby, geologist, and I. M. Naqvi, geochemist, spent one and two weeks in the field respectively.

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 the geologic mapping and sampling (the geologic map has been reduced in scale in this report).

Extensive field examination of the metamorphic terrane of the area with portable short wave ultraviolet lamps was carried out at night as an aid in detecting and sampling fluorescent tungsten minerals.

Geochemical sampling was selective and restricted to bedrock. Altogether 201 rock samples were collected and analyzed, 165 of these samples were collected during mapping, and 36 during lamping.

Chemical analyses were made in the Geological Survey laboratories at Jiddah, Saudi Arabia under the direction of W. L. Campbell. Tungsten and molybdenum were routinely determined by colorimetric methods by Ibrahim Baradja and Q. S. Osman, or in samples where there was interference with this method, by emission spectrographic analysis by M. S. Jambi. Bismuth, copper, gold, lead, manganese, and silver were determined by atomic absorption techniques by A. A. Masud and Abdulmohsin Abuzinadah.

In addition to chemical analysis, laboratory study consisted of thin section petrographic examination, modal analysis of sawed and stained plutonic rocks, specific gravity determination of mafic dike rocks, and separation of powellite. A. M. Helaby and M. Z. Elkollak accomplished much of this work.

GEOLOGY

The Buhairan-Abu Khurg area occupies a small rectangle along the southeast margin of the Uyaijah ring structure. The structure consists of a 15 to 20 kilometer diameter circular dike and associated sheets of quartz monzonite which have intruded a large, pre-existing granodiorite to quartz monzonite batholith and pre-batholithic metamorphic rocks. The 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). Theobald and Allcott (1973) considered the metamorphic rocks to be a part of the Murdama Group, a group of dominantly detrital sedimentary rocks which crops out over extensive areas of the Arabian shield; however, other workers (Jackson and others, 1963; Whitlow, 1966a, b) have mapped the rocks as a part of the Halaban Group, a widespread sequence of metavolcanic and metasedimentary rocks older than the Murdama Group. Subsequent to emplacement of the ring dike, the entire structure was faulted, invaded by two sets of dikes and by quartz veins, and finally exposed by erosion.

Metasedimentary rocks

Pre-batholithic metamorphic rocks occur in a bow-like belt of septa along much of the length of the area, at or near the ring-dike contact, in large inclusions in the plutonic rocks, and in a large mass in the northeast corner of the area.

Fine-grained quartz hornfels and lesser amounts of biotite schist derived from siliceous shales or siltstones are the most abundant rocks. Near the contact with the ring dike the hornfels is interlayered with, and grades into the schist. Foliation in the schist is generally near-vertical, and is parallel to the ring dike-metamorphic rock contact. Bedding, also parallel to the contact, is common in outcrops of hornfels, but is rarely discernible in the schist. The siliceous hornfels and mica schist are dark-colored rocks, consisting chiefly of quartz, green biotite, intermediate plagioclase (andesine), and in some rocks, green hornblende. Microcline, epidote, apatite, carbonate minerals, zircon, sphene, and opaque minerals are also present in subordinate amounts. Chlorite is common as an alteration product of biotite. Sparse metaconglomerate, consisting largely of lithic fragments of vein quartz as much as two centimeters in diameter in a matrix of siliceous hornfels, is interlayered with the other metamorphic rocks.

Calc-hornfels occurs in thin, discontinuous bands or lenses, generally less than 10 centimeters thick that are interlayered with the siliceous hornfels or with the schist at a few localities. The calc-hornfels results from thermal metamorphism of limey shales in the original sedimentary sequence. It is a massive, light-colored rock consisting principally of garnet, clinozoisite, and diopside with lesser amounts of quartz, carbonate, calcic plagioclase (bytownite), sphene, pistacite, and powellite.

Granodiorite of Al Areyef

The oldest igneous rock unit in the Buhairan-Abu Khurg area is granodiorite here named after Al Areyef, the name of the entire area of plain and isolated jabals occupied by the Uyaijah ring structure. Outcrops of the granodiorite define a batholith covering a total area of about 180 square kilometers.

The granodiorite of Al Areyef ranges compositionally from granodiorite to quartz monzonite (fig. 1); color index ranges from 5 to 15, and averages about 10. The granodiorite has the same general appearance regardless of its composition.

Conspicuous phenocrysts of microcline are the most striking feature of the granodiorite. The commonly two centimeter long, tabular, euhedral phenocrysts are set in a medium-grained, hypidiomorphic granular groundmass. The groundmass minerals consist of anhedral quartz, subhedral, polysynthetic twinned, generally unzoned plagioclase (An_{27}-An_{37}), anhedral microcline, subhedral green biotite, and accessory amounts of sphene, apatite, epidote, and opaque minerals. Green hornblende is present in much of the granodiorite.

Commonly the granodiorite has a conspicuous foliation, marked by planar alignment of the microcline phenocrysts, alignment of mafic minerals, or by parallel orientation of lenticular mafic inclusions. In the Buhairan-Abu Khurg area, the foliation parallels the bow-like belt of metamorphic rocks and the batholith-ring dike contact, and dips vertically or steeply to the northwest.

Where exposed, contacts of the granodiorite with other rock units are generally sharp, and there is little evidence of reaction

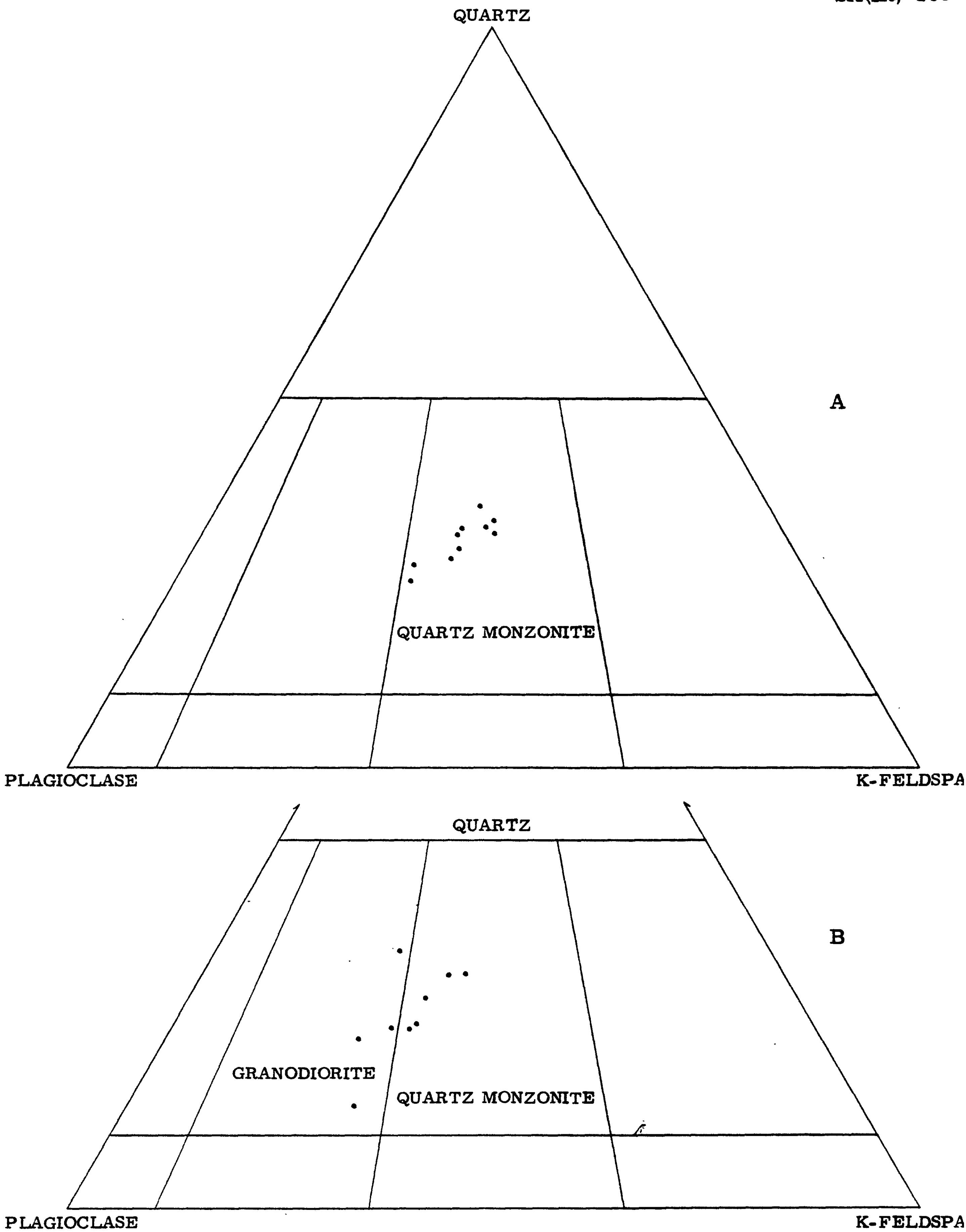

Figure 1. - Modal plots of granitic rocks of the **Buhairan-Abu Khurg area.** A, quartz monzonite of Abu Khurg. B, **granodiorite of Al Areyef**

between the granodiorite and adjacent rocks. The batholith is clearly intrusive into the metasedimentary rocks. In the northeast corner of the mapped area, steeply-dipping, sheet-like bodies of the granodiorite have intruded siliceous hornfels. This area has been mapped as a mixture of the two rock types, and the contact with the main mass of metamorphic rocks has been mapped on the basis of the last appearance of the granodiorite.

Quartz monzonite of Abu Khurg

Intrusive rocks of the ring dike are here named after Jabal Abu Khurg, one of the most prominent landmarks in the area. As with the metamorphic septa, the ring dike defines a bow-like belt, extending the entire length of the area. In addition, sill-like bodies, offshoots of the main ring dike, have intruded the metamorphic rocks and the granodiorite of Al Areyef on the convex side of the arcuate dike.

The ring dike consists of quartz monzonite (fig. 1). Color index ranges from one to five, and averages 1.5. On the basis of color index, the rock would be termed an alaskite. Commonly the rock has a pinkish hue. The typical quartz monzonite is seriate, medium-grained, and hypidiomorphic to allotriomorphic granular. Quartz, in a wide range of grain sizes, twinned and untwinned potassium feldspar, also with a wide range of grain sizes, and unzoned, twinned calcic oligoclase are the major minerals. Strikingly green biotite, frequently chloritized, is commonly present only in accessory amounts. Other sparse accessory minerals include muscovite, epidote, apatite, and opaque minerals. Thin iron oxide films in fine fractures and along grain boundaries are common.

In most places in the Buhairan-Abu Khurg area, the quartz monzonite appears structureless. Mafic inclusions are absent from the rock. A weak planar foliation, defined by a general elongation of mineral grains and clots of grains, sub-parallel to the ring dike-batholith contact, is present locally on the northwest slope of Jabal Buhairan.

A variety of small podiform and discontinuous dike-like bodies of plutonic rocks, possibly related to the quartz monzonite of Abu Khurg, are scattered throughout the area, but are most abundant in the metamorphic rocks east of Jabal Buhairan. Aplite and quartz monzonite are the commonest rock types, though rocks ranging from granite to leuco-quartz diorite are present. Generally the small bodies consist of fine- to medium-grained rocks, but minor pegmatitic rocks and massive quartz are represented.

Hypabyssal dike rocks

Felsic and mafic hypabyssal dike rocks crop out in the Buhairan-Abu Khurg area. Both types are intrusive into all the previously described rocks either within, or a short distance outside the area, but only minor effects of baking or alteration by the dikes on their hosts are apparent.

A wide, east-west trending, felsic dike forms a conspicuous, through-going, wall-like feature in the western half of the area. The dike has vertical walls, is as much as eight meters wide, and pinches to a width of only half a meter at its eastern extremity. It consists of fairly uniform, massive, dense, orange-brown, porphyritic rock. Groundmass of the rock is aphanitic and is made up of an apparently recrystallized mixture of sericite, quartz, feldspar, and carbonate. Quartz phenocrysts comprise about 10 percent of the rock, are predominantly euhedral, and are sometimes embayed. Altered euhedral feldspars, both plagioclase (An_{35}) and potassium feldspar, sparse epidote euhedra, and opaque grains also form phenocrysts. On the basis of quartz content the rock is a rhyolite.

At some localities along its length, the felsic dike is cut by younger, steep-sided, mafic dikes, clearly demonstrating the age relationship between the two types of hypabyssal dikes.

The dark-colored mafic dikes are ubiquitous in the area. Individual dikes trend N.80°W. to east-west and range from a few centimeters to more than two meters thick.

The mafic dikes have diverse compositions, as is illustrated by the range of bulk specific gravities of 12 typical samples (table 1). The range in specific gravities is from 2.71 to 2.94, the mean is 2.82, and the standard deviation from the mean is 0.08, indicating a rather large variability. The specific gravity values may be somewhat influenced by degree of vesicularity, nevertheless,

Table 1. Specific gravities of rocks from mafic dikes

Sample Number	Specific Gravity
72,097	2.81
72,098	2.85
72,111	2.74
72,114	2.84
72,115	2.89
72,120	2.71
72,132	2.94
72,143	2.94
72,147	2.84
72,153	2.71
72,178	2.75
72,185	2.81

composition is undoubtedly more important. Vesicules are commonly filled with a micro- to crypto-crystalline mixture of chlorite, carbonate, zeolite, and quartz. Plagioclase, the most abundant mineral in the mafic rocks, ranges from calcic oligoclase (An_{28}) to calcic labradorite (An_{68}), but within a single specimen shows little variability. Content and size of the phenocrysts, largely euhedral plagioclase, but including oxyhornblende and opaque minerals, display a wide range; some specimens contain as much as 15 percent phenocrysts, whereas others are virtually non-porphyritic. Plagioclase phenocrysts as long as 40 millimeters have been noted, though this is exceptional. Degree of alteration of the rocks varies considerably, however, mafic minerals, except for the opaque oxides, have generally been altered beyond recognition. Carbonate, chlorite, epidote, and sericite are common alteration products. Pilotaxitic texture is common to all rocks from the mafic dikes.

<u>Quartz veins</u>

A series of steeply-dipping, generally N.80°W. trending quartz veins are the youngest rocks which crop out in the Buhairan-Abu Khurg area. The relation between the maifc dikes and the veins is illustrated along a low ridge 1.5 kilometers north of Jabal Argooby where a vein parallels a mafic dike along the dike walls for several meters, and finally intrudes the dike. Alteration effects on rocks adjacent to veins is usually negligible. Vein width ranges from a few centimeters to over a meter. Exposed length of the veins is of the order of hundreds of meters. The veins consist of massive milky quartz, however comb structures are common locally, suggesting that the veins are epithermal. Prismatic quartz crystals as wide as four centimeters are present in vugs in the veins. Generally the quartz veins are barren of other material, although brecciated lithic fragments, white mica, amorphous iron oxide, fluorite, and trace amounts of the sulphide minerals, pyrite and molybdenite, occur in sparse amounts. Green stains indicative of copper minerals are present at two localities.

Surficial deposits

Approximately two-thirds of the Buhairan-Abu Khurg area is covered by surficial debris. The veneer of Quaternary debris consists of wadi sediments, eolian dune sands, and poorly-sorted, coarse-grained pediment materials.

Structure

The portion of the Uyaijah ring structure in the Buhairan-Abu Khurg area dominates structural patterns of the area.

The primary foliation in the granodiorite of Al Areyef originated as a result of either shear flow in the magma chamber or of outward expansion of the batholithic magma during crystallization. These two theories of primary structure in plutonic bodies have recently been reviewed by White (1973). The steeply-dipping foliation in the area tends to slant slightly inward, toward the center of the ring, suggesting a funnel-shaped structure. Likely the funnel-shaped structure reflects shear flow from a locus of magmatic upwelling.

In any case, the quartz monzonite of Abu Khurg has been emplaced subsequent to the formation of the older primary structure, as a ring dike whose form has been controlled by the older, pre-existing structure. A zone of weakness in the otherwise competent batholith likely existed in the space occupied by the septa of pre-batholithic rocks. The presence of sill-like bodies on the convex side of the ring dike, and their paucity on the concave side, suggests that the inner portion of the structure was a region of compression, whereas the outer portion was a region of tension or of least compression, an expected situation if the dike were forcibly emplaced. Schistosity in the metamorphic rocks parallel to the main ring-dike contact further indicates forcible emplacement of the dike.

The major fault of the area, which postdates emplacement of the quartz monzonite of Abu Khurg, has a left lateral displacement of approximately three-quarters of a kilometer. Vertical offset cannot be estimated. In addition to the readily discernible lateral offset, the fault is manifest by the presence of gouge along the northwestern part of its mapped trace. The northwesterly trending fault may be a member of the Najd fault system defined by Delfour (1970).

Although the felsic and mafic dikes and quartz veins follow east-west to northwest trends subparallel to the fault, they almost certainly postdate the period of active major faulting. Little evidence of shearing or slickensiding of these rocks or of offset along their strike lines is present in the Buhairan-Abu Khurg area.

Minor faults have been recognized at three localities elsewhere in the area. These faults have lateral displacements only in terms of a few meters.

Mineralization

Environments in the Buhairan-Abu Khurg area considered geologically favorable for concentration of various metals include reddish altered zones in the major intrusive rocks, the late epithermal quartz veins, and areas of contact metamorphism and high-temperature quartz-rich veinlets and pods in the metamorphic rocks. The few altered zones in the major intrusive rocks are small and show little evidence of metallization. Mineralization in the late epithermal quartz veins is sparse or absent.

Mineralized areas in the metamorphic rocks adjacent to the ring dike are responsible for the anomalous values of tungsten and molybdenum Theobald and Allcott (1973) discovered in panned sediment concentrates collected from the area. One principal area of mineralization has been located, a second smaller area has been found, and a few other occurrences of tungsten or molybdenum minerals have been recognized.

The first of these areas, which is about 100 meters wide, is on and parallel to the convex side of the ring dike, extending for about 1 kilometer from where the main mass of metamorphic rocks first crop out in the southwestern portion of the mapped area. Biotite schist is the predominant rock type although minor amounts of siliceous hornfels are interlayered with the schist. The metamorphic foliation in this area generally dips steeply toward the center of the circular ring structure; elsewhere it dips vertically. Mineralization is sparse and consists of powellite and scheelite[1/] in a few, less than 10 centimeters-long pod- and lens-like quartz bodies (fig. 2) oriented in the plane of schistosity. The bodies are generally several meters apart. The minerals occur in discrete, euhedral to subhedral crystals. Individual crystals of scheelite as long as 3 centimeters have been noted. Molybdian scheelite

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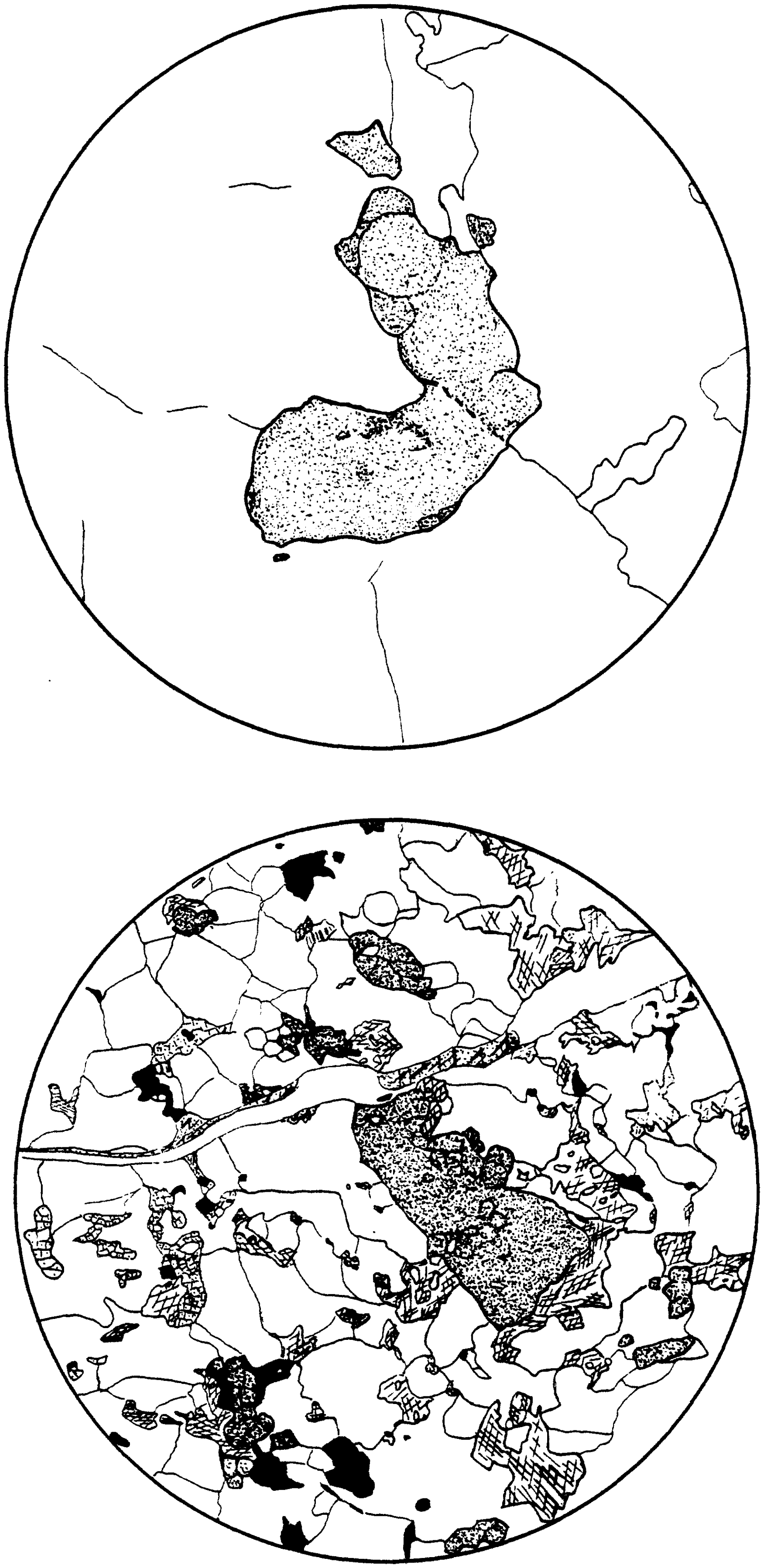
1/ Based on the usage of Palache and others (1951, p. 1076), scheelite is herein considered to contain up to 24 weight percent MoO_3 (16% Mo), whereas powellite contains more than 59 weight percent MoO_3 [39% Mo - end-member powellite contains 72 weight percent MoO_3 (48% Mo)]. Members of isomorphous series between these two limits do not exist in nature according to Palache and others. Molybdenum contents of the two minerals from the Buhairan-Abu Khurg area were determined using an ultraviolet light and a calibrated fluorescence analyzer.



A

B

Figure 2.- Microdrawings of scheelite- and powellite-bearing rocks. Diameter of both fields, 4.25 mm. Drawings by A. M. Helaby. A, powellite in podiform quartz (sample 72,084). B, molybdian scheelite disseminated in hornfels; scheelite has high relief; other minerals present include hornblende, calcite, epidote, quartz, plagioclase (andesine), and magnetite. (sample 72,053)

with from 0.96 to 2.4 weight per cent Mo is the commonest phase present, however Mo contents are variable, even within a single crystal. Abrupt concentric zoning with molybdian scheelite in cores, and near end-member scheelite around the outside of crystals as well as irregular zoning within crystals is present. A spectrographic analysis of a purified typical molybdian powellite is given in table 2. Sparse powellite occurs in film-like coatings along fractures and in fine disseminated grains both in the quartz pods and veinlets and in the metamorphic rocks. Molybdenite is a rare trace constituent in some quartz pods and much of the powellite may have been formed as an alteration product of the sulfide.

A second mineralized area, also in metamorphic rocks adjacent to the convex side of the ring dike, occurs in a narrow 100 meter-long belt on the northeastern lower slope of Jabal Abu Khurg. Here sparse finely disseminated grains of molybdian scheelite and powellite occur in thin lenses generally of fine-grained calc-hornfels and associated coarse-grained quartz-epidote pods and veins. The vertically dipping calc-hornfels lenses are interlayered with biotite schists and siliceous hornfels.

Trace amounts of fine-grained powellite and molybdian scheelite are present at a few other localities in the area. All occurrences are in metamorphic rocks, and generally associated with scarce thin bands and lenses of calc-hornfels.

Table 2. Semiquantitative spectrographic analysis of purified molybdian scheelite from podiform quartz

Element	Weight Concentration	Element	Weight Concentration
Fe	<.05%	Cu	<10 ppm
Mg	<.02%	La	<100 "
Ca	>20%	Mo	>2,000 "
Ti	<.005%	Ni	<10 "
Mn	<50 ppm	Pb	<50 "
Ag	<5 "	Sb	N
As	N	Sc	10 "
B	700 ppm	Sn	N
Ba	100 "	Sr	300 "
Be	<5 "	V	30 "
Bi	50 "	W	>10,000 "
Cd	>500 "	Y	100 "
Co	<20 "	Zn	1,500 "
Cr	<50 "	Zr	120 "

Footnotes:

Mineral separated from sample number 72,085.

N = Looked for, not detected.

GEOCHEMISTRY

Geochemical data for rocks collected during geologic mapping are presented herein separately (table 3) from data on rocks collected during lamping (table 4).

Data on the nine minor elements sought in rocks collected during geologic mapping are grouped according to rock unit or type in table 3. Arithmetic means have been calculated for those elements determined in at least one-half of the samples of each group. For analyses in which the element is below the limit of detection, a zero value has been assigned. Ranges are given for all the elements, but for many of the groups the lower limit does not exceed the determination limit.

Values of the elements for metamorphic rocks include 21 determinations on biotite schists, 11 on siliceous hornfels, and 13 on calc-hornfels. One tungsten value, determined on a calc-hornfels is anomalously high; otherwise tungsten values do not exceed 150 ppm. Molybdenum contents of 300 and 150 ppm for two calc-hornfels samples, are considerably higher than those of other samples (of which none exceed 20 ppm), but are not high enough to be considered indicative of potential economic significance. With the exception of these two samples, there is little difference in molybdenum contents of the three types of metamorphic rocks. The other seven elements are not present in significant amounts nor are they particularly concentrated in any one of the three rock types.

Table 3. Minor element contents of samples collected during mapping (in ppm)

Rock type	Number of Samples		W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
Metamorphic rocks	45	% detnd.	22	69	9	53	60	87	100	67	100
		mean	-	<5	-	.5	28	26	62	16	600
		range	N-2,000	<5-300	N-.05	N-1.2	N-225	N-71	5-220	N-70	100-2,100
Granodiorite of Al Areyef	12	% detnd.	0	50	8	42	42	58	100	42	100
		mean	-	<5	-	-	-	12	64	-	360
		range	-	<5-20	N-.05	N-.7	N-75	N-35	34-100	N-30	225-675
Mafic inclusion in granodiorite of Al Areyef	1	-	<1	5	.02	.7	N	23	83	N	375
Quartz monzonite of Abu Khurg	19	% detnd.	0	63	5	5	11	58	100	32	100
		mean	-	<5	-	-	-	11	50	-	217
		range	-	<5-10	N-.04	N-.3	N-75	N-40	5-225	N-13	125-500
Podiform granitic rocks	3	% detnd.	0	0	33	33	0	67	100	100	100
		mean	-	-	-	-	-	13	13	13	158
		range	-	-	N-.05	N-.3	-	N-23	5-18	-	125-200
Granodiorite dike rock	1	-	N	5	.02	.7	N	23	83	N	375
Aplites	2	range	N	<10-1,000	N	N-.5	N	N	8-9	25	250-1,000
Pegmatites	8	% detnd.	0	63	0	0	13	63	75	38	88
		mean	-	<5	-	-	-	11	14	-	156
		range	-	<5-15	-	-	N-50	N-23	<5-27	N-13	<50-250
Podiform quartz	23	% detnd.	13	78	4	22	43	17	78	87	83
		mean	-	5	-	-	-	-	10	11	127
		range	N-100	<5-20	N-.06	N-.7	N-325	N-25	<5-60	N-13	<50-250

Table 3. Minor element contents of samples collected during mapping (in ppm) (cont'd.)

Rock type	Number of Samples		W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn
Vein quartz	30	% detnd.	3	70	20	20	17	50	73	50	83
		mean	-	8	-	-	-	14	13	9	124
		range	N-40	<5-75	N-.1	N-1.2	N-1,250	N-63	<5-42	N-50	<50-560
Quartz-carbonate veinlet	1	-	<1	<5	.05	1.5	15	70	45	90	2,950
Fault gouge	5	% detnd.	0	80	40	100	40	100	100	40	60
		mean	-	38	-	1.5	-	50	30	-	1,205
		range	-	<5-150	N-.05	1-2	N-20	12-115	6-60	N-100	<50-3,500
Felsic dike rocks	2	range	N	5	N-.04	N	N-15	23	8-25	10-13	250
Mafic dike rocks	13	% detnd.	8	77	23	85	85	100	100	62	100
		mean	-	<5	-	.8	39	23	120	17	1,000
		range	N-5	<5-10	N-.05	<.5-1.4	N-90	15-50	50-370	N-50	100-1,500
All samples	165	% detnd.	8	68	14	38	39	64	91	59	93
		mean	-	15	-	-	-	17	44	13	410
		range	N-2,000	<5-1,000	N-.1	N-1.4	N-1,250	N-115	<5-370	N-100	<5-3,500

Footnotes:

N = element not detected
% detnd. = percent of samples in which element was present in amount equal to or greater than determinability level.

Table 4. Minor element contents of mineralized samples collected during lamping (in ppm)

Sample number	latitude (north)	longitude (east)	W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn	Sample Description
72,046	22°43'46"	44°28'11"	<100	<10	.1	.8	50	N	30	25	375	Biotite schist
72,047	22°43'45"	44°28'11"	>10,000	1,000	N	N	N	N	<5	25	100	Podiform quartz
72,048	22°43'46"	44°28'12"	10,000	280	N	.3	N	N	15	25	150	Silicified(?) granitic rock
72,049	22°43'47"	44°28'11"	<100	>2,000	N	.7	N	N	21	25	150	Aplite with assoc. vein qtz.
72,050	22°43'47"	44°28'12"	>10,000	1,500	N	N	N	N	<5	25	100	0.03 m wide quartz veinlet
72,051	22°43'46"	44°28'12"	<100	>2,000	.2	2.6	N	25	5	50	100	Podiform micro-pegmatite
72,052	22°43'46"	44°28'12"	<100	>2,000	N	N	N	N	<5	25	100	Podiform quartz
72,053	22°43'44"	44°28'19"	>10,000	>2,000	N	1.3	N	23	6	25	150	Siliceous hornfels
72,054	22°43'43"	44°28'17"	>10,000	500	.02	1.3	N	23	6	25	150	Vein aplite
72,055	22°43'43"	44°28'17"	<100	50	N	N	N	23	8	13	150	Sheared podiform aplite
72,056	22°43'43"	44°28'16"	<100	>2,000	N	N	N	N	<5	13	150	Podiform quartz
72,057	22°43'44"	44°28'19"	<100	>2,000	N	.5	N	N	<5	13	100	-do-
72,067	22°43'43"	44°28'28"	2,000	20	.01	.7	150	23	6	13	125	-do-

Table 4. Minor element contents of mineralized samples collected during lamping (in ppm) (cont'd.)

Sample number	latitude (north)	longitude (east)	W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn	Sample Description
72,068	22°43'43"	44°28'28"	<100	>2,000	.01	.3	N	15	<5	13	125	Podiform quartz
72,069	22°43'44"	44°28'26"	3,000	20	.01	.3	N	15	<5	13	100	-do-
72,070	22°43'44"	44°28'26"	>10,000	700	.01	.3	N	15	8	25	125	-do-
72,071	22°43'43"	44°28'26"	>10,000	700	N	.3	N	15	25	25	200	-do-
72,072	22°43'43"	44°28'25"	>10,000	500	N	.7	N	N	24	25	200	-do-
72,073	22°43'43"	44°28'26"	>10,000	700	N	.75	N	23	20	50	150	-do-
72,074	22°43'42"	44°28'27"	2,000	100	.02	.5	N	15	16	13	200	Podiform granitic rock
72,075	22°43'42"	44°28'27"	>10,000	700	N	.3	75	15	<5	13	125	0.02 m wide quartz veinlet
72,081	22°43'41"	44°28'28"	>10,000	700	.01	.95	N	23	50	25	400	0.01 m wide quartz veinlet
72,082	22°43'42"	44°28'31"	150	10	N	.75	N	15	80	13	500	Siliceous hornfels
72,083	22°43'40"	44°28'30"	10,000	500	N	1.3	N	25	155	13	500	Biotite schist
72,084	22°43'43"	44°28'34"	>10,000	1,500	N	N	N	N	5	13	100	Podiform quartz
72,085	22°43'44"	44°28'32"	3,000	200	.01	.3	N	N	6	13	125	-do-

Table 4. Minor element contents of mineralized samples collected during lamping (in ppm) (cont'd.)

Sample number	latitude (north)	longitude (east)	W	Mo	Au	Ag	Cu	Pb	Zn	Bi	Mn	Sample Description
72,086	22°43'44"	44°28'39"	>10,000	1,000	N	N	N	N	<5	13	100	0.5 m (?) wide quartz vein
72,087	22°43'45"	44°28'38"	100	20	N	1	300	25	102	25	750	Biotite schist
72,088	22°43'46"	44°28'38"	>10,000	1,000	N	N	N	N	6	13	100	Podiform quartz
72,193	22°45'35"	44°31'26"	100	600	<.01	1.1	N	25	15	55	950	Calc-hornfels
72,194	22°45'34"	44°31'26"	2,000	900	.05	.5	10	25	10	30	325	-do-
72,195	22°45'34"	44°31'26"	1,000	5,000	.05	.7	80	25	35	<5	210	-do-
72,196	22°45'33"	44°31'26"	1,000	4,500	.05	.7	25	50	20	75	1,450	Biotite schist
72,197	22°45'33"	44°31'25"	1,000	4,500	.05	.9	15	<15	10	25	140	Calc-hornfels
72,198	22°45'32"	44°31'25"	2,000	1,150	<.01	<.2	10	<15	40	25	250	-do-
72,223	22°46'04"	44°32'44"	300	30	.05	1	10	35	75	65	925	-do-
All samples	% detnd.		78	97	42	75	28	58	75	97	100	36 total samples
	mean		>4,650	>1,180	-	.6	-	13	22	25	275	
	range		<100->10,000	<10->2,000	N-.2	N-2.6	N-300	N-50	<5-155	<5-75	100-1,450	

The 12 samples of the granodiorite of Al Areyef include one altered sample. Minor element values on the altered granodiorite are not different than values on its unaltered counterparts. Average values of minor elements calculated for the granodiorite are quite similar to averages reported by Turekian and Wedepohl (1961) for high calcium granites of the earth's crust.

Minor element content of samples of the quartz monzonite of Abu Khurg are similar to those of the granodiorite of Al Areyef. Four of the 19 samples of the quartz monzonite are of altered rock; as with the granodiorite, there is little difference between altered and unaltered samples.

Minor element contents of other groups of rocks, with only a few exceptions, are present in insufficient amounts to be of potential economic interest, and they are not very different than values that would be anticipated from the respective rock types, even though several of the samples were collected from areas of suspected mineralization. One aplite sample with 1,000 ppm Mo is from an extremely small pod in the area of mineralization in the southwestern portion of the mapped area. A sample of quartz with a Cu value of 1,250 ppm was collected from a small area of 0.03 meter wide veinlets, again in a mineralized area.

Contents of individual minor elements show differences, though generally not great, between the different rock groups. Tungsten content is greatest in the metamorphic rocks; the element was determined in almost one-quarter of the metamorphic samples, whereas it was rarely present in sufficient amounts for determination in other rocks. Molybdenum shows no particular abundance in any specific rock type, with the exception of fault gouge. Gold is most consistently present in determinable amounts in mafic dike rocks, fault gouge, and vein quartz, but otherwise shows no particular concentration. Average silver and copper values are greatest for mafic dike and metamorphic rocks, and otherwise the two elements are commonly present in amounts below limits of determination. Lead was determined in more samples of mafic dike rocks than other rocks, but its average value is highest for the metamorphic rocks. Zinc is highest in the metamorphic rocks, and shows no particular abundance in any of the groups. Average values for both bismuth and manganese are highest in metamorphic and mafic dike rocks.

Minor element contents and locality data for the 36 samples collected during lamping are given in table 4. All samples contain either scheelite or powellite readily visible using ultra-violet lite. Other than tungsten and molybdenum contents, minor element values are not very different than in unmineralized equivalents.

EVALUATION OF ECONOMIC POTENTIAL

Areas of tungsten and molybdenum mineralization in the Buhairan-Abu Khurg area have been found which adequately account for previously discovered sediment anomalies. Because of the sparseness of mineralization, further work is not recommended at the present time; no mineral deposits which can be exploited at currently prevailing metal prices are known or thought to be present in the area.

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