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A MINERAL RECONNAISSANCE OF THE JABAL KHIDA QUADRANGLE, SAUDI ARABIA

by

Jesse W. Whitlow

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PREFACE

In 1963, in response to a request from the Ministry of Petroleum and Mineral Resources, the Saudi Arabian Government and the U. S. Geological Survey, U. S. Department of the Interior, with the approval of the U. S. Department of State, undertook a joint and cooperative effort to map and evaluate the mineral potential of central and western Saudi Arabia. The results of this program are being released in USGS open files in the United States and are also available in the Library of the Ministry of Petroleum and Mineral Resources. Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government agencies. The Government of Saudi Arabia makes this information available to interested persons, and has set up a liberal mining code which is included in "Mineral Resources of Saudi Arabia, a Guide for Investment and Development," published in 1965 as Bulletin 1 of the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral Resources, Jiddah, Saudi Arabia.

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Contents

ABSTRACT

Reconnaissance of the Jabal Khida quadrangle shows that granite and granodiorite (unit gg), biotite and hornblende granite (unit gr) and alkalic and peralkalic granite (unit gp) divisions for granites seems valid, but that two ages of metamorphic and extrusive rocks are mapped as the Halaban formation (unit ha/hc).

Semiquantitative analyses of 113 samples collected in the quadrangle were made spectrographically on minus 30 plus 80 mesh wadi sand for 27 elements, and chemically on concentrates of heavy minerals and magnetite from wadi sand. Anomalous amounts of silver, beryllium, molybdenum, niobium, tin, cobalt, chromium, copper, lead, nickel, titanium, and vanadium are found in the sand samples, but the anomalies are low. Anomalous tungsten is present in some concentrates from wadi sand.

A small alkalic and peralkalic granite (gp) at the west side of the quadrangle contains tin, niobium, and a low anomaly of lead. The area should be studies for commercial tin and niobium. Beryllium is in the granite and granodiorite (gg) adjacent to the alkalic granite. Concentrates from wadi sand derived from two alkalic granite (gp) bodies in the north-central part of the quadrangle contain 300 ppm tungsten.

INTRODUCTION

Purpose, scope and acknowledgement

A mineral reconnaissance of the area of the Jabal Khida quadrangle, Saudi Arabia, was completed in 15 days of field work between December 7, 1964 and May 29, 1965. The purpose of the work was to locate areas likely to contain economic minerals, to learn the areal distribution of metals, and to delineate districts that require additional economic geological study. A secondary purpose of the investigation was revision of the existing 1:500,000 scale geologic map of the area (Jackson and others, 1963). In order to accomplish these objectives in the short time available, the rocks, mines, and prospects were studies in reconnaissance fashion, and samples for geochemical analyses were taken at 113 stations. This report is based on field observations and the results of semiquantitative spectrographic and chemical analyses of the samples.

The work was performed by the United States Geological Survey in cooperation with the Directorate General for Mineral Resources, Kingdom of Saudi Arabia. The Ministry furnished funds, equipment, supplies, office and storage space, reports on mines and geologic investigations, aerial photographs at 1:60,000 scale, controlled photomosaics at 1:50,000 scale and 1:100,000 scale, and supporting personnel. Of the supporting personnel, Misri Madak, a senior driver, is to be commended for his help. The writer wishes to thank the officials of the Ministry for their assistance in accomplishing the survey here described.

Access.

Access is good to fair although few rudimentary roads and no villages are in the quadrangle. Absence of villages reflect the scarcity of potable water; most wells are too salty for human use. Small sandy areas are common, but there are no dune areas that are troublesome to cross.

Most of the eastern two-thirds of the quadrangle has low relief and has only small areas difficult to traverse. Much of the western third of the area is mountainous and is difficult to traverse. Areas underlain by rocks of the Halaban formation are difficult to sample properly because of access problems, but areas underlain by granitic rocks are generally easily traversed and sampled as desired. Many places in the quadrangle are suitable for the landing of light airplanes. The granitic areas are particularly favorable, but suitable sites to land can be found but are not common in areas of Halaban formation.

Procedure.

Procedure of work was to study aerial photographs of the area locating structural and lithologic features that should be examined in the field. The office work included a review of reports on mines and geologic investigations within the quadrangle and adjacent areas. Field work consisted of truck traverses of the area to study and sample the locations marked on the photographs, and to examine other areas which seem to deserve sampling, to study contact zones, and to search for abandoned mines. Locations of sample stations were plotted on 1:100,000 scale photomosaics. A bulk sample consisting of between 5 and 10 kilograms of rock debris was collected at 113 stations. Samples of detrital magnetite were collected at 41 stations, and only hand specimens at 3 stations (11,604, 11,677, and 11,681). Field work was a continuous traverse, and camp was set each evening at a different site.

Bulk samples, hand specimens collected during the day, and surficial debris in the camp area were scanned with a short-wave length ultra-violet light each evening for fluorescent minerals. Also the bulk samples were screened to remove about 55 grams of minus 30 plus 80 mesh sand. All samples were sent to Jiddah for further processing toward semiquantitative spectrographic and chemical analyses.

The bulk samples were wet panned with a gold pan in a pool at the Jiddah office to concentrate, separate, and recover minerals that have a specific gravity of about 3 or more from the lighter minerals. Magnetité was removed from the heavy mineral concentrate, hereafter referred to as concentrate, with a horseshoe magnetite. The magnetite was added to the detrital magnetite collected at the sample station. The concentrate was not scanned with an ultra-violet light. The concentrate, magnetite, and 55 grams of screened fraction were submitted to the Jiddah laboratory of the Directorate General for Mineral Resources for further processing and semiquantitative analyses for metal content.

Processing of the samples for analyses was completed at the laboratory. The magnetite samples were crushed in an agate mortar with an agate pestle, and then cleaned with a horseshoe magnet. The screened fraction, concentrate, and cleaned magnetite from each sample station were crushed in aluminium oxide ball mills to minus 200 mesh powders.

The samples were semiquantitatively analysed by chemists in the laboratory. The screened fraction of 113 samples were analysed spectrographically for 27 elements by C. E. Thompson of the U. S. Geological Survey; 84 of the samples were checked chemically for copper, zinc, and molybdenum. The concentrates were semiquantitatively analysed by chemical methods for copper, zinc, molybdenum, and tungsten by J. Goldsmith, L. Al Dugiather, and I. Baradja who also semiquantitatively analysed the magnetites for copper, zinc, and molybdenum.

GEOLOGY

Geologic units.

The geologic units granite and granodiorite (gg), biotite-hornblende granite (gr), Halaban formation (ha/hc), and alkalic and peralkalic granite (gp) of Jackson and others (1963) are used on the map in the order given by Jackson and others but with changes of some boundaries based on my work in 1964 and 1965. An anorthosite unit (an) that was discovered in 1964 is added. All consolidated and crystalline rocks appear to be Precambrian in age, but the sedimentary rock at station 11,677 may be Paleozoic in age; however, no fossils were found with which to date the rock and until more evidence is available, the above area is shown as Precambrian.

Granite and granodiorite.-- The granite and granodiorite (gg) is a gray, reddish-gray, and reddish, coarse-to fine-grained, biotite-and hornblende-containing granitic rock that is mostly medium-grained and is locally prophyritic. The porphyritic phase contains feldspar crystals as much as 4 cm long. This unit is commonly faintly gneissic. The boundary of this unit has been considerably revised from that shown by Jackson and others (1963) principally by including in the unit large areas formerly mapped as Halaban formation. Examination of these areas proved them to be granite and granodiorite that contain many dikes of andesite, rhyolite, breccia, and granite which are dark colored or darkened by desert varnish, and on aerial photographs resemble metamorphosed sedimentary and extrusive rocks. As redefined on the map, the granite and granodiorite (gg) underlies about half of the area of the Jabal Khida quadrangle.

The granite and granodiorite (gg) is shown in the explanation for the 1:500,000-scale map of the Southern Najd quadrangle (Jackson and others, 1963) as the oldest rock in the Jabal Khida quadrangle. The contact of this granite with other granites and with the Halaban formation is generally covered by sand or slope debris; thus contact relationships are difficult to determine. A fairly common sequence of rocks observed in outcrop when traveling from this granite to rock of the Halaban formation is granite to granodiorite or diorite-like rock to metamorphic rock of Halaban type. A small body of Halaban type rock at station 11,682 looks as if it has been metasomatized by the adjacent granite (gg) because it contains small pods and veins of feldspar and quartz. These metamorphosed and metasomatized sediments are in a roof pendant that is older than the granite.

Locally, the granite is broken by closely spaced joints and slightly altered by solutions moving along the joints and through the rocks. The altered rock is harder than the unaltered granite, and a few low reddish mountains are evidence of the resistance to erosion of the altered granite. Possibly the age of this alteration is the same as the age of the alkalic and peralkalic granite (gp).

Biotite-hornblende granite.--The biotite-hornblende granite unit (gr) is a light- gray, medium-to coarse-grained rock that according to Jackson and others (1963) is younger than the granite and granodiorite (gg) and older than at least part of the Halaban formation (ha/hc). Fragments of biotite-hornblende granite (gr) in conglomerate of the Halaban Formation at station 11,606 and 11,611 support the above age position. Fragments of graywacke, shale, and earlier flowrock in an intrusion of granite (gr) at Station 11,621 indicate that some Halaban rocks are as old or older than this granite.

Contacts of the biotite-hornblende granite (gr) with the granite and granodiorite (gg) and alkalic and peralkalic granite (gp) are difficult to evaluate in terms of relative ages. There are no good exposures of the contact of the biotite-hornblende granite (gr) with the granite and granodiorite (gg). The contact of the biotite-hornblende granite (gr) with the alkalic and peralkalic granite (gp) can be seen near stations 11,614, 11,615, and 11,777, but the younger alkalic granite did not affect the older biotite-hornblende granite.

Fractures in the biotite-hronblende granite (gr) commonly have a zone of harder rock containing red feldspar that may be as much as 10 cm wide from a fracture to unaltered granite. Areas of closely spaced fractures commonly form hills or low mountains because of the greater resistance to erosion. Possibly a few of the plugs mapped as alkalic and peralkalic granite (gp) are actually masses of biotite-hornblende granite (gr) slightly altered by movement of mineralizing solutions along closely spaced fractures.

Halaban formation.-- The Halaban formation in the Jabal Khida quadrangle comprises a large variety of variably metamorphosed rocks dominated by volcanic rocks of andesite affinity. The most common rocks in the western and southwestern part of the quadrangle are andesite, felsic andesite, graywacke, rhyolite, conglomerate, agglomerate, diorite-like rock, pyroclastic rocks, amphibolite schist, scarn and flow rocks of andesite-basalt, and andesite composition. The common rock in the eastern part of the quadrangle is metamorphosed sedimentary rock consisting of quartzite, limestone, green shale, and minor quartz sandstone. An area at and near the northern side of the quadrangle and north of Quaternary silt and gravel is questionable Halaban. Generally, epidote is common to abundant in rocks of the Halaban formation.

There is evidence that two ages of rock are mapped as Halaban formation. The agglomerate and conglomerate contain fragments of older conglomerates composed of pebbles and cobbles of greenstone and graywacke preserving older scour and fill structures. Granite (gr) at station 11,620 contains inclusions of schist and greenstone of the Halaban Formation, and a roof pendant of Halaban rock occurs in the granite and granodiorite (gg) indicating that part of the formation is older than either granite. Yet the presence of fragments of granite (gr) in andesite-basalt and andesite agglomerate-conglomerate of the Halaban Formation indicate that part of the Halaban is younger than the granite (gr).

The evidence for two ages of rocks mapped as Halaban formation is seen in the southwest quarter of the quadrangle. The relative age of rocks of the Halaban in the remainder of the quadrangle is more difficult to determine because of scarcity of outcrops. West of the anothosite (an) is a metamorphosed sedimentary rock with vertical to sub-vertical bedding that is older than the anorthosite and is mapped as (hc) unit of the Halaban formation. Metamorphosed shale and schist of Halaban type at 11,690 is intruded by many dikes of alkalic and peralkalic granite (gp). A more detailed study is necessary for an understanding of the Halaban formation as mapped and its relationship to other rocks in the quadrangle.

Anorthosite.— The anorthosite unit (an) is a gray, medium-to coarse-grained rock ranging in composition from 100 percent feldspar to about 90 percent feldspar and 10 percent combined amphibole and trace of limenite. The feldspar is medium gray, twinned andesine lacking chatoyancy. Weathered surfaces vary from polished medium gray to the dark grayish-brown of desert varnish, and the area underlain by anorthosite shows on aerial photographs as dark gray to black. The rock is hard. Its weathering characteristics cause fragments to vary from sub-angular with rounded edges to near spherical.

The large anorthosite body (an) was studied in some detail. The small body of anorthosite (an) north of station 11,785 at about 21°25'N. and 44°22'E. is anorthosite-gabbro that was not studied in detail. Its age relationship with the biotite-hornblende granite (gr) and the alkalic and peralkalic granite (gp) is not known.

The large anorthosite mass seems to intrude the granite and granodiorite (gg) and metamorphosed sedimentary rocks of the (hc) unit of the Halaban formation. The contact of the anorthosite with adjacent bodies of rock is covered by sand and slope debris. The nearest crystalline rock is gray, biotite granite and a porphyritic phase of the granite and granodiorite (gg) but it contains no anorthosite. No inclusions of granite or Halaban or intrusions of granite were seen in the anorthosite.

Alkalic and peralkalic granite.--The alkalic and peralkalic granite unit (gp) in the Jabal Khida quadrangle is a reddish-gray to red, coarse-to medium-grained, biotite granite. A minor amount of light-gray, fine-grained, granite is in the unit. The alkalic granite (gp) forms large fairly smooth to smooth-weathering outcrops that have a higher relief than other granite and metamorphic rock in the area, and debris from the unit is reddish. The granite and granidiorite (gg) and biotite-hornblende granite (gr) show no metamorphic effects from intrusions of the alkalic and peralkalic granite (gp) masses. Because of megascopic similarity of the granitic rocks, mixing of granites is rather difficult to see; however, a few inclusions of a light-colored granite are found in the alkalic and peralkalic granite (gp).

Most of the contacts of alkalic and peralkalic granite (gp) with the Halaban formation indicate that the granite is the younger at the rare localities where the contact is exposed (stations 11,789 and 11,790). At stations 11,542 and 11,543, the granite contains inclusions of pyroclastic rock and graywacke possibly belonging to the Halaban formation or a younger sedimentary unit. The granite at station 11,612 is in contact with andesite which may be a roof pendant or may be younger than the granite. Epidote and thin quartz veins in the Halaban at station 11,616 might be attributed to intrusion of the Halaban by alkalic and peralkalic granite (gp); however, granite (gp) at station 11,543 itself contains epidote and thin quartz veins.

Dikes and silicified zones.--Dikes in the Jabal Khida quadrangle consist of breccia (B), usually broken silicified rock healed by quartz; andesite (A); rhyolite (R); and granite (G). Dikes cut all Precambrian rocks, but they are more prominent in the granite and granodiorite unit (gg) and biotite-hornblende granite unit (gr) than in the young granite (gp). Many ridges in the Halaban formation have a dike-like core of andesite or rhyolite that does not show on the photographs because of similarity of color and of the resistance to erosion of the dike and host rocks.

The breccia dikes (B) are the largest in the quadrangle and the most interesting

Breccia dikes range from two or three meters wide and consist of silicified rock that was broken and then healed by quartz to a similar lithology as much as 30 meters wide that has a core of nearly pure quartz as much as 5 meters thick. Rarely the breccia dikes are traceable into silicified granite where they form low ridges. Red to orange-pink feldspars in granite are nearly always associated with breccia dikes. Feldspars commonly range from red near the dike to the pale colors of feldspars in normal granite outward over a distance of as much as 15 meters. Thin quartz veins are traceable from the core of breccia dikes rarely as much as 30 meters into the wall rocks. Rare traces of iron minerals and malachite are in the breccia dikes.

Andesite dikes (A) contain traces of iron sulfides. The feldspars in granite adjacent to the dikes are red but feldspars are never reddened for more than a few meters from the dike.

Rhyolite dikes (R) contain rare traces of iron sulfides, and feldspars in granite adjacent to the dike may or may not be red.

Granite dikes (G) are fine-grained, commonly felsic, and generally finer-grained near the border than in the core. Migmatization of the host rock rarely occurs where the Halaban formation is intruded by granite dikes that are near their source.

Dikes seen in photomosaics seem to end at or near the contact of granite with the Halaban formation (ha/hc). However on the ground most dikes are traceable into the Halaban and it is rare that a dike ends at the contact of the two rock types.

Silt and gravel. Unconsolidated sheet-like deposits of lag gravel (Qgp) consisting of quartz and pebbles of other rock from the bedrock complex, and unconsolidated deposits of silt, sand and gravel (Qu) are the surface material over a relatively small part of the area of the Jabal Khida quadrangle. Sand is common, but no large dunes exist in either the lag gravel (Qgp) or the silt (Qu) areas. Locally, rock fragments in the debris are interpreted to indicate that bedrock is near the surface; however, most of the fragments tend to be from dikes and veins that are more resistant to erosion than the bedrock and do not indicate the dominant underlying rock. Both the lag gravel (Qgp) and silt, sand, and gravel (Qu) areas in the Jabal Khida quadrangle should be sampled by a system that would show the distribution of metals in the unconsolidated debris and type of the underlying bedrock.

Structure.

Faults shown on the map are from Jackson and others (1963). Direct evidence of faults, except for alinement of erosional features, is rarely seen. Mylonite was found at Station 11,797. Breccia ridges are of fault origin as shown by the fractured silicified rock, but evidence of direction of movement is lacking. Probably there is little actual displacement along them. Several breccia ridges are parallel to the northwest-trending faults and to undeformed andesite dikes. Trend lines are shown to indicate alignment of structural features that control or partially control weathering of the rocks and direction of emplacement of dikes. Dike directions indicate fracture patterns. No trends are visible on aerial photographs of areas of the Halaban formation.

ANALYSES

Semiquantitative spectrographic analyses were made of the minus 30 plus 80 mesh fraction of wadi sand, and chemical analyses were made of heavy mineral concentrate and magnetite from wadi sand and 84 samples of wadi sand. Results of the spectrographic analyses for copper, zinc, molybdenum and positive anomalies for 10 selected elements are shown on the map and discussed in the text. Results of chemical analyses of the concentrates and magnetite are only discussed in the text. The purpose of the map is to show the distribution of anomalous elements and positive anomalies of selected elements in the quadrangle.

DISTRIBUTION OF SELECTED ELEMENTS

The results of semiquantitative spectrographic analyses are shown on the map by symbols for copper, zinc, and molybdenum, and by chemical symbols and content in parts per million (ppm) for positive anomalies of 10 selected elements (map explanation). The symbol for copper is used to show the location of a sample station except where copper is absent then the symbol for molybdenum is used. The presence of silver, beryllium, niobium, and tin in the quadrangle is considered as a positive anomaly and shown on the map. Positive anomalies for other selected elements were determined by an examination of the results of semiquantitative spectrographic analyses for each of the elements in 1200 samples from the Southern Najd quadrangle. The minimum detectable quantity and the minimum quantity in parts per million for a positive anomaly of the selected elements in the Jabal Khida quadrangle are:

Element	Minimum ppm detectable	Minimum ppm for positive anomaly
Cobalt	5	50
Chromium	5	200
Lead	10	30
Nickel	5	100
Titanium	20	10,000
Vanadium	20	100

Industrial demand was considered in selecting certain elements for discussion and showing anomalous contents on the map.

Distribution of the fluorescent tungsten and molybdenum minerals scheelite (a calcium tungstate) and powellite (a calcium-molybdenum tungstate) was made by examining bulk wadi sand from sample stations, rock fragments collected, and camp areas with an ultra-violet light. No scheelite was found. Powellite was identified in sample from 11,801 and was present in the camp area about 1 kilometer north of the sample station.

Copper, zinc, molybdenum, and tungsten.

The copper content of the 113 samples analyzed ranges from less than 10 ppm, the minimum amount detected, to 150 ppm. Copper was detected in 73 of the -30 +80 mesh sand samples analyzed spectrographically, and 69 of 84 of the same sand samples that were analysed chemically. Chemical analyses show copper in 86 of the concentrate, and 106 of the magnetite samples. All samples barren of copper are from the granites and the anorthosite rock. The histogram for copper shows that 70 samples contain 10 ppm or less of copper. Most of the 70 samples are from the eastern two-thirds of the quadrangle where the bedrock is granite and granodiorite (gg) and anorthosite (an).

There is more copper in wadi sand, concentrates, and magnetite samples from the western third of the quadrangle where most of the rocks are of the Halaban formation, but even here the highest values are 150 ppm in wadi sand and concentrates, and 100 ppm in magnetites. The highest values for copper for the three samples from each station are from station 11,623 through station 11,633, which shows that this area has a low copper anomaly.

The concentrates generally contain more copper than the sand samples. The concentrates and magnetites contain about the same amount of copper except for local differences. Spectrographic analyses and chemical analyses of wadi sand average about the same, but locally results by one method is greater than by the other method.

Zinc was detected spectrographically in two samples of wadi sand (stations 11,630 and 11,650, both contain 100 ppm, and chemically in 113 concentrate and magnetite samples. The lower limit of detection for zinc spectrographically is 100 ppm and chemically it is 25 ppm. The zinc content of concentrates ranges from 25 ppm to 150 ppm, and the content in magnetites ranges from 25 ppm to 1000 ppm. Zinc is more abundant in concentrates and magnetites from granitic rocks than from the Halaban formation. Generally the zinc content of magnetites from the granites is from 100 ppm to 600 ppm, but one (station 11,775) from granite and rhyolite contains 1000 ppm of zinc. Magnetite samples from the Halaban formation generally contain less than 100 ppm.

Molybdenum was detected spectrographically in 15 of 113 samples of wadi sand and chemically in 99 concentrate and 93 magnetite samples from wadi sand. The range of molybdenum is from 2 ppm, the minimum amount detected spectrographically to 5 ppm in wadi sand, from 5 ppm, the minimum amount detected chemically, to 40 ppm in 98 concentrates and 150 ppm from station 11,601, and from 5 ppm to 40 ppm in magnetite samples.

Concentrates from granitic areas generally contain from 10 to 20 ppm molybdenum but a few samples contain more than 20 ppm. The molybdenum content of concentrate from rocks of the Halaban formation is generally from 5 ppm to 10 ppm; a few samples contain more than 10 ppm, but molybdenum was not detected in 12 samples from this formation.

Chemical analysis for tungsten was made of concentrates from 113 bulk wadi samples. Tungsten was found in only 20 samples, and content ranged from 20 ppm, the minimum detected chemically, to 300 ppm. Most of the samples that contain tungsten are from granitic rocks, and the samples that contain 300 ppm (stations 11,690 and 11,697) are from alkalic and peralkalic granite (gp). No alteration of the rocks was seen at either station. The mineral source of tungsten was not determined, and scheelite was not found in the samples.

The concentrations of copper, zinc, molybdenum and tungsten detected in the Jabal Khida quadrangle show no significant amount of these elements at the localities examined.

Silver, beryllium, niobium, and tin.

Silver was reported in two of 113 sand samples analysed. The amount of silver is very low, but its presence is a positive anomaly. Station 11,638 is at an abandoned mine and dump debris contains 2 ppm silver and 150 ppm lead. The mine is in a vein of quartz in gray, biotite granite in the unit mapped as biotite-hornblende granite (gr) (see section on mines). The sample from station 11,648 contains 1 ppm silver, 2 ppm molybdenum, and 30 ppm lead. This sample is from biotite-hornblende granite (gr) mapped as granite and granodiorite (gg). Some alteration along joints in the granite is shown by red feldspars, but the rock is not mineralized. Neither the area at station 11,638 or at station 11,648 is a source for silver.

Beryllium occurs in sand from sample stations 11,601, 11,609, 11,687, 11,732, 11,774, 11,784, and 11,797. Two of these samples also contain tin (stations 11,687 and 11,732). Six of the samples contain 2 ppm beryllium, the minimum detected, and one contains 3 ppm. Four of the samples that contain beryllium are from alkalic and peralkalic granite (gp), two are from granite, and granodiorite (gg), and one is from biotite-hornblende granite (gr). A few crystals of beryl, a beryllium aluminum silicate, were seen in a small pegmatite vein at station 11,601.
on an emission spectrograph for beryllium by C. E. Thompson of the U. S. Geological Survey, Jiddah. One sample was a greenish to aquamarine hexagonal mineral and the other was a black platy mineral; both minerals are rare in the pegmatite. The minerals contain more than one percent beryllium. The greenish to aquamarine mineral is beryl but the black mineral was not identified.

Niobium was detected in two samples (11,542, and 11,611) from the alkalic and peralkalic granite. Both samples contain 50 ppm, the minimum that is detected. The stations are associated with alkalic granite (gp) which also contains a low anomaly of lead. Neither locality is a source for niobium.

Tin was detected in samples from stations 11,543, 11,687, and 11,732. Stations 11,543 and 11,687 are from areas underlain by alkalic and peralkalic granite (gp), and sample 11,732 is from an area underlain by biotite-hornblende granite (gr). Sample 11,543 contains 150 ppm tin in wadi sand and the concentrate which was not analysed for tin contains 160 ppm tungsten. Just west of the Jabal Khida quadrangle and about 6 km N. 70 W. of station 11,543, a sample in the
same body of granite contains 500 ppm tin in wadi sand and the concentrate contains as much as 20,000 ppm (2 percent) tin and 110 ppm molybdenum. Station 11,543 is about 4 km. from the pegmatite at station 11,601 which contains beryl; the concentrate from this station contains 150 ppm molybdenum. The other two samples contain 15 ppm tin or less and 2 ppm beryllium. A detailed study of the area from just south of station 11,543 to north of station 11,601 and to just west of station 11,599 in the adjacent quadrangle is recommended to determine the extent and value

of the tin, niobium, molybdenum, tungsten, and beryllium in the area.

Cobalt, chromium, lead, nickel, titanium, and vanadium.

The localities that contain positive anomalies for cobalt, chromium, lead, nickel, titanium, and vanadium are shown on the map; however, except for lead, the above elements are detected in most of the samples. A sample from station 11,775 contains 50 ppm cobalt and anomalous occurrences of nickel, titanium, and vanadium. This sample is from an area underlain by granite and granodiorite (gg) in the west central part of the quadrangle.

Chromium is anomalous in four samples (11,627, 11,783, 11,788, and 11,803). Three of the samples contain 300 ppm and are from areas underlain by the Halaban formation or Halaban intruded by biotite-hornblende granite (gr). Sample from station (11,788) contains 200 ppm chromium and is from a contact zone of granite and granodiorite (gg) and intrusive alkalic granite (gp). The histogram (see geologic map) shows the concentration of chromium, which is not economic in the quadrangle.

Lead is 30 ppm or more in nine samples from this quadrangle (see histogram, geologic map). Seven samples contain 30 ppm of which samples from stations 11,542, 11,543, 11,609, and 11,784 are from areas underlain by alkalic and peralkalic granite (gp). Samples 11,648 and 11,796 are from areas underlain by granite and granodiorite (gg), and sample (11,802) is from an area of biotite-hornblende granite (gr). The sample from station 11,612 contains 70 ppm and is from the alkalic granite. The sample from 11,638 contains 150 ppm lead and is from mine dump material that also contains a trace of silver. The mine is in an area of biotite-hornblende granite (gr). The concentration of lead is usually greater in granitic rocks than in the Halaban formation in the quadrangle.

Anomalous nickel (see histogram, geologic map) is in samples from two stations (11,775 and 11,783). Sample 11,775 contains 100 ppm nickel and is from an area underlain by granite and granodiorite (gg). Sample 11,783 contains 200 ppm nickel and is from the Halaban formation. Both samples are from the western part of the quadrangle.

Titanium is present in all samples from the Jabal Khida quadrangle, but samples from only three stations (11,630, 11,775, and 11,788) contain an anomalous amount, 10,000 ppm or more. The samples are from areas underlain by the Halaban formation at station 11,630, by granite and granodiorite at station 11,775, and by biotite-hornblende granite (gr) and alkalic granite (gr) at station 11,788. The anorthosite (an) contains a reddish mineral that has a hardness of about 5. This mineral was identified from X-ray analysis by Mary E. Mrose, U. S. Geological Survey, Washington, D. C., as ilmenite, geikielite, or pyrophanite; an ilmenite series mineral (M. E. Mrose, written communication, March 22, 1965). Microspectrochemical analyses by Claude Waring, U. S. Geological Survey, Washington, D. C., showed that it contained more than 10 percent titanium, 10 percent iron, 0.3 percent calcium-silicon, 0.1 percent magnesium, and 0.3 percent aluminum (M. E. Mrose, written communication, August 12, 1965). Although no titanium ore was discovered, a detailed study of the anorthosite (an) should be made to determine the titanium content and the possibility of ore in the area.

Vanadium content of 100 ppm or more is in 23 samples from the southwestern and western part of the quadrangle; but 300 ppm is the highest content of vanadium, which is not enough for ore grade. Fifteen of the samples are from areas underlain by the Halaban formation, six of the samples are from areas underlain by granite and granodiorite (gr), and two of the samples are from areas underlain by biotite-hornblende granite (gr). The Halaban formation (ha/hc) contains more vanadium than the granitic rocks.

MINES

Two mines were found in the Jabal Khida quadrangle. They are the Rayyaniyah(?) Mine at $21^{\circ}01'$N. Lat. and $44^{\circ}09'$E. Long., and the Za'in(?) Mine at $21^{\circ}01'$ N. Lat. and $44^{\circ}13'$E. Long. (Ministry of Petroleum and Mineral Resources 1965). Although the above locations are not exactly as given in the reference, they are the only mines found in the area. Both are reported to be gold mines, but grinding stones and other evidences of gold mines are lacking. Debris from the dump of the Rayyaniyah Mine (station 11,632) contained 100 ppm copper, the only anomalous element in the sample. The Rayyaniyah Mine is in a quartz vein in diorite or diorite-like rock. Debris from the dump at the Za'in Mine (station 11,938) contained 2 ppm silver and 150 ppm lead, which are anomalous but not unusual for a mine dump. No silver or lead minerals were seen in the mine debris. The Za'in Mine is in a quartz vein in biotite granite in the unit mapped as biotite-hornblende granite (gr) near its contact with the Halaban formation. Spectrographic analyses of wadi sand and chemical analyses of concentrates and magnetites from other stations in the area show low anomalies for copper but no anomaly for any other element.

SUMMARY

Two areas in the Jabal Khida quadrangle are interesting mineralogically and need more study. The more important area is from south of station 11,543 to north of station 11,601 and to west of station 11,599 in the adjoining quadrangle. Sand samples from this area contain beryllium, niobium, and as much as 500 ppm tin. A concentrate contains 150 ppm molybdenum, and two concentrates contain 80 ppm and 160 ppm respectively of tungsten. This area may contain commercial quantities of tin and enough beryllium, molybdenum, niobium, and tungsten to be valuable by-products. The second area includes stations 11,690 and 11,979. Concentrates from these stations contain 300 ppm tungsten; the highest in the quadrangle; however, no tungsten-bearing minerals were seen at either place.

The southwest corner of the Jabal Khida quadrangle and adjacent areas in adjoining quadrangles is an excellent place to study the Halaban formation (ha/hc) to learn if unconformities or disconformities are present, and the relation of the Halaban Formation to the granites.

REFERENCES CITED

Jackson, R. O., Bogue, R. G., Brown, G. F., and Gierhart, R. D., 1963, Geology of the Southern Najd quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-211A.

Ministry of Petroleum and Mineral Resources, 1965, Mineral resources of Saudi Arabia, a guide for investment and development: Kingdom of Saudi Arabia, Ministry of Petroleum and Mineral Resources, Directorate General for Mineral Resources, Bull. 1, pp. 73.