

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

RECONNAISSANCE GEOLOGY OF THE AL UFAYRIYAH QUADRANGLE,

SHEET 20/42 A

KINGDOM OF SAUDI ARABIA

by

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ABSTRACT

The Al Ufayriyah quadrangle is located in the Najd Plateau of southwestern Saudi Arabia between lat 20°30' and 21°00' N., long 42°00' and 42°30' E. Two-thirds of the quadrangle is underlain by Precambrian metasedimentary, metavolcanic, plutonic, and hypabyssal intrusive rocks; this area is in part mountainous and in part uneven plains. One-third is underlain by Cenozoic basalt and is part of Harrat Buqum. Flows, which surround volcanic cones, form an east-dipping surface of low relief.

Precambrian metavolcanic and metasedimentary rocks are mostly metamorphosed andesite and basalt flow rocks and tuffs and are divided into two principal belts in the eastern and central to western parts of the quadrangle. Plutonic rocks, which are part of the An Nimas batholith, consist of tonalite, diorite, and some quartz diorite. These rocks are postdated by younger plutonic and hypabyssal rocks that include extensive graphic granite and rhyolite, several small bodies of granite, and meta-andesite dikes.

Volcanoes on Harrat Buqum are cinder cones, composite cones, shield volcanoes, and lava cones; basalt flows originating in some of the volcanoes can be traced down the slope of the harrat, and some have blocked Wadi Ranyah causing deposition of silt, sand, and gravel.

Radiometric age dating of Precambrian rocks from adjacent quadrangles suggests that the layered rocks of the Al Ufayriyah quadrangle may have formed about 900 Ma ago, plutonic rocks of the An Nimas batholith 835 to 800 Ma ago, and younger plutonic rocks from 640 to 570 Ma ago. Basalts of Harrat Buqum range in age from 3.5 to 1.72 Ma.

A zone in the eastern part of the quadrangle contains small gold-quartz veins, a quartz breccia reef, and a contact metasomatic iron deposit.

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INTRODUCTION

The Al Ufayriyah quadrangle, sheet 20/42 A, is located in southwestern Saudi Arabia between lat 20°30' and 21°00' N., long 42°00' and 42°30' E. and has an area of about 2870 km² (fig. 1). The center of the quadrangle is about 200 km east-southeast of At Taif and about 90 km northwest of Bishah.

The quadrangle is named for the village, Al Ufayriyah, that extends for a few kilometers along Wadi Ranyah in the southwestern part of the quadrangle and that is the only permanent settlement. The rest of the quadrangle is sparsely inhabited by bedouin who raise camels, sheep, and goats. The area most favored by the bedouin is near the center of the quadrangle and is underlain by silt, sand, and gravel (pl. 1). Other bedouin grazing areas are the granite highlands in the south-central part of the quadrangle, the lowlands directly east of there, and the alluviated area near the crest of Harrat Buqum near the northwest corner of the quadrangle.

No paved highways enter the quadrangle, and the area is difficult to reach by vehicle. The main track serving the center of the quadrangle enters at the southern boundary and generally follows Wadi Ranyah. Branch tracks go east from the center of the quadrangle to the eastern boundary, and one track goes northwest onto Harrat Buqum. Other minor tracks make most of the quadrangle accessible.

Previous work and present study

The Al Ufayriyah area is covered by the 1:500,000-scale geologic map of the Southern Najd quadrangle (Jackson and others, 1963). Surrounding quadrangles except those to the west and northwest have been mapped as part of the 1:100,000-scale mapping program of the U.S. Geological Survey (USGS). The mapped quadrangles include Harrat Nawasif to the north (Greene, *in press*), Ranyah to the northeast (Greene, *in press*), Wadi al Miyah to the east (Schmidt, 1981b), Al Junaynah to the southeast (Schmidt, 1981a), Thaniyah to the south (Greene, *unpub data*), and Al Aqiq to the southwest (Greenwood, 1975).

The geology of the Al Ufayriyah quadrangle was mapped by helicopter in February, March, and April 1979, November 1980, and January and November 1981; samples were collected at 415 field stations. Volcanoes on Harrat Buqum were similarly mapped. Each volcano has been numbered in a sequence continuous with that used in the Harrat Nawasif quadrangle to the north (Greene, 1981).

Mineral localities described in this report are identified by a unique five-digit number (MODSxxxxx) and are

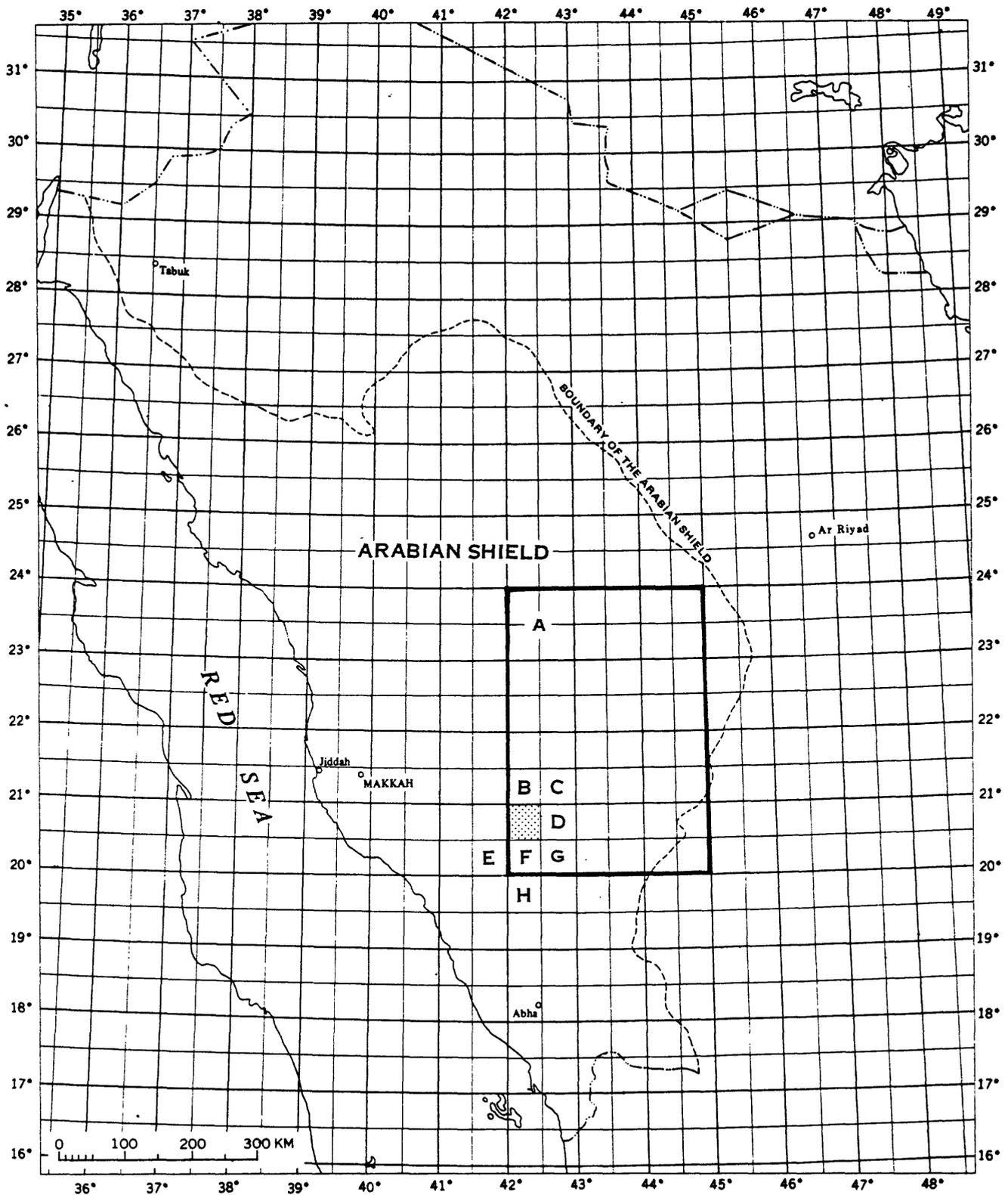


Figure 1.—Index map of western Saudi Arabia showing location of the Al Ufayriyah quadrangle (shaded) and other quadrangles referred to in this report: A, Southern Najd (Jackson and others, 1963); B, Harrat Nawasif (Greene, *in press*); C, Ranyah (Greene, *in press*); D, Wadi al Miyah (Schmidt, 1981b); E, Al Aqiq (Greenwood, 1975); F, Thaniyah (Greene, 1982); G, Al Junaynah (Schmidt, 1980a); H, Wadi Tarj (Anderson, *data*).

recorded in the Mineral Occurrence Documentation System (MODS) data bank. Inquiries regarding this data bank may be made through the Office of the Technical Advisor, Saudi Arabian Deputy Ministry for Mineral Resources, Jiddah.

The work for this report was performed by the U.S. Geological Survey in accordance with a work agreement with the Saudi Arabian Ministry of Petroleum and Mineral Resources.

Physiography

The Al Ufayriyah quadrangle lies in the western part of the Najd physiographic province of western Saudi Arabia. In the southern part of the quadrangle, areas underlain by granite are mountainous with summit altitudes of about 1300 m. In the southeastern part of the quadrangle, lowlands underlain by tonalite, quartz diorite, and diorite have altitudes of 1050 to 1100 m. Areas underlain by metamorphic rocks or rhyolite mostly have valley and ridge topography of moderate relief, but a few ridges in the easternmost part of the quadrangle are prominent. Altitudes of these areas are 1200 to 1260 m in the southwestern part of the quadrangle and 960 to 1100 m in the eastern part.

The northwestern and north-central parts of the quadrangle are mostly underlain by lava flows of Harrat Buqum. The surface of the harrat has little relief but is rough in detail (see description of basalt flows) and includes numerous volcanoes, particularly along the harrat axis in the northwestern part of the quadrangle. Along this axis, near the northwest corner of the quadrangle, altitude is about 1500 m; it decreases southward to 1200 m and eastward to 930 m at the edge of the lava flows.

In the central part of the quadrangle, numerous large and small kipukas, or hills of older rock, emerge above the surrounding lava flows. Relief on these rather striking features rarely exceeds 100 m. Wadi Ranyah enters the quadrangle at the southern boundary in a broad valley at an altitude of about 1170 m. In the central part of the quadrangle, it flows in a canyon of considerable scenic beauty that is as deep as 300 m. The canyon walls are in part basalt of Harrat Buqum and in part granite. Wadi Ranyah leaves the quadrangle at the northern boundary at an altitude of about 930 m.

PRECAMBRIAN ROCKS

Layered rocks

Metavolcanic rocks, western belt

Metavolcanic rocks of the western belt (mw) underlie some of the southwestern part of the quadrangle north of Jabal Rafa. This rough country of small relief has abundant outcrop. The rocks are mostly meta-andesite flow rock, tuff, and breccia, in part porphyritic. Some metabasalt is also present. The absence of bedded tuffaceous sedimentary rocks distinguishes this unit from the metamorphic rocks of the central belt.

The meta-andesites are medium to dark gray, locally olive green or greenish gray, and have aphanitic to fine-grained groundmass. Some are distinctly porphyritic, particularly those from the northeasternmost outcrop area. Plagioclase phenocryst content is as much as 20 percent, and a few percent clinopyroxene phenocrysts are locally present. The groundmass mostly consists of various amounts of plagioclase, actinolite, chlorite, epidote, opaque minerals, and rock fragments. Groundmass textures are locally flow and locally fragmental; the more porphyritic rocks are generally fragmental.

This unit and the rhyolite unit are the probable equivalents of metavolcanic rocks of the western belt in the Thaniyah quadrangle, although the outcrop is not continuous.

Metavolcanic and metasedimentary rocks, central belt

Metavolcanic and metasedimentary rocks of the central belt (mc) are found in the southwestern part of the quadrangle and are continuous with those of the similarly named unit in the Thaniyah quadrangle (Greene, ^{unsub} ~~data~~). The most distinctive rocks in this unit are gray to greenish-gray, greenish-black, and grayish-black tuffaceous siltstone, sandstone, and conglomerate of andesitic composition. They are characteristically well-bedded; coarser and finer grained layers a few meters thick weather into differential relief and form distinctive small ridges. Framework grains and pebbles mostly consist of plagioclase and andesitic rock fragments, although silicified fragments are locally present. Strike lines (pl. 1) generally show bedded sedimentary rocks.

Interlayered with the sedimentary rocks are more massive andesite tuffs and flow rocks, which are also gray and greenish gray and aphanitic to fine grained. Where strike lines are not shown on plate 1, the belt entirely consists of massive tuffs and flow rocks. Tuffs and flow rocks consist

of plagioclase, quartz, actinolite or hornblende, chlorite, epidote, opaque minerals, and altered phenocrysts of plagioclase and hornblende. Rock fragments are visible in the coarser tuffs.

At several localities near Wadi Ranyah, both north and south of Al Ufayriyah, a distinctive, very fine grained, thinly bedded, grayish-black tuffaceous siltstone is exposed. A lustrous black patina has developed on outcrops that have bedding weathered into differential relief. This siltstone is interlayered with coarser grained, lighter colored tuffaceous sedimentary rocks.

South of Jabal Rafa, near the northeast corner of the Al Aqiq quadrangle (lat 20°26'40" to 20°27' N., long 41°58' to 41°59'20" E.), this distinctive siltstone is the most abundant rock type. Greenwood mapped this part of the Al Aqiq quadrangle as Rafa formation of the Ablah group, which he describes as mostly consisting of medium- to coarse-grained arkose and poorly sorted, nonbedded conglomerate (1975a, p. 6). This area is more nearly on strike with the metavolcanic rocks of the western belt and the rhyolite units of the Al Ufayriyah quadrangle than it is with the metavolcanic rocks of the central belt, where the continuation of the distinctive siltstone is found. I believe that the structure and stratigraphy both north and south of Jabal Rafa are too poorly understood to justify extending the names Ablah group or Rafa formation into the Al Ufayriyah quadrangle.

Metavolcanic and metasedimentary rocks, eastern belt

Metavolcanic and metasedimentary rocks of the eastern belt (me) are in part compositionally similar to those in the Thaniyah quadrangle to the south (Greene, ^{W.C.U.P.} ~~data~~), although separated from them by intrusive granite. The belt is continuous northward across the Al Ufayriyah quadrangle and into the Harrat Nawasif quadrangle.

The rocks in this unit include meta-andesite, metabasalt, amphibolite, and tuffaceous sedimentary rocks, which are mostly dark-gray and greenish-gray to black and very fine to medium grained. Meta-andesite and metabasalt consist mostly of plagioclase and actinolite or hornblende with trace amounts of opaque minerals. The more altered rocks also contain quartz, epidote, chlorite, and calcite. Amphibolite contains more than 50 percent hornblende. In places, textures indicate flow rocks or tuffs, but the primary textures are commonly obscured by replacement. The tuffs grade into tuffaceous sedimentary rocks of similar composition; the sedimentary rocks are well bedded in contrast to the tuffs. Rocks in this belt are metamorphosed to greenschist and amphibolite facies assemblages.

Rhyolite

Two areas in the southwestern part of the quadrangle are underlain by rhyolite (rh). The rhyolite is well exposed on low, rough ridges and in small kipukas and is varied in color and texture. It is brownish gray to reddish brown or light to dark greenish gray and commonly aphanitic, but it may show flow-banding or breccia texture. Most of the rhyolite is aphyric but some contains trace to a few percent phenocrysts of quartz, plagioclase, and (or) opaque minerals. Groundmass texture is mostly granular or spherulitic, but some has the distinct eutaxitic texture of ash-flow tuff.

Mixed rocks

Metavolcanic rocks of eastern belt and granite

Metavolcanic rocks of eastern belt and granite (meg) consist of a mixed unit of metavolcanic rocks similar to those described for the eastern belt (me) and granite and rhyolite similar to that described for the graphic granite and rhyolite unit (ggr).

Diorite and tonalite

Diorite and tonalite (dqt) consist of a mixed unit of diorite and quartz diorite similar to that described for the diorite and quartz diorite unit (dq) and tonalite similar to that described for the tonalite and quartz diorite unit (to).

Diorite and granite

Diorite and granite (dgg) consist of a mixed unit of diorite and quartz diorite similar to that described for the diorite and quartz diorite unit (dq) and granite and rhyolite similar to that described for the graphic granite and rhyolite unit (ggr).

Plutonic and hypabyssal intrusive rocks

Diorite and quartz diorite

Diorite and quartz diorite (dq) are found in a discontinuous north-trending band in the eastern part of the quadrangle and in additional areas in the central, south-central, and southwestern parts. In both the eastern and southwestern parts, they are locally combined with tonalite and quartz diorite in a mixed unit. They are also locally combined with graphic granite and rhyolite. Diorite and quartz diorite are generally associated with the metavolcanic rocks and constitute the oldest part of the An Nimas batholith in this area (Greenwood, 1975; Anderson, 1977; Greene, ^{unpub.} data).

Areas underlain by these rocks have low relief but abundant outcrop. These areas commonly are higher than adjacent areas underlain by tonalite but are generally lower than those underlain by metavolcanic rocks or granite. Outcrops of diorite and quartz diorite are very heterogeneous in appearance. Coarse-grained, black and light-gray rocks intrude medium- to fine-grained, dark-gray rocks, and all are commonly sheared and fractured.

Most of the diorite consists principally of 60 to 80 percent plagioclase, and 10 to 30 percent hornblende. Some contains 1 to 10 percent clinopyroxene forming the cores of hornblende grains. Most of the rocks contain 1 to 15 percent quartz, although in those that are more altered this may be entirely secondary. Rocks in which quartz constitutes 5 to 20 percent of the light-mineral content are classified as quartz diorite (Streckeisen, 1973). Biotite, sphene, and opaque minerals in trace amounts are common accessory minerals. In most of the rocks, part of the hornblende is altered to chlorite and epidote, and, in some, actinolite replaces hornblende. Textures are xenomorphic to hypidiomorphic granular and are modified by replacement or cataclasis.

Tonalite and quartz diorite

Tonalite and quartz diorite (to) underlie a continuous although partly concealed belt and crop out as several outliers in the eastern part of the quadrangle. They also crop out in small areas in the southwestern and south-central parts of the quadrangle. Two areas at the southern quadrangle boundary form the northern ends of two belts that are more fully developed in the adjacent Thaniyah quadrangle (Greene, ^{unseen} ~~date~~). Tonalite and quartz diorite form the younger phase of the An Nimas batholith; they post-date and intrude diorite and quartz diorite.

The tonalite and quartz diorite are mostly medium to coarse grained and light gray to white with a greenish-black to black speckle caused by grains of mafic minerals. The outcrops generally are covered with dark-gray to black patina. In the Al Ufayriyah quadrangle, these rocks generally underlie low-lying pediments. Outcrop surfaces slope gently away from low ridges that have meta-andesite dikes on the crests.

The most abundant rock in this unit is tonalite, which consists of 60 to 80 percent plagioclase, 20 to 35 percent quartz, and from trace to 10 percent mafic minerals. Fresh tonalite contains from trace to 5 percent each of hornblende and biotite. Commonly, hornblende and biotite are partly to completely altered to chlorite and epidote. Apatite and sphene are common accessory minerals, and opaque minerals are always present. Textures are xenomorphic to hypidiomorphic granular and are locally cataclastic.

Quartz diorite, containing 10 to 20 percent quartz, is less abundant but is otherwise similar to tonalite.

Gabbro

Gabbro (gab) underlies a small jabal directly east of Wadi Ranyah at the southern boundary of the quadrangle. This outcrop is in line with several larger bodies of gabbro that form a belt that strikes N. 45° E. across the Thaniyah quadrangle (Greene, ^{unpub.} ~~data~~). The gabbro is coarse grained and is black with light-gray mottle. The sample studied was melagabbro containing about 50 percent hornblende that is in reaction relationship to clinopyroxene (25 percent), 25 percent plagioclase, 1 percent hypersthene, and trace amounts of biotite and opaque minerals.

Biotite granite

Biotite granite (bg) forms a nearly circular pluton adjacent to Wadi Ranyah at the southern boundary of the quadrangle. The area underlain by the granite is flat but outcrop is abundant. The granite is coarse grained and dominantly light to dark pink; the pink, light-gray, and black of individual mineral grains form a distinctive granular texture.

The granite consists of about 65 percent perthitic potassium feldspar, about 25 percent quartz, about 10 percent plagioclase, 0.5 to 1 percent biotite and chlorite, and trace amounts of zircon, sphene, and opaque minerals. The presence of biotite and the absence of both muscovite and amphibole distinguish this granite.

Perthite granite of Jabal Suily

Perthite granite of Jabal Suily (grs) underlies a small area near the northeast corner of the quadrangle. Jabal Suily is part of a rugged north-trending mountain range that is partly in the Harrat Nawasif, Ranyah, and Wadi al Miyah quadrangles.

Most of the granite is salmon pink flecked with black mafic minerals and is medium to very coarse grained. Some is slightly porphyritic and some has rapakivi texture. The granite consists mostly of 60 to 75 percent cloudy perthitic potassium feldspar and 25 to 35 percent quartz. Discrete grains of plagioclase are sparse or absent; only locally do they form 1 to 15 percent of the rock. Mafic minerals include trace to a few percent hornblende, biotite, and, locally, alkali amphibole. Accessory sphene, zircon, and opaque minerals and secondary chlorite and epidote are also present.

Perthite granite, fine grained

Part of Jabal Suily is underlain by a distinctive fine-grained granite (grf), which is characteristically reddish-brown and darker in color than the related perthite granite of Jabal Suily; however, these two granites have similar mineralogies.

Graphic granite and rhyolite

Graphic granite and rhyolite (ggr) underlie large areas in the south-central and southeastern parts of the quadrangle and extend northwest into Harrat Buqum where they form many large and small kipukas. These rocks also underlie Jabal Rafa, which lies in the southwestern part of the quadrangle and extends into the adjacent unnamed quadrangle to the west, and into the Thaniyah and Aqiq quadrangles.

Graphic granite and rhyolite generally underlie rough, mountainous areas. The abundant outcrops are segmented by many faults and joints, which gives them a blocky appearance. Surface patina is brown, and the rocks are commonly weathered and crumbly.

Graphic granite is the most distinctive rock in this unit. It is dull pink and medium to coarse grained. It consists of 35 to 65 percent potassium feldspar, 25 to 35 percent quartz, and 1 to 25 percent plagioclase, with trace amounts of hornblende, biotite, opaque minerals, sphene, and zircon, and secondary epidote and chlorite. Locally, traces of alkali amphibole are also present. The potassium feldspar is somewhat perthitic, especially in rocks containing little plagioclase. Some quartz is in large anhedral grains but most is intimately mixed with potassium feldspar in graphic texture.

Some granite is very coarse grained and the pink, gray, and black colors of the individual minerals are visible. Mineral composition is the same as the graphic granite, but texture is xenomorphic granular. Other granite is fine to very fine grained and grades into rhyolite. These rocks are uniform pink or may be streaked lighter and darker pink. These are single-feldspar granites with variable proportions of quartz. Graphic texture grades into vermicular, plumose, and spherulitic textures.

Monzogranite

Monzogranite (grw), which is distinct from granite of the graphic granite and rhyolite unit, underlies part of the area west of Wadi Ranyah in the southern part of the quadrangle. The monzogranite is pink, gray, or greenish gray, medium to

coarse grained, and contains prominent black grains of mafic minerals. It consists of about 35 percent potassium feldspar, about 25 percent quartz, and about 40 percent plagioclase, trace to a few percent hornblende, and trace amounts of biotite, sphene, zircon, and opaque minerals. Secondary chlorite and epidote are nearly ubiquitous. This granite is characterized by even, hypidiomorphic-granular texture.

Meta-andesite dikes

Meta-andesite dikes are abundant in all areas underlain by tonalite and quartz diorite and in some areas underlain by diorite and quartz diorite and metavolcanic rocks of the central belt. The dikes commonly crop out on the crests of low ridges because the dike rock is more resistant to weathering than the adjacent country rock. The meta-andesite is brown and aphanitic to fine grained. It mostly consists of cloudy, saussuritized plagioclase, chlorite, epidote, and opaque minerals.

CENOZOIC VOLCANIC AND SEDIMENTARY ROCKS

Much of the northwestern and north-central parts of the quadrangle are covered by volcanic rocks which are a part of Harrat Buqum. Harrat Buqum is continuous with Harrat Nawasif directly to the north, and together they form a harrat, or volcanic upland, 180 km long, one of several in western Saudi Arabia (Jackson and others, 1963; U.S. Geological Survey and Arabian/American Oil Company, 1963; Greene, *in press*).

Basalt flows

Basalt deposited as flows (QTb) forms the bulk of Harrat Buqum. The basalt is dark gray to black, fresh, and aphanitic to fine grained. Original flow surfaces are abundantly exposed, and the routes of individual flows can be locally traced (pl. 1). Sections of one or more flows, each 1 to 10 m thick, are seen locally in canyons. Thicker flows have vesicular zones on top and bottom; thin flows may be entirely vesicular.

These rocks are typical alkali-olivine basalt. Their mineralogy is virtually identical from sample to sample but proportions vary considerably. They contain 40 to 65 percent plagioclase, 15 to 40 percent clinopyroxene, 5 to 10 percent olivine, 1 to 10 percent opaque minerals, and 1 to 10 percent glass and altered glass; a few contain secondary calcite. Olivine is present as phenocrysts in some rocks; in others it is present as both phenocrysts and groundmass grains. Samples from Harrat Buqum were not tested for nepheline; however, they are similar to samples collected in the Harrat Nawasif quadrangle (Greene, *in press*) that contain trace amounts of this

mineral. Therefore, it is likely that the basalts from the Al Ufayriyah quadrangle also contain nepheline.

Cinder cones

Cinder cones (Qcc) are abundant in the axial part of Harrat Buqum. Most (for example, numbers 298, 299, 310, 320) are roughly circular in plan and are formed around a single vent; others (for example, numbers 303, 316, 326) are complex and are related to several vents.

Most of the cinder cones are moderately to severely eroded; gullies expose the internal structure. A typical cinder cone consists of well-bedded, steeply dipping reddish-brown cinder. The cinder is angular, commonly 0.5 to 5 cm in maximum dimension, and mostly loose but locally slightly welded. The cinder beds dip outward away from the vent, and bedding surfaces form dip slopes.

Most cinder cones have a central crater at the top that generally is covered with welded spatter. Most of the spatter dips into the crater. It consists of firmly welded cinders and bombs that locally have flowed for short distances.

Composite cones

Composite cones (Qco) are those which contain inter-layered lavas and cinders. A few composite cones are present in the axial area of Harrat Buqum, and a few larger ones are on the flank of the axial zone and farther east (pl. 1).

Some composite cones (numbers 304, 306) are essentially similar to cinder cones but have one or more interlayered lava flows. Others (numbers 315, 322) are more complex in nature and contain substantial amounts of both lavas and cinders, commonly irregularly distributed. Still other composite cones (numbers 339, 341, 351) are similar to shield volcanoes but have cinders interlayered with the lavas near the vent.

Shield volcanoes

Shield volcanoes (Qsh) are found mostly in the axial zone of Harrat Nawasif and Harrat Buqum. Only one volcano is located completely in the Al Ufayriyah quadrangle. These are broad cones of low slope, and are formed entirely of lavas flowing radially outward from the central vent.

The shield volcanoes in this quadrangle do not have large, open craters, but several in the Harrat Nawasif quadrangle have such craters, which reveal the structure of the upper part of the volcano. There the shields are shown to be

composed of 1- to 5-m-thick basalt flows that commonly thicken and thin over short distances.

Lava cones

Two small features (numbers 346, 347) are mapped as lava cones (Q1). These are volcanoes composed entirely of basalt flows, but their shape is more irregular and steeper-sided than that of the shield volcanoes.

Silt, sand, and gravel

Near Wadi Ranyah in the central part of the quadrangle, extensive deposits of silt, sand, and gravel (Qs) apparently are interlayered with the terminal edges of basalt flows of Harrat Buqum.

The principal material of these deposits is light-yellowish-gray to greenish-gray, weakly consolidated silt. The silt contains thin (~1 cm) layers of gypsum and local nodules of caliche. Fine- to medium-grained sand in 0.1- to 2-m-thick beds is interlayered with the silt. The sand locally contains pebbles.

The deposits are capped with lag gravels. These are found at several levels descending toward Wadi Ranyah. The lag gravels consist of pebbles and cobbles, 1 to 20 cm in diameter, that are composed of volcanic rocks, minor vein quartz, and diorite. The surface gravel is coated with black patina. Beneath the surface, the gravel is cemented with calcite to form a caliche. Gravel 1 to 2 m thick overlies the silt with a sharp contact.

Alluvium

Alluvium (Qa) is present in the channels of all the major and minor wadis and locally covers a flood plain and low terraces as well. This alluvium consists mostly of sand but may contain cobbles and gravel in the stream channels.

Alluvium mapped near the axis of Harrat Buqum near the northwest corner of the quadrangle consists mostly of eolian silt.

PRECAMBRIAN STRUCTURE AND GEOLOGIC HISTORY

The oldest rocks in the Al Ufayriyah quadrangle are the metavolcanic and metasedimentary rocks of the western, central, and eastern belts. All the belts trend northward and mostly consist of steep- to vertically dipping layered rocks. Fold axes are rarely seen, however, and the direction of tops or the amount of repetition of section has not been determined.

Diorite and quartz diorite are the oldest intrusive rocks and are closely associated with the layered rocks. Tonalite and quartz diorite intrude both the layered rocks and the diorite and quartz diorite unit. These two major intrusive rock units (to and dq) are part of the An Nimas batholith, a major north-trending plutonic body that extends at least 165 km south of the quadrangle boundary. The full length of the An Nimas batholith remains uncertain because its northern end is buried by lavas of Harrat Buqum and Harrat Nawasif; however, the most northerly exposures of tonalite in the Harrat Nawasif quadrangle indicate a minimum length of 230 km (Greene, *in press*).

Graphic granite and rhyolite form a belt extending across parts of the Al Junaynah, Thaniyah, and Al Ufayriyah quadrangles that is 15 to 20 km wide and 68 km long. This body trends northwesterly and cuts across the An Nimas batholith and the belts of layered rocks.

The predominant trend of faults and dikes in the south-central part of the quadrangle is N. 70° W., and in the southwestern part the predominant trend becomes N. 45° E. Some of these faults curve and join and others intersect, forming a rhombic pattern of fault blocks. In the southeastern part of the quadrangle faults trend N. 60° E. parallel to dikes to the north. Dikes commonly intrude the rocks of the An Nimas batholith, but some intrude the graphic granite and rhyolite near its margins.

These trends of faults and dikes are related to the Najd faulting episode. Shear direction of N. 70° W. caused the development of faults in parallel and conjugate directions and provided zones of weakness for dike intrusion.

CENOZOIC GEOLOGIC HISTORY

Eruption of basalt to form Harrat Buqum probably began at rifts near the axis of the harrat. Such eruptions produced thick basalt flows such as the Wadi Ranyah tongue in the Ranyah quadrangle (Greene, *in press*). Eruption of basalt and cinders from central-vent type volcanoes followed, particularly along the axis of Harrat Nawasif in the Harrat Nawasif quadrangle (Greene, *in press*). South of lat 21° N. in the Al Ufayriyah quadrangle and in the unnamed quadrangle to the west, the axis is less clearly defined and the volcanoes are more scattered. Nevertheless, most of the basalt now at the surface in the Al Ufayriyah quadrangle originated in volcanoes high on the harrat near the axis that crosses the quadrangle near the northwest corner (pl. 1).

Lavas also emanated from several composite cones low on the harrat in the central part of the quadrangle (pl. 1, only a few flow directions shown). These lavas dammed Wadi Ranyah, causing the formation of a series of lakes, whose existence is recorded by the silt, sand, and gravel deposits still present there. Wadi Ranyah eventually overflowed the lakes and cut a substantial canyon through the lavas as it re-established its course to the northeast. Its course, however, was guided parallel to the flow lobes of lava.

GEOCHRONOLOGY

Radiometric ages of Precambrian rocks that may correlate with rocks in the Al Ufayriyah quadrangle are discussed in the reports on adjacent quadrangles (Ranyah, Greene, *in press*; Wadi al Miyah, Schmidt, 1981b; Harrat Nawasif, Greene, *in press*; Thaniyah, Greene, *in press*). The dates available suggest the following age ranges for plutonic rocks in the Al Ufayriyah quadrangle: diorite, quartz diorite, and tonalite of the An Nimas batholith, 835 to 800 Ma; biotite granite and gabbro, 640 to 620 Ma; perthite granite of Jabal Suily, 600 Ma; graphic granite and rhyolite, 570 Ma.

The ages of the layered rocks are difficult to decipher. A date of 912 Ma from a sample collected near An Nimas (Fleck and others, 1980) may be too old in absolute terms, but is consistent with ages of rocks of the An Nimas batholith that intrude it (835 to 800 Ma). A date of 785 Ma for layered rocks from the Al Junaynah quadrangle (Fleck and others, 1980) is generally accepted as the time of formation; however, this age is younger than the An Nimas batholith, and all units of layered rocks in the Al Ufayriyah quadrangle appear to be intruded by this batholith, and hence must be older.

Potassium-argon (K-Ar) dates on basalts from Harrat Buqum and Harrat Nawasif are as follows: 1.72 ± 1.16 Ma from lat $20^{\circ}49'$ N., long $42^{\circ}17'$ E. in the Al Ufayriyah quadrangle and 1.1 ± 0.3 Ma and 3.5 ± 0.3 Ma from two localities in the Ranyah quadrangle (Hotzl and others, 1978). The last age is from a sample collected near the terminus of a thick flow, the Wadi Ranyah tongue, which probably originated in an early stage fissure eruption on Harrat Nawasif. Thus, eruption of basalt on the harrats began not later than Pliocene and lasted as long as 2.5 Ma, possibly into the Holocene.

ECONOMIC GEOLOGY

Mineral occurrences in the Jabal Selm area

A zone containing a number of mineral occurrences lies in the east-central part of the quadrangle and extends from lat 20°41' N., long 42°28' E. to lat 20°47'30" N., long 42°22'30" E. This area includes a contact metasomatic iron deposit (MODS01123), a quartz breccia reef (MODS01121), and many small gold-quartz veins (MODS01116, 01117; Schmidt, 1980b, p. 68, 76, 80; tables 4, 9; fig. 18).

The contact metasomatic iron deposit consists of massive garnet-magnetite-quartz gneiss and caps a ridge locally known as Jabal Selm. Magnetite is locally concentrated, and there is potential for a massive magnetite deposit.

The quartz-breccia reef does not contain anomalous quantities of gold; however, selected grab samples from prospects and one ancient mine (MODS01116; plate 1) in gold-quartz veins have gold values as high as 89 ppm (Schmidt, 1981a, p. 80, table 9).

Geochemical survey

A geochemical survey of the mineral potential of the Al Ufayriyah quadrangle was carried out by M. D. Fenton (Fenton, ^{no. cont.} ^{data:} 1992). Fenton analyzed splits of rock samples that the author collected during mapping and collected additional samples both of normal rocks and altered or mineralized rocks. Metavolcanic and plutonic rocks were analyzed for gold, silver, copper, lead, and zinc by the atomic absorption method using nitric acid extraction. In addition, plutonic rocks were analyzed on an X-ray fluorescence spectrometer for zirconium, yttrium, niobium, molybdenum, rubidium, strontium, and thorium.

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