UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Reconnaissance geology of the Thaniyah quadrangle, sheet 20/42C, Kingdom of Saudi Arabia

by

Robert C. Greene 1/

Open-File Report 83- 448

Prepared for the Ministry of Petroleum and Mineral Resources
Deputy Ministry for Mineral Resources
Jiddah, Kingdom of Saudi Arabia

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

1/ U.S. Geological Survey, Reston, VA 22092

1983

CONTENTS

ILLUSTRATIONS

[Plate is in pocket]

RECONNAISSANCE GEOLOGY OF THE THANIYAH QUADRANGLE, SHEET 20/42 C, KINGDOM OF SAUDI ARABIA

by

Robert C. Greene

ABSTRACT

The Thaniyah quadrangle, sheet 20/42 C, is located in the transition zone between the Hijaz Mountains and the Najd Plateau of southwestern Saudi Arabia between lat 20°00' and 20°30' N., long 42°00' to 42°30' E. The quadrangle is underlain by Precambrian metavolcanic, metasedimentary, plutonic, and dike rocks. Metavolcanic rocks consist of metamorphosed basalt and andesite with minor dacite and rhyolite and underlie three discontinuous northwest-trending belts. Metasedimentary rocks are confined to small areas underlain by quartzite, metasandstone, marble, and calc-silicate rock.

Plutonic rocks include an extensive unit of tonalite and quartz diorite and a smaller unit of diorite and quartz diorite, which occupy much of the central part of the quadrangle. A small body of diorite and gabbro and a two-part zone of tonalite gneiss are also present. All of these plutonic rocks are assigned to the An Nimas batholith.

Younger plutonic rocks include extensive graphic granite and rhyolite in the northeastern part of the quadrangle and several smaller bodies of granitic rocks and of gabbro.

The metavolcanic rocks commonly have strong foliation with northwest strike and steep to vertical dip. Diorite and quartz diorite are sheared and brecciated and apparently syntectonic. Tonalite and quartz diorite are both foliate and nonfoliate and were intruded in episodes both preceding and following shearing. The granitic rocks and gabbro are posttectonic.

Trends of faults and dikes are mostly related to the Najd faulting episode.

Radiometric ages, mostly from adjacent quadrangles, suggest that the An Nimas batholith is 835 to 800 Ma, gabbro and granite, except the graphic granite and rhyolite unit, are about 640 to 615 Ma, and the graphic granite and rhyolite 575 to 565 Ma old.

Metavolcanic rocks similar to those hosting copper and gold mineralization in the Wadi Shuwas mining district adjacent to the southwestern part of the quadrangle are abundant. An ancient copper mine was discovered at the edge of the tonalite gneiss belt east of Wadi Ranyah. Granite and gabbro have economic potential as building stone.

INTRODUCTION

The Thaniyah quadrangle, sheet 20/42 C, is located in southwestern Saudi Arabia between lat 20°00' and 20°30' N., long 42°00' and 42°30' E., and has an area of 2,875 km^2. The center of the quadrangle is about 225 km southeast of At Taif (fig. 1). The southeast corner of the quadrangle is only 10 km west of Bishah.

Permanent population is concentrated in several villages along Wadi Tabalah in the south-central part of the quadrangle. Date palms, hay, and vegetable crops are raised here. The largest of these villages, Thaniyah, lies directly west of a water gap in a prominent north-south ridge. Thaniyat is an Arabic word for gorge, and apparently the village, and thus the quadrangle, was named for the water gap (see Pl. 1).

A modern paved highway connects Bishah with the At Taif-Abha highway south of Biljurshi. West of Bishah, the highway cuts across the southeastern corner of the Thaniyah quadrangle and continues westward just south of the quadrangle boundary. Thaniyah and the other villages along Wadi Tabalah are served by short secondary roads. The rest of the quadrangle is served by a network of ungraded tracks that provide good access. A rather spectacular mountain road winds west from Thaniyah to Wadi Shuwas in the northeastern part of the Biljurshi quadrangle. A main track of historical significance, formerly the main route from At Taif to southern Saudi Arabia and Yemen, extends from northwest to southeast across the quadrangle.

Previous work and present study

The Thaniyah area is covered by the 1:500,000-scale geologic map of the Southern Najd quadrangle (Jackson and others, 1963). Most of the surrounding quadrangles have been mapped as part of the 1:100,000-scale mapping program of the U.S. Geological Survey (USGS) (fig. 1). These include Al Aqiq to the west (Greenwood, 1975a), Biljurshi to the southwest (Greenwood, 1975b), Wadi Tarj to the south (Anderson, 1977), Wadi Harjab to the southeast (Cornwall, 1973), Al Junaynah to the east (Schmidt, *1980b, 1991*), Wadi al Miyah to the northeast (Schmidt, *in press*), and Al Ufayriyah to the north (Greene, 1982, *1993*).

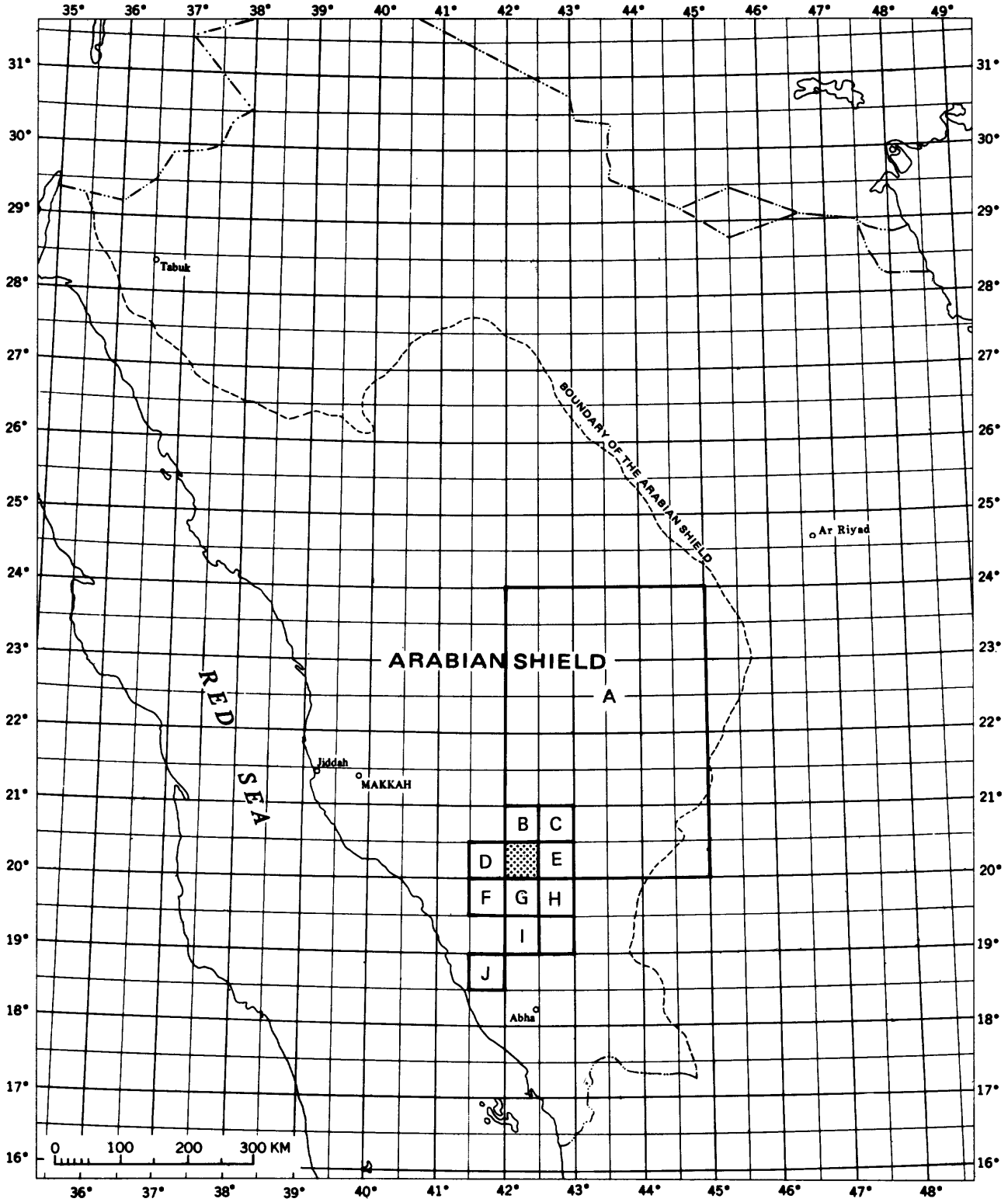

Figure 1.–Index map of western Saudi Arabia showing location of the Thaniyah quadrangle (shaded) and other quadrangles referred to in this report: A–Southern Najd, Jackson and others, 1963; B– Al Ufayriyah, Greene, 1982 , 1983; C–Wadi al Miyah, Schmidt, in press; D–Al Aqiq, Greenwood, 1975a; E–Al Junaynah, Schmidt, 1980b, 1981 ; F–Biljurshi, Greenwood, 1975b; G–Wadi Tarj, Anderson, 1977; H–Wadi Harjab, Cornwall, 1973; I–An Nimas, Greenwood, 1980; J–Wadi Hali, Hadley, 1975.

Fieldwork in the Thaniyah quadrangle was conducted in February and March 1979. Additional field checks were made in November 1980, and January 1981. Most of the 690 stations in the quadrangle and immediately adjacent areas were visited by helicopter; a few were reached by vehicle.

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 Thaniyah quadrangle lies in a transition zone between the Hijaz Mountains to the west and the Najd Plateau to the east. The southwesternmost part of the quadrangle is clearly in the Hijaz; rugged mountain peaks and ridges, rising as high as 1,670 m, are separated by deep canyons. Although much of the rest of the quadrangle has a rough, dissected surface developed on bedrock and local relief of less than 100 m, some areas are mountainous, including Jabal Rafa in the northwest corner, Kawr Burayha in the north-central part, and a series of ridges to the south and southeast of Shaib Sudayrah. Plains dotted with small jabals characterize the southeastern part and a small area near the northeast corner of the quadrangle; these clearly belong to the Najd plateau.

Altitude generally decreases from northwest to southeast across the area. The summit at Jabal Rafa is about 1,350 m, at Kawr Burayha about 1,320 m and south of Shaib Sudayrah altitudes range from 1,300 to 1,150 m. Altitude of the plains in the northeastern part is about 1,050 m and in the southeastern part about 1,150 m.

Drainage in the northwestern part of the quadrangle is provided by north-flowing Wadi Ranyah and its tributaries. Southern, central, and eastern parts are drained by Wadi Tabalah, Wadi al Khalij, Shaib al Mutaarridah, Shaib Sudayrah, and other east-flowing tributaries to Wadi Bishah, a north-flowing trunk stream that lies a few kilometers to the east of the quadrangle.

PRECAMBRIAN ROCKS

A geologic map of the quadrangle is shown as plate 1; the map units (symbolized and generally described in the map explanation) will be more fully discussed in the following paragraphs.

Layered rocks

The layered rocks in this quadrangle and in the Al Ufayriyah quadrangle adjacent to the north, are divided into western, central, and eastern belts. These belts are separated by belts of plutonic rocks. The layered rocks are primarily metavolcanic; minor units are metasedimentary.

Formation and group names given to the layered rocks in quadrangles adjacent to the east and west have not been extended into this quadrangle.

The term granulite is used in this report to refer to the texture of structureless, equigranular metamorphic rocks.

Metavolcanic rocks, western belt

A mountainous area along the western boundary of the quadrangle is underlain by metavolcanic rocks (mw) consisting of flow rock, tuff, and breccia ranging in composition from basalt to rhyodacite. Most common are greenish-gray to brownish-gray andesite and dacite flow rocks and tuffs that weather to slabs and fragments with brownish-black patina.

Metabasalt and meta-andesite consist of plagioclase, actinolite, chlorite, epidote, and opaque minerals in various proportions. Some of the volcanic rocks contain a few percent plagioclase phenocrysts. Groundmass texture may show flow foliation, tuff and breccia microfragments, or cataclastic granulation.

Metadacite and rhyodacite consist of sparse phenocrysts of plagioclase and quartz in groundmass that may contain identifiable plagioclase, quartz, actinolite, chlorite, and epidote or that may be cryptofelsite. Like the more mafic rocks, the groundmass shows flow, fragmental, or cataclastic textures.

Although not seen in the Thaniyah quadrangle, abundant pillow structure is exposed in metavolcanic rocks, which are on strike with those described above, along Wadi Ranyah and Wadi Thurat in the adjacent Al Aqiq quadrangle. The entire sequence appears to have originated as submarine lavas and pyroclastic flows. They have been deformed in one or more orogenies and metamorphosed to greenschist facies of chlorite grade.

Metavolcanic rocks, central belt

Metavolcanic rocks of the central belt (mc) are found in the northwestern part of the quadrangle, both east and west of Wadi Ranyah. The rocks consist of meta-andesite and metabasalt that are medium to dark gray and greenish gray, fine grained, and locally porphyritic. Most of the rocks consist of plagioclase, actinolite, chlorite, epidote, and opaque minerals. Some contain a few percent, and some as much as 40 percent, plagioclase phenocrysts. Textures indicate that both flows and tuffs are present. Some of the rocks contain a few percent quartz, and one contains hornblende.

The rocks are mostly metamorphosed to greenschist facies of chlorite grade but locally attain amphibolite facies.

Metavolcanic rocks, eastern belt

Metavolcanic rocks of the eastern belt (me) underlie an area extending from the southeast corner of the quadrangle north and northwest to Shaib Sudayrah, where they become mixed with granite. The rocks include meta-andesite, metabasalt, and amphibolite. They are mostly fine to medium grained and dark gray to black but locally are streaked and mottled with lighter colors.

Meta-andesite consists of plagioclase, quartz, and hornblende with minor epidote and opaque minerals. Metabasalt consists of plagioclase, hornblende, and epidote, and grades into amphibolite where hornblende content exceeds 50 percent. The rocks are largely recrystallized but textures suggesting both flows and tuffs are present. They are metamorphosed to the amphibolite facies.

Layered metavolcanic rocks

In a small area along the eastern boundary of the quadrangle a distinctive sequence of layered metavolcanic rocks (ml) includes metadacite, meta-andesite, and metabasalt. Steeply dipping layers, each only a few meters thick, can be readily observed in the field.

Metadacite is brownish gray and aphanitic. It consists largely of cryptofelsite, but may contain a few percent plagioclase or quartz phenocrysts. The groundmass locally contains flow-alined plagioclase microlites, but elsewhere it is clearly fragmental.

Meta-andesite and metabasalt are dark gray to greenish gray and fine grained. They consist of plagioclase and hornblende with minor epidote and opaque minerals. Some meta-andesite contains as much as 20 percent plagioclase phenocrysts.

The layered metavolcanic rocks, like those of the adjacent eastern belt, are metamorphosed to the amphibolite facies.

Quartzite

Quartzite (qz) underlies three small areas in the western part of the quadrangle. The southernmost area is a residual sliver in plutonic rocks of the An Nimas batholith, the other two are surrounded by metavolcanic rocks of the western belt, but their structural relationship to that unit is uncertain.

In the southernmost occurrence (lat 20°02' N., long 42°10' E.) quartzite is light gray and fine grained with thin, flaggy bedding. It consists of quartz with minor amounts of hornblende, biotite, garnet, plagioclase, and opaque minerals.

Quartzite underlies a prominent jabal near Wadi Ranyah (lat 20°16'30" N., long 42°00'15" E.). The rock is light gray and medium grained; outcrops are massive and have a rusty-brown to black patina. The rock consists solely of quartz with traces of opaque minerals, probably hematite.

A third quartzite underlies a group of steep-sided jabals 9 km farther north at the western boundary of the quadrangle (lat 20°21'30" N., long 42°00' E.). It is fine grained and light gray, but weathers to a rusty color with purple stains. The rock consists of quartz with 5 to 30 percent clinozoisite and trace amounts of muscovite, garnet, and opaque minerals.

Marble, metasedimentary, and metavolcanic rocks

A small area near the northwest corner of the quadrangle, and a larger one near the northeast corner, are underlain by rocks of the marble, metasedimentary, and metavolcanic unit (mm). In the area near the northwest corner, white marble is interlayered with gray metasandstone. Surface rock is mostly weathered brown and crumbly. The marble is nearly pure carbonate; the metasandstone consists of recrystallized quartz, plagioclase, and biotite.

The area near the northeast corner is a flat plain on which sparse outcrops of metasedimentary and metavolcanic rocks are distributed in irregular fashion. Adjacent to the granite that forms the mountains to the south of the plain, outcrops consist mostly of quartz-plagioclase granulite, some contain abundant epidote, and most contain minor biotite, chlorite, sphene, and opaque minerals. Amphibolite is interlayered.

In the center of the flat and near its northern edge, marble and calc-silicate granulite crops out as a ribbon rock of alternating layers of marble and granulite, 1 to 4 cm thick, and commonly folded or boudinaged. The marble consists of carbonate and minor diopside and scapolite; the granulite consists of about equal parts of diopside and scapolite, and locally minor carbonate, plagioclase, and trace amounts of epidote, sphene, and opaque minerals. Other outcrops in this area are metabasalt and amphibolite.

Mixed rocks

Metavolcanic rocks of western belt and diorite.--Metavolcanic rocks of western belt and diorite (mwd) consist of a mixed unit of metavolcanic rocks similar to those described for the western belt (mw) and diorite and quartz diorite similar to that described for the diorite and quartz diorite unit (dq).

Metavolcanic rocks of western belt and tonalite.--Metavolcanic rocks of western belt and tonalite (mwt) consist of a mixed unit of metavolcanic rocks similar to those described for the western belt (mw) and tonalite and quartz diorite similar to that described for the tonalite and quartz diorite unit (to).

Metavolcanic rocks of central belt and diorite.--Metavolcanic rocks of central belt and diorite (mcd) consist of a mixed unit of metavolcanic rocks similar to those described for the central belt (mc) and diorite and quartz diorite similar to that described for the diorite and quartz diorite unit (dq).

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 (dqg) 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).

Tonalite and granite.--Tonalite and granite (tog) consist of a mixed unit of tonalite and quartz diorite similar to that described for the tonalite and quartz diorite unit (dq) and granite similar to that described for the graphic granite and rhyolite unit (ggr).

Plutonic rocks

Plutonic rocks are dominant in the Thaniyah quadrangle and underlie about 90 percent of the surface. They range in composition from gabbro to granite, but tonalite, quartz diorite, and diorite of the An Nimas batholith are the most voluminous. Plutonic rocks are classified according to the recommendation of the International Union of Geological Sciences (IUGS) (Streckeisen, 1973).

Diorite and quartz diorite

Diorite and quartz diorite (dq) are the principal rock types in parts of three zones extending north-northwesterly across the quadrangle. Most diorite and quartz diorite are spatially associated with the metavolcanic rocks and constitute the oldest part of the An Nimas batholith (Anderson, 1977; Greenwood, 1980).

In outcrop, the appearance of rocks of this unit is very heterogeneous. Coarse-grained, black and light-gray rocks intrude medium- to fine-grained, dark-gray rocks, and all are commonly sheared, fractured, and metamorphosed. Where diorite and quartz diorite are mixed with substantial quantities of metavolcanic rocks, tonalite, or granite, mixed units have been mapped.

The diorite commonly consists of 60 to 85 percent plagioclase and 15 to 40 percent hornblende. Meladiorite may contain as much as 50 percent hornblende. Part of the hornblende commonly is altered to chlorite and (or) epidote. Opaque minerals are generally present, but apatite and sphene are rare. About half of the samples studied contain 1 to 15 percent quartz; those with more than 5 percent quartz are quartz diorite.

Tonalite and quartz diorite

Much of the Thaniyah quadrangle is underlain by tonalite and quartz diorite (to). These rocks are part of the An Nimas batholith and form the younger phase of that batholith.

The tonalite and quartz diorite are largely medium to coarse grained and light gray to white; many are speckled black and white due to visibly separate grains of mafic and felsic minerals. The more altered rocks are commonly pinkish. Most outcrops are covered by a dark-gray to black patina. In some areas the unit underlies rough, dissected land that has nearly continuous outcrop; elsewhere it underlies flat pediments where outcrops form numerous low jabals.

Tonalite, which consists of 70 to 80 percent plagioclase, 20 to 30 percent quartz, and trace to 10 percent mafic minerals, is more abundant than the quartz diorite, which contains 10 to 20 percent quartz but is otherwise similar to tonalite. Fresh tonalite contains 1 to 5 percent hornblende and 1 to 5 percent biotite. Total mafic mineral content is commonly less than 5 percent; only rarely does it exceed 10 percent. Commonly hornblende and biotite are partially altered to chlorite and epidote, and in the more altered, pinkish rocks, chlorite and epidote are the only mafic minerals. Zircon is rare, sphene is common, and opaque minerals are nearly always present.

Tonalite and quartz diorite are generally strongly flow foliated (pl. 1), but only rarely cataclastic. Foliation trends change abruptly and suggest multiple intrusion.

Tonalite gneiss

Tonalite gneiss (tgn) crops out in two zones directly in line with each other; one is 8 km long and lies in the south-central part of the quadrangle, the other is 21 km long and lies to the north-northwest. The rock is light to dark gray, fine to medium grained, and strongly foliate. Distinct layers of contrasting color, a few cm to about 1 m wide, are visible in much of the outcrop.

The tonalite gneiss consists of 65 to 85 percent plagioclase, 20 to 35 percent quartz, and 1 to 10 percent hornblende, with trace amounts of opaque minerals, secondary chlorite and epidote, and, locally, biotite. Locally, the rock contains as much as 25 percent hornblende.

The tonalite gneiss is cataclastic, and is derived from tectonic shear of less granulated tonalite, which lies to the west of the zone of gneiss. At the northwestern end of the outcrop zone, the gneiss is tectonically mixed with metavolcanic rocks of the central belt.

Khalij tonalite and quartz diorite

An additional unit of tonalite and quartz diorite (yt) has been separated from the main unit (to) south of Jabal Hate in the south-central part of the quadrangle. This unit cuts across the tonalite gneiss (tgn) belt, dividing it into two parts. The tonalite and quartz diorite are medium to coarse grained and are similar in composition to rocks of the main unit. There are fewer very coarse, white rocks in this unit and more pinkish, altered ones.

Diorite and gabbro

A prominent black jabal near the center of the quadrangle is underlain by diorite and gabbro (dg), which is coarse grained and speckled light gray and black. Most of the rock is slightly altered hornblende diorite containing 45 to 80 percent plagioclase, 15 to 55 percent hornblende, and trace to 5 percent epidote. Locally, the hornblende is altered to actinolite. Gabbro is also present and consists of about 60 percent plagioclase, 7 percent olivine, 20 percent clinopyroxene, 5 percent hornblende, 1 percent opaque minerals, and 7 percent actinolite that is derived by alteration of the primary mafic minerals.

Gabbro

A belt containing several bodies of gabbro (gab) extends from midway along the eastern boundary of the quadrangle northwest toward the center of the northern boundary. The largest of these is the southernmost, which underlies a prominent jabal and which is very coarse grained at its center.

The gabbro is medium to very coarse grained and light to dark gray; the individual minerals give it a speckled appearance. The gabbro consists of 60 to 80 percent plagioclase, 1 to 25 percent olivine, 1 to 35 percent clinopyroxene, trace to 10 percent hornblende, and trace to 5 percent opaque minerals. Some gabbro contains small amounts of biotite and (or) secondary chlorite. Most of the plagioclase and the mafic minerals are fresh; however, the reaction series olivine to clinopyroxene to hornblende to biotite is seen in some samples. The gabbro is undeformed and unmetamorphosed.

Two-mica granite

Two-mica granite (big) is present in two areas near the center of the quadrangle and in another area near the northeast corner. The southernmost of the central areas includes two prominent jabals, the surrounding lowlands, and several small, steep-sided jabals. The north-central area is largely a lowland but contains four prominent small jabals that consist of white quartz (q). The area near the northeast corner is a lowland that contains both flat outcrops and small jabals of whaleback form.

Most of the two-mica granite is coarse grained, and individual pink, very light gray, and black minerals are distinguishable in hand specimen. The granite weathers reddish brown that is distinct from the black characteristic of tonalite, diorite, and metavolcanic rocks. The two-mica granite of the more northern of the central areas is distinctly white.

The granite consists of 30 to 50 percent potassium feldspar, 25 to 35 percent quartz, and 20 to 40 percent plagioclase, with trace to 1 percent muscovite, and traces of biotite, chlorite, epidote, zircon, and opaque minerals. Garnet is locally present.

Variants of the rock include a pale-pink granite with large feldspar phenocrysts (lat 20°18'20" N., long 42°13' E.) and a quartz-feldspar pegmatite (lat 20°12'40" N., long 42°15'30" E.), both of which underlie prominent small jabals.

Biotite granite

Biotite granite (bg) forms a nearly circular pluton adjacent to Wadi Ranyah at the northern boundary of the quadrangle. The area underlain by the granite is flat but outcrops are abundant. The granite is coarse grained and dominantly light to dark pink speckled with black.

The granite consists of about 65 percent perthitic potassium feldspar, about 25 percent quartz, and about 10 percent plagioclase, 0.5 to 1 percent biotite and chlorite, as well as traces of zircon, sphene, and opaque minerals. The presence of biotite with neither muscovite nor amphibole distinquishes this granite from others in this quadrangle.

Granite and granodiorite

Small areas in the southeastern part of the quadrangle are underlain by granite and granodiorite (ggd). The flat pediment surface is dotted with small jabals. The rocks of this unit are heterogeneous, fine to coarse grained, and light gray to pink. Most of the outcrops have a black patina and are similar in appearance to outcrops of tonalite and quartz diorite.

The granite and granodiorite are composed of 5 to 50 percent potassium feldspar, 20 to 30 percent quartz, 30 to 60 percent plagioclase, and 2 to 10 percent mafic minerals. All samples contain both biotite and hornblende, and nearly all contain accessory zircon and opaque minerals. Secondary epidote is common, and chlorite is rare.

Graphic granite and rhyolite

Graphic granite and rhyolite (ggr) underlie an extensive mountainous area in the northeastern part of the quadrangle, Jabal Rafa, a mountainous area in the northwestern part of the quadrangle; and parts of adjacent quadrangles. In most places, these rocks are mottled dull pink and gray and are medium grained; finer grained rocks are light to medium pinkish gray.

Graphic granite consists of about 60 to 70 percent potassium feldspar, 25 to 35 percent quartz, and 1 to 10 percent plagioclase, with traces of hornblende, sphene, and opaque minerals and secondary epidote and chlorite. Traces of alkali amphibole are also present locally. The potassium feldspar is slightly perthitic and generally clouded with opaque "dust". Quartz is intimately intermixed with potassium feldspar in graphic texture; that is, the quartz has crystal outlines, commonly triangular, with connecting bars.

In the finer grained granite and rhyolite, the graphic texture grades into vermicular, plumose, and spherulitic textures. Most of these rocks are composed of quartz and one feldspar in undetermined proportions.

Metabasalt and meta-andesite dikes

Hypabyssal intrusive dikes occur in all but the southeastern part of the quadrangle (pl. 1) and are abundant in some areas. Most dikes are dark-gray, fine-grained metabasalt or meta-andesite. Color indices range widely, from 5 to as much as 60. The dike rocks consist of plagioclase, clinopyroxene, and actinolite and minor amounts of chlorite, epidote, opaque minerals, and, in rocks of low color index, quartz.

SURFICIAL DEPOSITS

Alluvium

Alluvium (Qa) is present along major and minor wadis and locally covers large flat areas. (pl. 1). It consists mostly of sand, but may contain cobbles and gravel in major stream channels.

STRUCTURE AND GEOLOGIC HISTORY

The metavolcanic rocks of the western belt (pl. 1) are continuous with similar rocks on the adjacent Al Aqiq quadrangle (Greenwood, 1975a) forming a north-south belt about 12 km wide. These rocks are commonly foliated and locally layered and have dips that are mostly vertical. The rocks must be either isoclinally folded or imbricately faulted, perhaps a combination of the two, as fold axes are not commonly seen. If there were no such repetition of the section, the total thickness of volcanic rocks would equal 12 km, the width across strike. This is an unreasonably large figure.

The metavolcanic rocks of the central belt, in contrast to those of the western belt, are more commonly massive and exhibit strong foliation only in the shear zone on strike with the belt of tonalite gneiss.

The metavolcanic rocks of the eastern belt and the layered metavolcanic rocks are continuous with similar rocks in the adjacent Al Junaynah quadrangle (Schmidt, 1980b). This belt increases in width from about 10 km at the common southern boundary of the quadrangles to about 20 km near the center of the boundary between the quadrangles. From this point north, the belt is segmented by plutonic rocks. The metavolcanic rocks exhibit strong foliation with vertical dips near the southeast corner of the Thaniyah quadrangle; farther north the foliation is irregular and commonly parallels the contact with the adjacent tonalite and quartz diorite.

The two principal plutonic rock units in the quadrangle, the tonalite and quartz diorite unit and the diorite and quartz diorite unit, are part of the An Nimas batholith, a major plutonic rock body extending at least 110 km south of the southern boundary of the Thaniyah quadrangle (Anderson, 1977; Greenwood, 1980a), and 70 km north of the northern boundary (Greene, 1982, 1983). Several of the mixed rock units mapped in this quadrangle also belong, at least in part, to the batholith. For simplicity, the names of the two principal rock units are shortened to tonalite and diorite, respectively, in the following discussion.

The structure and compositional variety of these rocks show that the An Nimas batholith consists of multiple intrusions of several different rock types. Most of the finer grained diorite is extremely deformed; it is sheared, brecciated, and intruded by later, coarser grained diorite. It was evidently emplaced syntectonically while the adjacent metavolcanic rocks were being folded. Intrusion of the main body of tonalite followed; it is not brecciated but is commonly sheared and cataclasized. The areas of strongest foliation are shown by form lines on plate 1.

At the climax of orogeny, a shear zone formed, which extends from at least 12 km south of the quadrangle boundary through Thaniyah north-northwest to Wadi Ranyah. It is named the Tabalah shear zone in the Wadi Tarj quadrangle (Anderson, 1977). This shear zone is represented by the tonalite gneiss, a belt of cataclasized rock derived from the adjacent tonalite. The shapes of contacts and form lines (pl. 1) suggest domal uplift of diorite bodies both east and west of Thaniyah during this episode.

As stress waned, additional late tonalite was intruded, interrupting the tonalite gneiss belt in the south-central part of the quadrangle. Here the foliation in the tonalite cross-cuts the preexisting foliation in the tonalite gneiss. Elsewhere, weakly foliated to nonfoliated tonalite was emplaced.

A variety of posttectonic plutonic rocks crops out in the quadrangle. The small diorite and gabbro body in the center of the quadrangle is believed to be the earliest of these because it is intruded by dikes, not shown on plate 1, that apparently are derived from the adjacent granite. The granite and granodiorite to the south, the two-mica granite in the center, and the biotite granite at the northern boundary of the quadrangle are on the strike of the axis of the An Nimas batholith and appear to have formed in a central zone of weakness. The granite and granodiorite may represent a concluding phase of the batholith. However, potassium feldspar-bearing rocks are not included in the batholith elsewhere (Anderson, 1977, Greenwood, 1980).

Graphic granite and rhyolite in the northeastern part of the quadrangle are a part of a large and complex body. Their outcrop extends only 3 km to the east in the Al Junaynah quadrangle (Schmidt, 1980b, 1981), but at least 40 km northwest in the Al Ufayriyah quadrangle (Greene, 1982, 1983), where they are covered by late Cenozoic lava of Harrat Buqum. The granite intimately intrudes the metavolcanic rocks of the eastern belt and the diorite (pl. 1, mixed units meg and dqg).

The small body of two-mica granite near the northeast corner of the quadrangle is arcuate in shape and may have intruded ring fractures following major intrusion and cauldron subsidence. Such a structure implies late intrusion at a shallow crustal level following extensive erosion of the An Nimas batholith.

The graphic granite and rhyolite, as well as some of the two-mica granite, are severely broken up by faults and joints. Only a schematic representation of the full pattern of joints and faults is shown on plate 1. This deformation is probably of Najd age.

The faults in the western half of the quadrangle, which trend from due north to N. 30° W., are parallel to, and locally form the edge of, the An Nimas batholith. They may represent brittle fracture during a concluding phase of uplift of batholithic rocks. Another series of faults trends N. 60 to 70° W. in the southwestern part of the quadrangle; one of these left-laterally displaces a belt of diorite. These are clearly Najd faults, as are several long faults of similar trend in the northeastern part of the quadrangle.

Dikes in the east-central part of the quadrangle trend N. 70° W. Some faults and dikes in the west-central and northwestern parts of the quadrangle have the same trend. In the northwestern part a more dominant set of dikes has a conjugate trend of about N. 40° E. These may also be Najd trends. In the north-central part of the quadrangle, the densest dike-swarm also has an average trend of N. 70° W., but a curvature, mirrored by associated faults, indicates that the trend is altered to east-west at the eastern end of the swarm. This intersects, rather than parallels, the Najd fault that runs up a straight valley from Shaib Sudayrah to the northern boundary of the quadrangle. Left-lateral shear on this fault, however, would tend to open en-echelon fractures along the trend.

Some faults trend N. 70° E.; in particular, a line of such faults crosses the center of the quadrangle. Some dikes in the center of the quadrangle parallel this trend as do some in the southwestern part. Other dikes parallel the Najd trend or the foliation in the plutonic rocks.

GEOCHRONOLOGY

Radiometric-age dates obtained from rocks collected in the Thaniyah quadrangle and from probably correlative rocks give conflicting results, and considerable discretion is needed in deciding which dates to accept.

Aldrich and others (1978, sec. 1) report ages of 720 Ma (Rb-Sr, biotite) and 740 Ma (K-Ar, biotite) on granite (tonalite and quartz diorite unit of this report) from lat 20°21'00" N., long 42°01'36" E., near Wadi Ranyah. These mineral ages, obtained before 1963, are believed to reflect partial resetting because subsequent whole-rock Rb-Sr and zircon U-Pb ages for correlated rocks are distinctly older, as discussed below.

Aldrich and others (1978, sec. 2) report K-Ar ages of 826±16 Ma (biotite) and 711±30 Ma (hornblende) on granite (tonalite and quartz diorite unit) from lat 20°17' N., long 42°08' E., directly east of Wadi Ranyah. These two ages from the same rock are so different from each other that an isotopic disturbance is suspected; however, the biotite age is similar to whole-rock ages for the An Nimas batholith.

A number of Rb-Sr whole-rock and two U-Pb ages have been obtained on rocks from the An Nimas batholith in the Wadi Tarj, An Nimas, and Wadi Hali quadrangles to the south of Thaniyah. Fleck and others (1980) report ages of 818±95 Ma and 837±50 Ma on quartz diorites and 838 Ma (two-point isochron) on trondhjemite. Cooper and others (1979) report a

U-Pb age of 816±4 Ma on one of the same samples (Fleck's 837 Ma age) and an age of 797±15 Ma for tonalite gneiss from the southern An Nimas batholith. These ages are all in the same range and suggest 835 to 800 Ma as the probable age of the An Nimas batholith.

Fleck and others (1980) report a Rb-Sr, whole-rock age of 912±76 Ma on metavolcanic rocks from an inlier in the An Nimas batholith 15 km north of An Nimas. This is one of the oldest Rb-Sr ages reported to date from the Arabian Shield. It may be too old, but it is consistent inasmuch as it is older than the batholithic rocks that intrude it.

The ages of gabbros in the southern Arabian Shield are discussed by Coleman and others (1972) and by Fleck and others (1976). Several concordant biotite and hornblende K-Ar ages for unaltered samples with igneous textures suggest that the intrusion age of most of the gabbro bodies range from 640 to 625 Ma. Because the gabbros of the Thaniyah quadrangle are petrographically similar, it is likely that their age range is similar.

A number of late and postorogenic plutonic rocks from the southern Arabian Shield have been dated (Fleck and others, 1976, 1980). Those that intrude the An Nimas batholith or layered rocks marginal to it are most likely correlated with two-mica granite and biotite granite in the Thaniyah quadrangle; there are several Rb-Sr dates for such rocks from the Al Aqiq quadrangle. These include ages of 636±20 Ma on quartz monzonite of Wadi Shuwas (Fleck and others, 1980) and 617±10 Ma on granodiorite (Brown and others, 1978). These dates all fall in the early Pan-African event (Fleck and others, 1980).

Aldrich and others (1978) report Rb-Sr dates of 575 and 565 Ma on peralkaline granite from Jabal Rafa in the Al Aqiq quadrangle. These rocks, mapped as graphic granite and rhyolite (ggr) in the Thaniyah and Al Ufayriyah quadrangles (Greene, 1982, 1983) constitute an extensive unit. The ages fit the later part of the early Pan-African event as reported by Fleck (1976) if the bounding dates for this event are revised about 10 Ma older (R. J. Fleck, written commun., 1980). If these ages are correct, the youngest plutonic rocks in the Thaniyah quadrangle were intruded just before the beginning of Cambrian time.

ECONOMIC GEOLOGY

Ancient copper and gold mines

During the course of geologic investigations in the Thaniyah quadrangle, an apparently heretofore unreported ancient copper mine was discovered (MODS number requested). It is located in a fault sliver of tonalite gneiss east of the elbow in Wadi Ranyah (lat 20°17'50" N., long 42°09'40" E., Pl. 1). At the site, a diorite dike about 10 by 200 m long cuts across sheared tonalite. A pit near one end is surrounded by heaps of gossan, some of which is malachite stained. An open shaft 30 m east of the pit and about 10 m deep in fresh rock is probably recent. Nearby are many heaps of slag and numerous stone foundations, but neither waste rock piles nor grinding stones were found.

Dumps from several ancient gold mines are said to exist in the area directly east of Wadi Ranyah at the northern end of the tonalite gneiss belt (lat 20°23' to 25' N., long 42°07' to 10' E. (not shown on plate 1); D. L. Schmidt, written commun., 1981). No additional information is presently available.

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

Wadi Shuwas district

The Wadi Shuwas district contains many ancient gold and copper mines and is located in the southeasternmost Al Aqiq and northeasternmost Biljurshi quadrangles (Greenwood, 1975a,b) adjacent to the southwestern part of the Thaniyah quadrangle. Considerable geological and geochemical work has been done in the district by geologists from the Japanese Geological Survey and the Directorate General of Mineral Resources (DGMR) over the past 10 years, but deposits that have been discovered are not of economic value at the present time. The results of investigations are described in a series of open-file reports (Ozawa, 1978; Fujii, 1979; Kato and Fujii, 1979; and other reports released by the Saudi Arabian Deputy Ministry for Mineral Resources; for example, see Saudi Arabian Directorate General of Mineral Resources Bulletin 20 and Saudi Arabian Deputy Ministry for Mineral Resources Bulletin 27). Adjacent parts of the Thaniyah quadrangle, underlain by metavolcanic rocks similar to those in the Wadi Shuwas district, may have equally good mineral potential.

Geochemical survey

A geochemical survey and evaluation of the mineral potential of the Thaniyah quadrangle were carried out by M. D. Fenton (Fenton, 1982, 1983). Fenton analyzed splits of rock samples that the author collected during mapping and collected additional samples of both normal and altered or mineralized rocks. Plutonic and volcanic rocks were analyzed for gold, silver, copper, lead, and zinc by atomic absorption using nitric acid extraction. In addition, plutonic rocks were analyzed by X-ray fluorescence for zirconium, yttrium, niobium, molybdenum, rubidium, strontium, and thorium.

Building stones

Some of the granites and gabbros found in the Thaniyah quadrangle are exceptionally attractive and might make excellent dimension stone for building facings, steps, and floors. Stone from the two-mica granite, graphic granite and rhyolite, or gabbro units might be suitable. Exceptionally attractive granites are located at lat 20°18'20" N., long 42°13'00" E., and lat 20°26'20" N., long 42°28'15" E., and gabbro at lat 20°27' N., long 42°16' E.

REFERENCES

Aldrich, L. T., Brown, G. F., Hedge, Carl, and Marvin, Richard, 1978, Geochronologic data for the Arabian Shield: Sec. 1 - Radiometric age determinations of some rocks from the Arabian Shield, by L. T. Aldrich, Sec. 2 - Tabulation of Rb-Sr and K-Ar ages given by rocks of the Arabian Shield, by G. F. Brown, Carl Hedge, and Richard Marvin: U.S. Geological Survey Open-File Report 78-75, 20 p.

Anderson, R. E., 1977, Geology of the Wadi Tarj quadrangle, sheet 19/42 A, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-29, 24 p., scale 1:100,000.

Coleman, R. G., Brown, G. F., and Keith, T. E. C., 1972, Layered gabbros in southwest Saudi Arabia: U.S. Geological Survey Professional Paper 800-D, p. D143-D150.

Cooper, J. A., Stacey, J. S., Stoeser, D. B., Fleck, R. J., 1979, An evaluation of the zircon method of isotopic dating in the southern Arabian craton: Contributions to Mineralogy and Petrology, v. 68, p. 429-439.

Cornwall, H. R., 1973, Geology of the Wadi Harjab quadrangle, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-3, 5 p., scale 1:100,000.

Fenton, M. D., 1982, Mineral resource potential of the Al Ufayriyah and Thaniyah quadrangles, sheets 20/42 A and C, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-3; also, 1983, U.S. Geological Survey Open-File Report , (IR)SA-534.

Fleck, R. J., Coleman, R. G., Cornwall, H. R., Greenwood, W. R., Hadley, D. G., Schmidt, D. L., Prinz, W. C., and Ratte, J. C., 1976, Geochronology of the Arabian Shield, western Saudi Arabia; K-Ar results: Geological Society of America Bulletin, v. 87, no. 1, p. 9-21.

Fleck, R. J., Greenwood, W. R., Hadley, D. G., Anderson, R. E., and Schmidt, D. L., 1980, Rubidium-strontium geochronology and plate-tectonic evolution of the southern part of the Arabian Shield: U.S. Geological Survey Professional Paper 1131, 38 p.

Fujii, K., 1979, Geology of the north Wadi Shwas area, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Technical Record TR-1979-5, 9 p.

Greene, R. C., 1982, Reconnaissance geology of the Al Ufayriyah quadrangle, sheet 20/42 A, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report USGS-OF-03-3, 18 p., scale 1:100,000; also, 1983, U.S. Geological Survey Open-File Report 83-295.

Greenwood, W. R., 1975a, Geology of the Al 'Aqiq quadrangle, sheet 20/41 D, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-23, 15 p., scale 1:100,000.

Greenwood, W. R., 1975b, Geology of the Biljurshi quadrangle, sheet 19/41 B, Kingdom of Saudi Arabia, with a section on Geophysical investigation, by G. E. Andreasen, and a section on Geochemical investigation and mineral resources, by V. A. Trent and T. H. Kiilsgaard: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-25, 31 p., scale 1:100,000.

Greenwood, W. R., 1980, Reconnaissance geology of the An Nimas quadrangle, sheet 19/42 C, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-37, 33 p., scale 1:100,000.

Hadley, D. G., 1975, Geology of the Wadi Hali quadrangle, sheet 18/41 B, Kingdom of Saudi Arabia, with a section on Aeromagnetic investigations, by G. E. Andreasen: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-21, 19 p., scale 1:100,000.

Jackson, R. O., Bogue, R. G., Brown, G. F., and Gierhart, R. D., 1963, Geologic map of the Southern Najd quadrangle, Kingdom of Saudi Arabia: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-211 A, scale 1:500,000, reprinted 1979, Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-211 A, scale 1:500,000.

Kato, K., and Fujii, N., 1979, Geochemical reconnaissance in the northern Wadi Shwas area, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Technical Record TR-1979-6. 14 p.

Ozawa, A., 1978, Copper deposit of the Sha'bat as Suqah prospect, Wadi Shwas area, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Technical Record TR-1978-2, 9 p.

Saudi Arabian Deputy Ministry for Mineral Resources, 1981, Annotated bibliography, 1396-1400 A.H. (1976-1980 A.D.): Saudi Arabian Deputy Ministry for Mineral Resources Mineral Resources Bulletin 27, 102 p.

Saudi Arabian Directorate General of Mineral Resources, 1977, Annotated bibliography, 1970-1975 A.D.: Saudi Arabian Directorate General of Mineral Resources Mineral Resources Bulletin 20, 98 p.

Schmidt, D. L., *in press*, Geology of the Wadi al Miyah quadrangle, sheet 20/42 B, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry of Mineral Resources Geologic Map series, scale 1:100,000.

Schmidt, D. L., 1980b, Geology of the Al Junaynah quadrangle, sheet 20/42 D, Kingdom of Saudi Arabia: U.S. Geological Survey Saudi Arabian Mission Technical Record 11 (Interagency Report 351), 67 p., scale 1:100,000; also, 1981, U.S. Geological Survey Open-File Report 81-185.

Streckeisen, A. L., 1973, Plutonic rocks, classification and nomenclature recommended by the IUGS Subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26-30.