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MINERAL INVESTIGATIONS IN THE JABAL RADWA QUADRANGLE, NORTHWEST HIJAZ, SAUDI ARABIA

by

Robert F. Johnson and Virgil A. Trent

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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 Also on open file in that office is a large amount of material, in the form of unpublished manuscripts, maps, field notes, drill logs, annotated aerial photographs, etc., that has resulted from other previous geologic work by Saudi Arabian government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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ABSTRACT

Wadi sediments in the Jabal Radwa quadrangle in the Northwest Hijaz were sampled for trace element analysis as part of a mineral reconnaissance of Western Saudi Arabia that is being made by the Ministry of Petroleum and Mineral Resources and the U. S. Geological Survey. The Jabal Radwa quadrangle lies between 24°30' and 25°N. latitude and between 38° and 39° E. longitude. A photomosaic base at a scale of 1:100,000 was used for map compilation.

Except for basalt flows of Tertiary or Quaternary age all the rocks of the area are believed to be of Precambrian age. An older group of slightly metamorphosed mafic and felsic volcanic rocks with interbedded metasedimentary rocks is unconformably overlain by argillite and slightly metamorphosed sandstone and conglomerate. The bedded rocks are cut by many intrusions that range in composition from olivine gabbro to syenite but are predominantly granite, granodiorite, and diorite.

Little is known of the structure of the rocks. The layered rocks are strongly folded and commonly dip at high angles. Faults are common and many appear to be large; some contacts have been offset several hundred meters. Most of the larger faults trend northeasterly or northwesterly but some trend east and others nearly north.

Screened samples of wadi sediments were collected for trace-element analysis. The results described in this report are concerned with the amount of copper, zinc, and molybdenum in the magnetic fraction of the wadi sediment. The accompanying map shows sample locations with identifying marks on those samples that contained the greatest amounts of the three elements. Magnetite from the Jabal Radwa granite and surrounding rocks contains an unusually high quantity of zinc, ranging up to 1,500 parts per million. Other anomalous zinc samples occur in the northwestern part of the quadrangle. Copper and molybdenum anomalies are more scattered. Several samples with high molybdenum were obtained on the eastern side of Jabal Radwa.

The significance of the results is not known. Except for a few quartz veins that were mined for gold more than 1,000 years ago, no mineralized structures or areas of possible economic significance were seen in the course of the work. The zinc anomaly at Jabal Radwa is large enough to be of interest and further geochemical work there is recommended. The circular syenitic intrusion (gp) near the north edge of the map may also be of interest as gabbroic rocks with as much as 35 percent magnetite occur on the margins of the intrusion. The other areas that show relatively high metal content in the magnetite are not of immediate interest.

INTRODUCTION

Under the terms of an agreement made in 1963 between the governments of Saudi Arabia and the United States, geologists of the U. S. Geological Survey were to aid in a search for mineral deposits in the crystalline rocks of Western Saudi Arabia. The map that accompanies this report shows partial results of this survey in the Jabal Radwa quadrangle in the Northwestern Hijaz. The area is part of the published quadrangle, I-204, prepared by Brown and others (1963). Jabal Radwa is a prominent granite peak that lies 60 kilometers northwast of the town of Yanbu al Bahr. The Jabal Radwa quadrangle is covered by a photomosaic on a scale of 1:100,000; the area lies between 24°30' and 25°N. latitude and between 38° and 39° E. longitude.

Only the western half of the quadrangle was investigated and sampled. The analytical results shown on the map refer to trace amounts of copper, zinc, and molybdenum in magnetite separated from wadi sediments. These three elements have

proved to be useful in geochemical prospecting as indicators of mineralized areas (Hawkes and Webb, 1962, pp 364-376). It should be emphasized that, except for several ancient gold mines, no evidence of potentially economic mineral deposits was found in the course of the field work, and the reasons for the geochemical anomalies are not known. The anomalies do show areas with higher than normal metal content and serve as a guide in the event more detailed field work is contemplated.

The Jabal Radwa area lies between the Arabian plateau and the Red Sea and has been considerably dissected by erosion. Most of the area is drained by Wadi Far'ah and its tributaries. The larger wadis are filled with alluvium and have moderate gradients. They have cut deep, steep-walled valleys with relief ranging up to 500 meters. In the Jabal Radwa massif the relief is as much as 1,200 meters with spectacular boulder-choked gorges cut into the mountains.

Accessibility of much of the area is rather poor. The main road north from Yanbu al Bahr crosses the quadrangle, and tracks follow most of the larger wadis. The wadis draining areas of granite or argillite are relatively smooth and easy to traverse, but wadis in areas of metavolcanic rocks are stony and many can be traversed only by camel or on foot.

Previous mineral investigations have been confined to the gold mines in the central part of the area that were worked more than 1,000 years ago. Unpublished reports on these properties by Ahmad Shanti (1963) and K. S. Twitchell (1937) are in the files of the Ministry of Petroleum and Mineral Resources. The ancient working of Al Agangal in the northwestern part of the area has been described in an unpublished report by M. A. Bhutta (1960). The old workings have been extensively sampled and the two largest mines were drilled by the Saudi Arabian Mining Syndicate in the 1930s. The results showed only traces of gold and the work was abandoned. Only a superficial examination was made of these vein deposits during the present study.

The work was made possible by the cooperation of officials of the Ministry of Petroleum and Mineral Resources and their help is greatly appreciated. Mr. Ghazi Sultan, Chief Geologist of the Ministry, accompanied us on our first field trip into the area and helped us to make contacts to continue the work.

GEOLOGIC SETTING

Except for basalt flows of Tertiary or Quaternary age the rocks in the area are believed to be Precambrian in age. They have been divided into two stratiform units, one largely metavolcanic and one metasedimentary. These layered rocks have been intruded by several kinds of granitic and mafic rocks.

The basic geologic mapping was done by Brown and his colleagues (1963). We were able to divide Brown's schist unit into metavolcanic or metasedimentary rock so the symbol sc shown on his map has not been used on our map. Work in other parts of quadrangle I-204 has shown that rocks mapped as greenstone (gd) are not separable in the field from those mapped as Halaban andesite (ha). The two units appear to be correlative in age. They are shown in the same color on the map but the symbol 'ha' has been retained in the area not examined by us.

The oldest rocks are slightly metamorphosed lava and pyroclastic rocks interbedded with slate and slightly metamorphosed graywacke, conglomerate and, rarely, limestone. Rocks of volcanic origin predominate. They range in composition from andesite to rhyolite. The andesitic rocks are dark brown to dark greenish brown and contain clouded plagioclase phenocrysts in an aphanitic groundmass. Some chlorite has developed and that together with the slight alteration of the feldspar is commonly the only evidence of metamorphism. The rhyolitic volcanic rocks are light-colored fine-grained rocks that could not be classified in the field. Tuffs as well as flows may well be present.

Metamorphosed sedimentary rocks are interbedded with the metavolcanic rocks. They become more abundant to the west and the section is largely metasedimentary in Wadi Araj near the west border of the map. More detailed work may show these

latter rocks to be a different formation.

Slightly metamorphosed beds of the Hadiyah Formation lie unconformably on the metavolcanic rocks. Gray argillite is the predominant rock type. Red and green argillite are abundant and beds of sandstone and conglomerate are common. Several hundred meters of conglomerate crop out near the north edge of the map at 38°20'E. The conglomerate is similar to that in the Hadiyah Formation but is much thicker and is separated from the main area of Hadiyah rocks by a belt of metavolcanic rock.

The youngest layered rocks are the basalt flows of Tertiary or Quaternary age that cover the ridge crest in the eastern part of the quadrangle and enter the northwest corner. The flows are thought to be from fissure eruptions that occurred during development of the Red Sea rift.

Intrusive rocks ranging in composition from olivene-pyroxene gabbro to syenite occur in the mapped area. Granitic rocks are the most abundant. Hornblende granite, biotite granite, and granite with both hronblende and biotite occur. Hornblende granodiorite, hornblende diorite, adamellite, and quartz porphyry were also recognized in the area. Gabbro occurs in a small ring structure north of Jabal Radwa and also in the mafic ring surrounding the syenitic intrusive near the north edge of the map. The core of this latter intrusion is made up of several varieties of syenitic rock.

Only four of the many intrusions are known to intrude the Hadiyah formation. This and the presence of granite pebbles in Hadiyah conglomerate indicate that at least two ages of intrusive activity are represented.

Mafic and felsic dikes are common in the mapped area; they are most abundant in the metavolcanic rocks and in the older intrusive rocks. The dark dikes are largely lamprophyre, diabase, and andesite; the light colored dikes are reddish rhyolitic types. Classification of these fine-grained rocks is not satisfactory in the field and was not attempted. Some of the mafic dikes contain fresh

disseminated pyrite and the felsic dikes are commonly iron stained but in general the dikes do not appear to be related to sulfide mineralization.

The structure of the area is complex. The layered rocks are folded, in places isoclinally, and all rocks are cut by faults. Folds are well exposed in the Hadiyah formation. Study of the structure was beyond the scope of our work and only the larger faults that are recongizable on the air photographs are shown on the map. Several wadis that follow fault lines were sampled.

Northeast-and northwest-trending faults predominate except in the southwest corner of the map where east-trending faults are shown. In most places the fault trace is not exposed and faulting is indicated by linear valleys aligned with gaps in ridge lines. Where seen the fault trace is marked by a belt of broken rock and in places mylonite. The amount of offset and direction of movement was not determined for most faults. Some contacts are offset several hundred meters as shown on the map.

GEOCHEMICAL SAMPLING

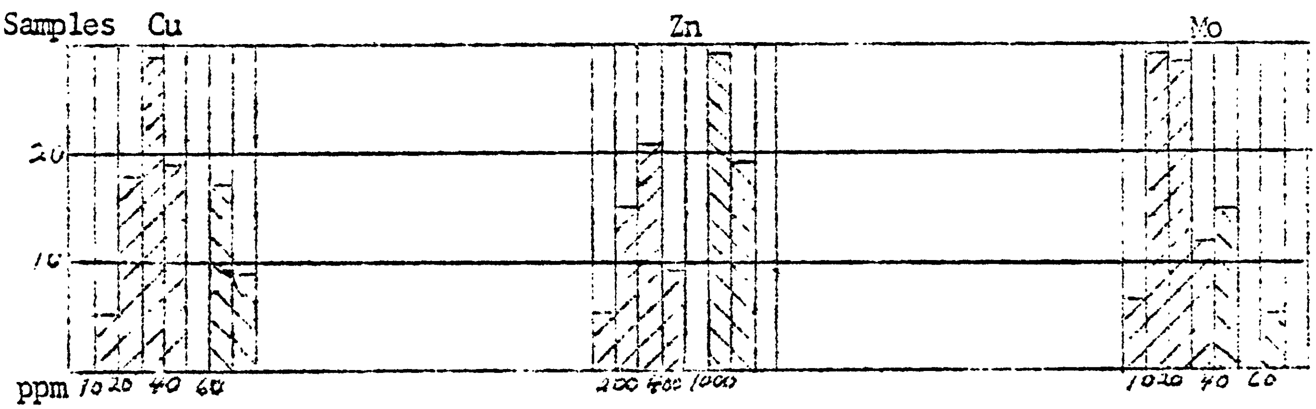
Samples for trace-element analysis were obtained form wadi sediments and in places from residual soil. Collecting was not systematic. Most samples were taken in areas that showed some evidence of possible mineralization such as bleached or dark areas, intrusive contacts, fault zones, and quartz veins. A group of samples was taken around the northern side of Jabal Radwa to further explore a zinc anomaly that had been disclosed in the course of the work. The possibility of this anomaly was pointed out by Paul Theobald, USGS (personal communication).

Samples were screened to minus 30 plus 80 mesh at the sample site. At the laboratory a portion of the sample was separated for analysis by means of a Jones splitter. Magnetite for analysis was recovered from the remainder of the sample. The samples were analysed semi-quantitatively for 27 elements using the modified method of emission spectrometry employed by the U. S. Geological Survey. The samples were also analysed by standard colorimetric techniques for copper, zinc,

and molybdenum. The spectrometric analyses were made by Charles Thompson and the colorimetric analyses by Thompson and L. AlDugaither.

Analytical results in the mapped area are complete as of this writing only for trace amounts of copper, zinc, and molybdenum in the magnetic fraction of the sample. Control work on the analysis of wadi sediments has shown that considerably more copper, zinc, and molybdenum is contained in magnetite than in bulk wadi sands (Thompson and Theobald, personal communication). This results in a greater variation in range of metal content with consequent emphasis of the anomalous samples.

The samples locations are shown on the accompanying map and samples with the highest quantities of copper, zinc, and molybdenum have distinguishing marks. Marked samples contain more than 60 parts per million (ppm) of copper, 1,000 ppm zinc, and 40 ppm molybdenum. These limits were arbitrarily determined from a histogram of analyses of all the samples. In addition to the distinguishing



mark at the sample site, the drainage area of the wadi above the anomalous sample is shown by a distinctive pattern for each of the three elements. The pattern is not used for isolated anomalous samples or if the drainage area is small.

RESULTS

The largest area with anomalous metal content is in and adjacent to the northeast quadrant of the Jabal Radwa granite. The limits of the anomalous area have not been reached, the anomaly is less marked to the west but appears to

continue strongly to the south. The anomaly is emphasized by the density of the sampling. Due to time limitations and the difficulty of access for vehicles, most samples were taken at some distance from the granite contact. Where the contact was reached the zinc content of the magnetite is almost always high. The magnetite content in the metamorphosed volcanic and sedimentary rocks is much less than that of the granite. Consequently, within those wadis that head in granite, the magnetite in the sample may be largely derived from the granite. Magnetite from some wadis that do not reach the granite also show anomalous metal content. Whether this metal is in magnetite derived from the adjacent rocks or is in reworked magnetite from an earlier erosion cycle is not known. Further sampling is needed within the intrusion to try to locate the source of the anomalous magnetite. The granite is not homogeneous. At least two kinds of hornblende granite occur as well as large masses of amphibolitic material as pendants or inclusions.

Molybdenum is present in anomalous amounts on the east side of the Jabal Radwa intrusion whereas anomalous amounts of copper are more common on the west side.

North of Jabal Radwa a few anomalous samples are in a belt about 10 kilometers wide, but they become more abundant northward to the edge of the map. It should be noted that nearly all of the anomalous samples are near intrusive rocks or are in wadis that drain intrusive rocks. Samples taken in metavolcanic rocks at some distance from the intrusive rocks are commonly not anomalous. Most samples taken to test fault zones were not anomalous.

The area underlain by rocks of the Hadiyah formation appeared in the field to have very little mineral potential and this seems to be borne out by the results from a few widely scattered samples. Some of the veins that were mined for gold are in rocks of the Hadiyah formation near the crest of a fold that has metavolcanic rocks in its core. Sparse sulfides occur in some veins but they are not economic. The sample with anomalous zinc in the Hadiyah formation near the north edge of the map is from a north-trending brecciated zone adjacent to a small plug of biotite granite.

The syenitic and related mafic rocks that form a roughly circular intrusion into the Hadiyah formation near the north edge of the map should be studied in more detail. The importance of the anomalous samples is not known but is of interest. In addition gabbroic rocks near the outer edge of the intrusion contain in places as much as 35 percent magnetite. Some geophysical work may be warranted in this area.

The reason for the anomalous amounts of metals in the magnetite is not known. No sulfide-bearing veins or structures were seen during the course of the work except the gold-bearing veins and a few outcrops with copper carbonate on fracture surfaces. Both the veins and the copper stains are several kilometers from anomalous samples. Theobald (personal communication) has pointed out that the high zinc anomaly at Jabal Radwa may be due to a high-zinc magnetite not necessarily related to an ore deposit. Magnetite and the zinc-bearing spinel franklinite are end members of a continuous series. The presence of anomalous amounts of molybdenum in the same samples is more difficult to explain. The anomalous copper in the metavolcanic rocks may be due to differences of copper content of individual flows. The copper content of the metavolcanic rocks in the mapped area is much lower than that found in many parts of the world. Hawkes and Webb (1962, p.364) give a figure of 140 ppm as average for mafic igneous rocks. We have only one sample that exceeded this figure and most of the anomalous samples contained 60 to 80 ppm.

Further work is recommended only at Jabal Radwa and at the syenitic intrusion near the north edge of the map. Neither area is of immediate interest due to the scant surface evidence for metallization, but each may be classed as third or fourth priority in a nationwide mineral program. In the event of a future more detailed mineral study the other anomalous samples shown on the map can serve as a guide to areas that should be prospected.

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Explanation

Alluvium and wadi fill

Basalt and andesite

Syenitic, sy, and associated mafic intrusives, ma. Reddish hornblende and hornblende-biotite syenite and monzonite. Mafic rocks are gabbro, in places magnetite-rich, and diorite.

Light-colored massive calc-alkaline granite. Hornblende granite at Jabal Radwa.

Gabbro. Olivene-pyroxene gabbro in ring structure.

Hadiyah formation. Gray, green, and maroon argillite with beds of fine-to medium-grained arkosic sandstone and vari-colored conglomerate.

Reddish to gray hornblende granite, biotite granite and hornblende-biotite granite. Forms discordant plutons commonly with sharp unmineralized contacts.

Gray hornblende granite with numerous inclusions and dikes. Tends to be concordant with structure in enclosing rocks. Contacts commonly gradational.

Hornblende diorite, di; hornblende granodiorite, dg. Includes one intrusion of adamellite. Dark colored rocks with inclusions and cut by numerous dikes.

Quartz prophyry intrusion possibly associated with felsic metavolcanic rocks.

Slightly metamorphosed andesitic to rhyolitic volcanic rocks including flows and pyroclastics. Mafic rocks are dark green and brown. Interbedded slate, metamorphosed graywacke, and conglomerate, and rarely limestone. Cut by many dikes that range from lamprophyres to rhyolites in composition. Rocks correlate at least in part with Halaban andesite, ha.

Contact. Dashed where approximately located dotted where concealed.

Fault. Dashed where approximately located, dotted where concealed

Road

Sample locality

Sample with more than 1000 ppm (parts per million) zinc in magnetic fraction of wadi sand. Lines show drainage area of wadi.

Sample with more than 60 ppm copper in magnetic fraction of wadi sand. Lines show drainage area of wadi.

Sample with more than 40 ppm molybdenum in magnetic fraction of wadi sand. Lines show drainage area of wadi.