RECONNAISSANCE GEOLOGY OF THE WADI DHAHABAN QUADRANGLE, SHEET 18/41 D, KINGDOM OF SAUDI ARABIA

by

Donald G. Hadley

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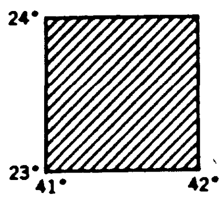
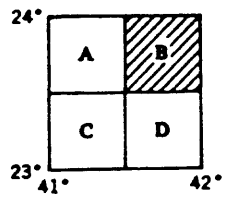


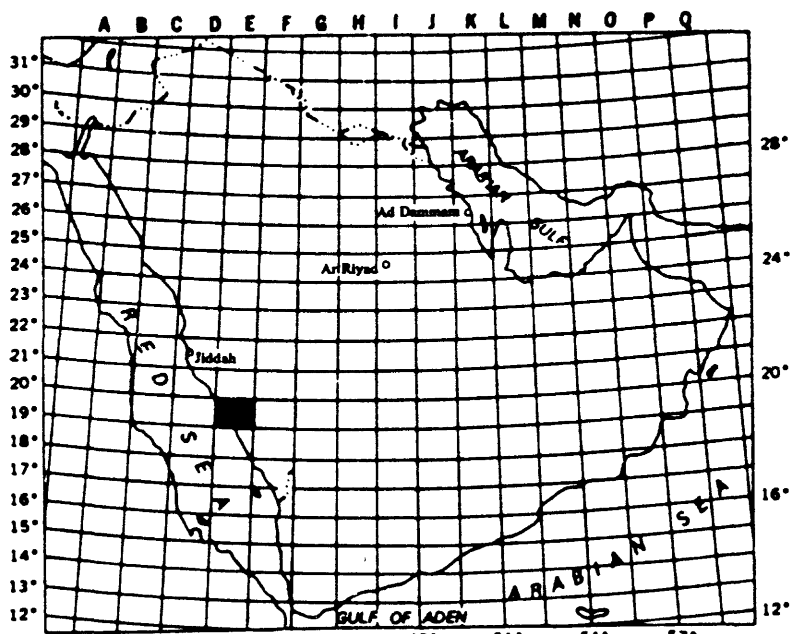
23/41

1-degree
quadrangle



23/41 B

30-minute
quadrangle



19E

1x1½-degree
quadrangle

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RECONNAISSANCE GEOLOGY OF THE
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ABSTRACT

The Wadi Dhahaban quadrangle (sheet 18/41 D) lies between lat 18°00 and 18°30' N. and long 41°30' and 42°00' E. and encompasses an area of 2,937 km^2 located along the Red Sea coast and includes part of the escarpment-mountains province. The geologic formations exposed in the quadrangle are comprised of Precambrian layered and intrusive rocks, Tertiary gabbro dikes, Quaternary basaltic lavas and pyroclastic rocks, and Quaternary surficial deposits. No economic mineral deposits have been found.

The Precambrian rocks include layered sedimentary and volcanic rocks that have been assigned to the Baish, Bahah, and Ablah groups. They have been folded, metamorphosed, and invaded by three separate intrusions. The Precambrian rocks are cut by Miocene gabbro dikes that were intruded during the initial stages of the opening of the Red Sea rift. The Quaternary rocks include basalt, and coastal, pediment, and alluvial deposits of various kinds.

The area is of special interest because of its unique display of the Tertiary and Quaternary basaltic volcanism that was associated with the opening of the Red Sea rift and that has continued in other parts of the Kingdom until historic times.

INTRODUCTION

The Wadi Dhahaban quadrangle (sheet 18/41 D) lies between lat 18°00 and 18°30' N. and long 41°30' and 42°00' E. (fig. 1) and encompasses an area of 2,937 km^2 along the Red Sea coast and over part of the escarpment mountains province, the rugged region between the coastal plain and the edge of the elevated hinterland of the Arabian Shield. Altitudes in the quadrangle range from sea level to about 350 m on the rims of some of the volcanic cinder cones that rise from the lava fields of the coastal plain to 1,110 m in the north-central part of the quadrangle.

The area is located about 450 km southeast of Jiddah and 150 km northwest of Jizan. It is served by the coastal road through Al Birk and Al Qahmah, and by an inland road that

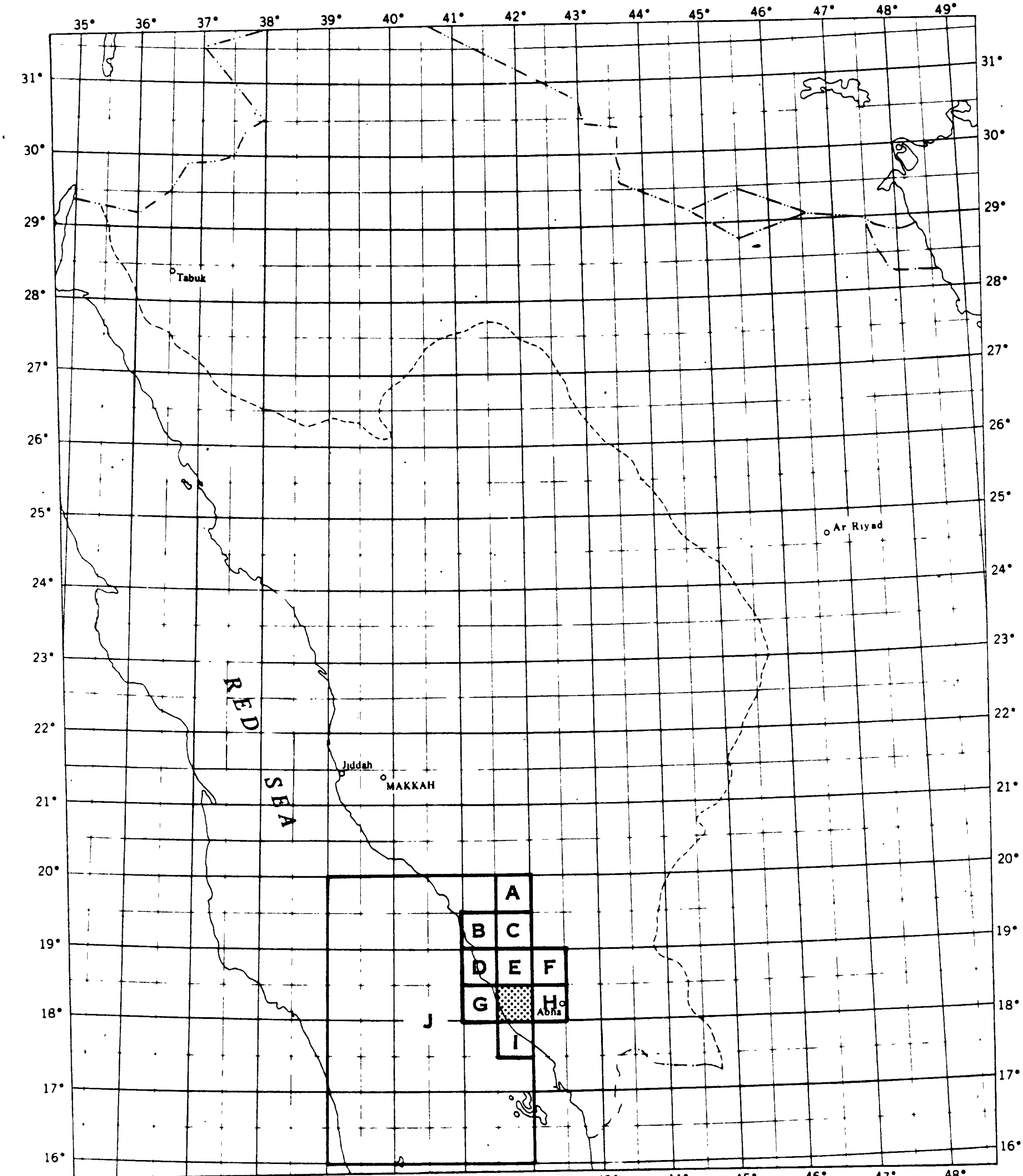

Figure 1.– Index map of western Saudi Arabia showing the location of the Wadi Dhahaban quadrangle (shaded) and other quadrangles cited in this report: A, Biljurshi (Greenwood, 1975b); B, Al Qunfudhah (Hadley, 1975a); C, Wadi Yiba (Bayley, 1972); D, Manjamah (Hadley, 1982c); E, Wadi Hali (Hadley, 1975b); F, Jabal Aya (Prinz, 1975); G, Wadi Amq (Hadley, 1982a); H, Jabal Sawdah (Ratte and Andreasen, 1974); I, Jabal Hashahish (Hadley, 1982b); J, Tihamat ash Sham (Brown and Jackson, 1958).

follows Wadi Bahr and Wadi Khiya through Umm Rhata, Khamis Bahr, Mahduwah, and Bin Hadi, with a branch along Wadi Majzuah to Ghanah; airstrips are maintained near Bin Hadi and Khamis Bahr. Al Birk and Al Qahmah are coastal trading villages, but the main occupation of the inhabitants in the other small communities in the area is agriculture, particularly along Wadi Dhahaban and in the area drained by Wadi Bahr and its tributary, Wadi Majzuah.

The geology of the quadrangle was first studied by Brown and Jackson (1958) during preparation of the 1:500,000-scale geologic map of the Tihamat ash Sham quadrangle. The quadrangle and its surroundings are shown on the 1:2,000,000-scale geologic map of the Arabian Peninsula (U.S. Geological Survey/Arabian American Oil Company, 1963). More detailed work and mineral-resource studies were started in 1970 and included work in the following quadrangles: Wadi Yiba, 19/41 D (Bayley, 1972); Jabal Sawdah, 18/42 C (Ratte and Andreasen, 1974); Al Qunfudhah, 19/41 C (Hadley, 1975a); Wadi Hali, 18/41 B (Hadley, 1975b); and Jabal Aya, 18/42 A (Prinz, 1975).

Fieldwork was done by the author in the Wadi Dhahaban, Wadi Amq 18/41 C (Hadley, 1982a), Jabal Hashahish 17/41 B (Hadley, 1982b), and Manjamah 18/41 A (Hadley, 1982c) quadrangles between mid-December 1973 and late March 1974; he was assisted in the field and office by Ghanim Jeri Alharbi, Yacob Essa Takrony, Murshid Abdo Ahmad, and Saud Muslih Ashybani. Logistic, drafting, and laboratory support were provided by the Directorate General of Mineral Resources.

All the work on the Wadi Dhahaban quadrangle was done under an agreement between the Saudi Arabian Ministry of Petroleum and Mineral Resources and the U.S. Geological Survey.

PRECAMBRIAN ROCKS

Layered rocks

The Precambrian layered rocks of the Wadi Dhahaban quadrangle are assigned to the Baish, Bahah, and Ablah groups. Those assigned to the Baish group include basic to intermediate volcanic rocks, sedimentary rocks, and minor amounts of chert. Those assigned to the Bahah group include clastic and calcareous sedimentary rocks with subordinate amounts of basic and intermediate volcanic rocks. The rocks assigned to the Ablah group are all of sedimentary origin. The layered rocks have been intruded by syntectonic and posttectonic granodiorite to granite intrusions and have been strongly affected by faults with north to north-northwest trends parallel with the Miocene gabbro dikes, the escarpment at the edge of the mountainous hinterland of the Arabian Shield, and the Red Sea rift.

The layered rocks have been regionally metamorphosed to greenschist facies and contact metamorphosed to amphibolite facies in a zone as much as 5 km wide around the granodiorite to granite batholiths. The intrusive rocks are gneissic in some places near their margins. The greenschist facies mineral assemblage includes chlorite, plagioclase, epidote, sphene, sericite, and calcite, and the amphibolite facies assemblage includes hornblende, quartz, andesine, biotite, garnet, apatite, and sphene. Despite this metamorphism, the original layered character of the rocks can generally be determined.

Baish group

The Baish group (Schmidt and others, 1973) includes the oldest rocks in the quadrangle and is represented in the Wadi Dhahaban quadrangle by basalt, andesite and related volcaniclastic rocks, graywacke, slate, argillite, and chert. These rocks form a series of fault-bounded belts in the eastern part of the quadrangle, a doubly plunging anticline in the southeastern part, and an "r-shaped" fold belt that extends from the southeastern part of the quadrangle into the northern part of the Jabal Hashahish (17/41 B) quadrangle (Hadley, 1982b). The rocks are moderately to strongly schistose in appearance, especially near fault zones.

The flow rocks form layers 5 to 20 m thick and are green to dark green, commonly amygdaloidal and porphyritic, and commonly contain phenocrysts 0.2 to 2 cm long in a fine-grained chloritic groundmass. Most of the amygdules are filled with chlorite, but some contain calcite, quartz, and (or) epidote. Glomeroporphyritic textures are common in the andesite flow rocks. Plagioclase phenocrysts aligned along planes of schistosity are smeared out into roughly circular discs as much as 4 cm in diameter.

Relict ophitic, subophitic, intergranular, and felted textures can be seen in thin sections of the flow rocks. Most of the rocks contain 40 to 60 percent plagioclase, which occurs as phenocrysts and in the groundmass. Most of the plagioclase has been altered to sericite, sphene, and epidote. Other minerals present include, in order of decreasing abundance, chlorite, altered clinopyroxene, magnetite, epidote, sphene, apatite, calcite, and quartz.

Volcaniclastic rocks of the Baish group are subordinate to flow rocks in many areas but are dominant in others. They include gray, green, red, and tan tuffs and conglomerates.

They are fine to medium grained except for the agglomerates, in which the clasts are as much as 30 cm in diameter. These rocks crop out in layers that range from about 5 to 30 cm in thickness. Most original bedding textures have been obliterated by shearing; the tuffs are commonly spotted or mottled where this shearing has affected feldspar fragments and lapilli. Rhombs of limonitic siderite make up as much as 20 percent of some tuffs and give them a spotted appearance.

The sedimentary rocks in the Baish group include graywacke and graphitic slate or argillite. Chert is a minor constituent. Limonitic siderite is common in the argillites. The rocks are gray to dark gray and fine to medium grained. Sedimentary structures and bedding generally have been obscured by shearing.

The Baish group in the neighboring Wadi Hali quadrangle (sheet 18/41 B) is divided into four units (Hadley, 1975b), three of which strike into the Wadi Dhahaban quadrangle. The lowermost unit, which crops out in the Wadi Bahr area, consists mainly of metabasalt with some meta-andesite. These rocks are porphyritic and contain abundant amygdules; commonly pillow structures are crudely preserved. Minor amounts of mafic metapyroclastic rocks and meta-agglomerates occur between the flows, as well as sparse amounts of chert. This unit is overlain to the west by meta-agglomerate and chlorite schist derived from waterlaid tuff, black chert, and minor mafic metavolcanic flow rocks. Graded rhythmic bedding within this unit suggests turbidite deposition, although sedimentary structures indicative of turbidity, such as flute casts and sole marks, were not found. However, a minor conglomerate bed suggests deposition by subaqueous slumping that was probably associated with turbidity currents. This part of the Baish group is therefore considered to represent deep-water marine sedimentation, possibly concomitant with silica precipitation. The volcanic rocks in the Baish group, many of which formed as subaqueous lavas, are compatible with this depositional interpretation. The third unit in the Baish group in the Wadi Hali quadrangle crops out in the Wadi Dhahaban quadrangle immediately east of the Quaternary basaltic lavas and consists of metabasalt, meta-andesite, and interbedded metapyroclastic rocks, thin marble beds, metaconglomerate, and chlorite schist derived from water-laid tuff.

Bahah group

The Bahah group (Schmidt and others, 1973) is represented in the Wadi Dhahaban quadrangle by clastic sedimentary rocks, marble, and some flow rocks and tuffs; the marble is easily recognized and provides good marker beds. These rocks crop out in several north- and northwest-trending belts in the central, south-central, and eastern parts of the quadrangle.

The clastic rocks include graywacke, siltstone, and argillite. They are schistose, fine to medium grained, and mostly gray. Limonitic siderite is common to abundant; sericite and chlorite impart a characteristic sheen to planes of schistosity.

The marble is white, gray, or buff. It consists of a mosaic of small to large calcite crystals enclosing 5 to 20 percent magnetite, quartz, feldspar, and mica. The marble is interbedded with clastic rocks in sheared units as much as 50 m thick in which individual beds range from 10 cm to 1 m in thickness. The clastic rocks make up about 70 percent of the thickness of the unit.

Flow rocks and pyroclastic rocks are subordinate to the sedimentary rocks and include andesite, basalt, agglomerate, and lapilli tuff. The rocks are gray to green, contain abundant chlorite, are moderately to strongly schistose, and are interbedded with minor amounts of fine-grained clastic rock.

The Bahah group in the neighboring Wadi Hali quadrangle (sheet 18/41 B) is divided into five units (Hadley, 1975b), of which the two lowest strike into the Wadi Dhahaban quadrangle in an area located between the two belts of Baish group rocks. The lower of these units consists of pebbly chloritic quartzite, pyritic quartz-feldspar schist, and sideritic chlorite schist; the quartzite is distinguished by the blue color of the quartz grains. The composition of the rocks probably originally ranged from lithic subarkose to graywacke. The upper of the two units that strike into the Wadi Dhahaban quadrangle consists of chlorite schist, chloritic quartzite, minor metagraywacke, and chert.

Ablah group

Schistose siltstone, graywacke, quartzite, and conglomerate in the Wadi Dhahaban quadrangle are assigned to the Ablah group. These rocks crop out in a north-trending belt along most of the eastern margin of the quadrangle and are thus continuous with the biotite-quartz schist, graphitic phyllite, calcareous schist, and quartzite located in the neighboring Jabal Sawdah quadrangle (18/42 C) that have been assigned to the Hali group (Ratte and Andreasen, 1974). However, rocks in the Wadi Yiba quadrangle (19/41 D) that are similar to upper Hali group rocks in the Jabal Sawdah quadrangle have been assigned to the Ablah formation by (Bayley, 1972).

These differences in stratigraphic assignment arise from an early tendency to interpret the most highly metamorphosed

Precambrian rocks as the oldest; the balance of recent opinion is that some, if not all, of the highly metamorphosed rocks assigned to the Hali schist or Hali group, for example, are in fact stratigraphically equivalent to younger and less metamorphosed rocks. The Ablah formation of Brown and Jackson (1960) was named for the village of Ablah in quadrangle 20/41 D and was considered to correlate with the Fatima formation. The Ablah formation was raised in rank to the Ablah group by Schmidt and others (1973) and described by Greenwood (1975a) as including the Ablah formation of Bayley (1972) and parts of the Hali Group of Ratte and Andreasen (1974) and Prinz (1975) that are contiguous with the Ablah group in the Wadi Hali quadrangle (Hadley, 1975b); these precedents are followed here.

The nonconglomeratic rocks in the unit are fine to medium grained, tan and gray, and contain abundant biotite and sericite; bedding and other sedimentary features are poorly preserved. The conglomerate crops out in the extreme southeastern part of the Ablah belt east of a fault that juxtaposes the Baish and Ablah groups. The base of the conglomerate was not seen in the Wadi Dhahaban quadrangle; Greenwood described the basal contact of the Ablah group in the Biljurshi quadrangle (1975b) as an unconformity. The conglomerate is poorly sorted and contains clasts as much as 30 cm in diameter composed mainly of metavolcanic, metasedimentary, and lesser amounts of metaplutonic rock.

The Ablah group in the neighboring Wadi Hali quadrangle (Hadley, 1975b) is divided arbitrarily into the Sarban and Hadab formations; the latter strikes into the northeastern corner of the Wadi Dhahaban quadrangle and consists of garnet amphibolite, garnet-biotite schist, and hornblende-biotite schist intertongued with biotite gneiss, garnet-hornblende schist, biotite schist, quartzite, and other metasedimentary rocks. Small-scale isoclinal folds and ptygmatic folds are common. Mineral lineation generally plunges steeply, as do the axes of the small-scale folds. Relict sedimentary bedding is preserved in places, especially in fine-grained beds. Textures are nematoblastic and lepidoblastic. Epidote and sphene are common accessory minerals, and andesine is the dominant feldspar. The garnet porphyroblasts generally show quartz-pressure shadows.

Intrusive rocks

Granodiorite

Biotite granodiorite has been intruded into Bahah group rocks along Wadi Dhahaban and one of its tributaries in the center of the quadrangle area. It is light gray to white, medium to coarse grained, and contains abundant plagioclase phenocrysts as much as 1.5 cm long; biotite is the main mafic mineral, constituting 1 to 3 percent of the rock.

Granodiorite to quartz monzonite

A granodiorite to quartz monzonite pluton occupies about 60 km^2 in the southeastern corner of the quadrangle. This pluton and a small satellite intrusion to its northwest were intruded into Baish group metavolcanic rocks that were highly metamorphosed and syntectonically foliated at contacts with the pluton. The intrusive rock is light gray, medium grained, leucocratic, and gneissose near the margins of the pluton.

Granodiorite

A granodiorite stock about 1.5 km in diameter has been intruded into the Bahah group in the east-central part of the quadrangle. It consists of gray, medium- to coarse-grained, hypidiomorphic-granular biotite granodiorite containing 2 to 5 percent biotite; this rock is much less altered and metamorphosed than the other granodiorites of the quadrangle.

Quartz monzonite

Quartz monzonite crops out at the head of three small wadis approximately 6 km east northeast of the coastal village of Al Qahmah in the southeastern part of the quadrangle. The outcrop is limited by pediment sand and gravel deposits along its southern edge and is overlain by basalt of the Al Birk lava field to the northwest. This quartz monzonite exposure may be related to small quartz monzonite exposures in the north-central part of the Jabal Hashahish quadrangle.

The quartz monzonite is light orange to light gray and is equigranular to extremely porphyritic with phenocrysts commonly as much as 3 cm long. It is strongly weathered and friable. Quartz, plagioclase, and potassium feldspar in about equal proportions constitute about 90 percent of the rock; other minerals include 3 to 7 percent biotite, and traces of chlorite, opaque minerals, sphene, apatite, and epidote.

TERTIARY ROCKS

Gabbro Dikes

Gabbro dikes in the Wadi Dhahaban quadrangle are part of a system of dikes that extends from the Yemen to the Gulf of Aqaba. These rocks have yielded potassium-argon (K/Ar) whole-rock dates ranging from 19 to 27 million years (m.y.) before present, averaging 22 m.y. (Brown, 1972; Blank, 1978). These Miocene dikes were apparently formed toward the close of the initial opening of the Red Sea rift and are believed to represent oceanic crust. They give rise to prominent aeromagnetic lineaments trending north-northwest and consisting of narrow negative and positive anomalies and steep gradients (Andreasen and Petty, 1974; Blank, 1978). Ground geophysical surveys have shown that the most intense anomalies are produced chiefly by near-vertical dikes that have very strong reversed remanent magnetization, particularly in chilled margins.

The dikes in the Wadi Dhahaban quadrangle trend north-northwest (fig. 2), are as much as 300 m wide in places, and tend to branch and anastomose, though some individual dikes can be traced for several kilometers. They are coarse grained in the middle but were chilled along the margins and are consequently diabasic, fine grained, and resistant to weathering and erosion on their margins; therefore most of their outcrops have U-shaped profiles. They are composed of clinopyroxene and plagioclase with accessory magnetite, chlorite, and apatite; hornblende is common to abundant in some of them. The wallrocks of the dikes are metamorphosed in many places. A dike near Khamis Bahr is crudely layered parallel with its walls and spotted with abundant plagioclase segregations near its margins. The intense distortion, fracturing, and folding of the country rock bordering the dike indicates forceful injection of the dike material.

Specimens were collected by Blank and Brown in 1970 from several parts of the Tertiary dike system, especially in the sector between Jiddah and Jizan (Blank, 1978). Almost all of these specimens show some degree of protoclasis or cataclasis and extensive (deuteric?) alteration involving conversion of mafic minerals to hydrous phases. These changes suggest that dike emplacement was accompanied by some tectonic movement and by considerable hydrothermal activity. Specimens collected by Blank and Brown in the Wadi Dhahaban quadrangle include monzodiorite and quartz monzonite or quartz monzogabbbro.

QUATERNARY ROCKS AND DEPOSITS

Volcanic rocks

Part of the Al Birk basalt field occupies more than 1,500 km^2 in the western part of the Wadi Dhahaban quadrangle (fig. 2). Similar basaltic rocks form an elongate north-trending area west of Khamis Bahr and two smaller areas west of Mahduwah, all in the eastern half of the quadrangle. Survival of easily eroded volcanic features, relationships with underlying alluvium and weathered bedrock, radiometric age determinations of 0.5 m.y. or less (Ghent and others, 1979), and superposition of successive flows indicate that

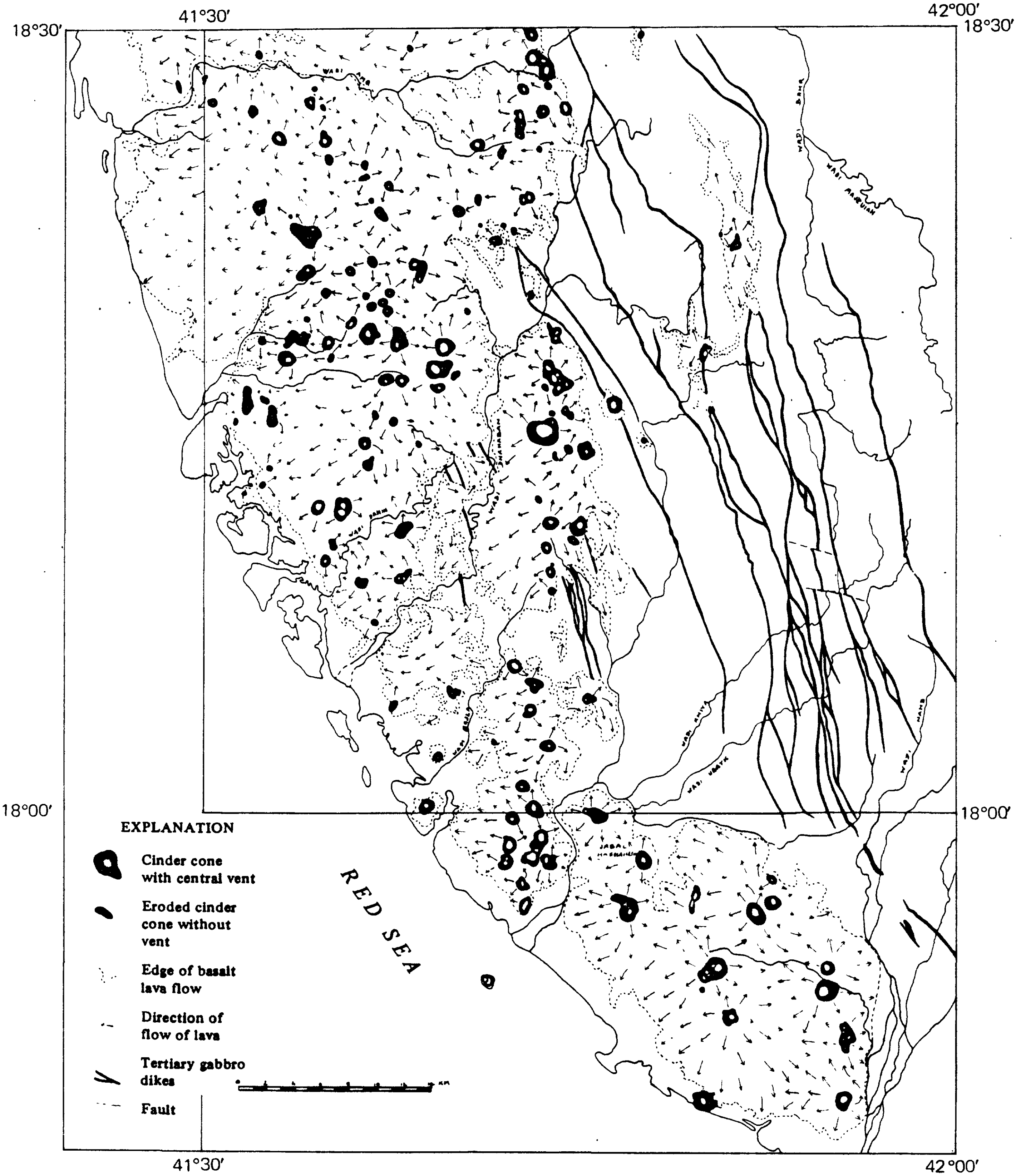

Figure 2.– Generalized map of the Wadi Dhahaban quadrangle and adjoining areas showing Tertiary dikes and Quaternary volcanic features.

the eruptions occurred periodically during Quaternary times; two samples from Wadi Amq gave potassium-argon (K/Ar) ages of 2.0±1.0 and 2.4±1.5 m.y. (late Pliocene), respectively (Hadley, 1975a), and basaltic volcanism is known to have continued into historic times in the Al Madinah area in the northern part of the Shield. The basalt fields are therefore interpreted as having resulted from the continuation of the opening of the Red Sea rift after intrusion of the Miocene gabbro dikes. The composition of the flow rocks and pressure-temperature calculations based on the composition of inclusions suggest that the flows were derived from partial melting of the upper mantle (Ghent and others, 1979).

The surfaces of the basalt fields are composed of angular blocks of lava as much as 40 cm in diameter. The flow rocks beneath are vesicular columnar basalt (fig. 3). No detailed stratigraphic succession of flows has been worked out but, in general, the dark flows overlie older flows of lighter color. In places, the flow rocks overlie loosely consolidated tephra beds as much as 8 m thick. In places, flow rocks and tephra are underlain by Precambrian rocks that are weathered and stained with hematite to a depth of as much as 30 cm; in other places, they overlie alluvium (fig. 4 and 5).

Many large cinder cones rise above the general level of the fields (fig. 6). They range up to 2.5 km in diameter and up to 400 m in height. Some are well preserved, with a complete, enclosed, bowl-shaped central vent, but most are partly eroded; in some instances the vent or vents have been breached or completely obliterated. Some of the cones have a single vent, but composite cones may have as many as six overlapping or separate vents. Many of the cones have been breached all the way to their bases by lava flowing from more or less circular feeder pipes (Ghent and others, 1979), and many are cut by more or less radially disposed feeder dikes. In some places, lava has flowed from the base of cones composed entirely of cinders and surrounded by an eroded trough.

The basalt is unaltered and includes, in order of decreasing abundance, twinned labradorite laths, clinopyroxene, olivine, magnetite, iddingsite, and apatite; some of the very abundant vesicles are partly filled with white calcite. Euhedral olivine and augite grains, which are probably xenocrysts, are as much as 3 cm long and are embedded in the basalt or have been weathered out and strewn over the flows. Abundant blocks of harzburgite, websterite, and gabbro as much as 25 cm in diameter occur on the slopes of some of the cinder cones. Both the xenocrysts and these blocks are considered to represent material derived from the mantle or lower crust (Ghent and others, 1979).

The results of chemical analysis of two basalt samples from Wadi Amq (Hadley, 1982a) are shown in table 1.

Figure 3.– Photograph showing columnar jointing in Quaternary basalt near Wadi Dhahaban in the north-central part of the quadrangle.

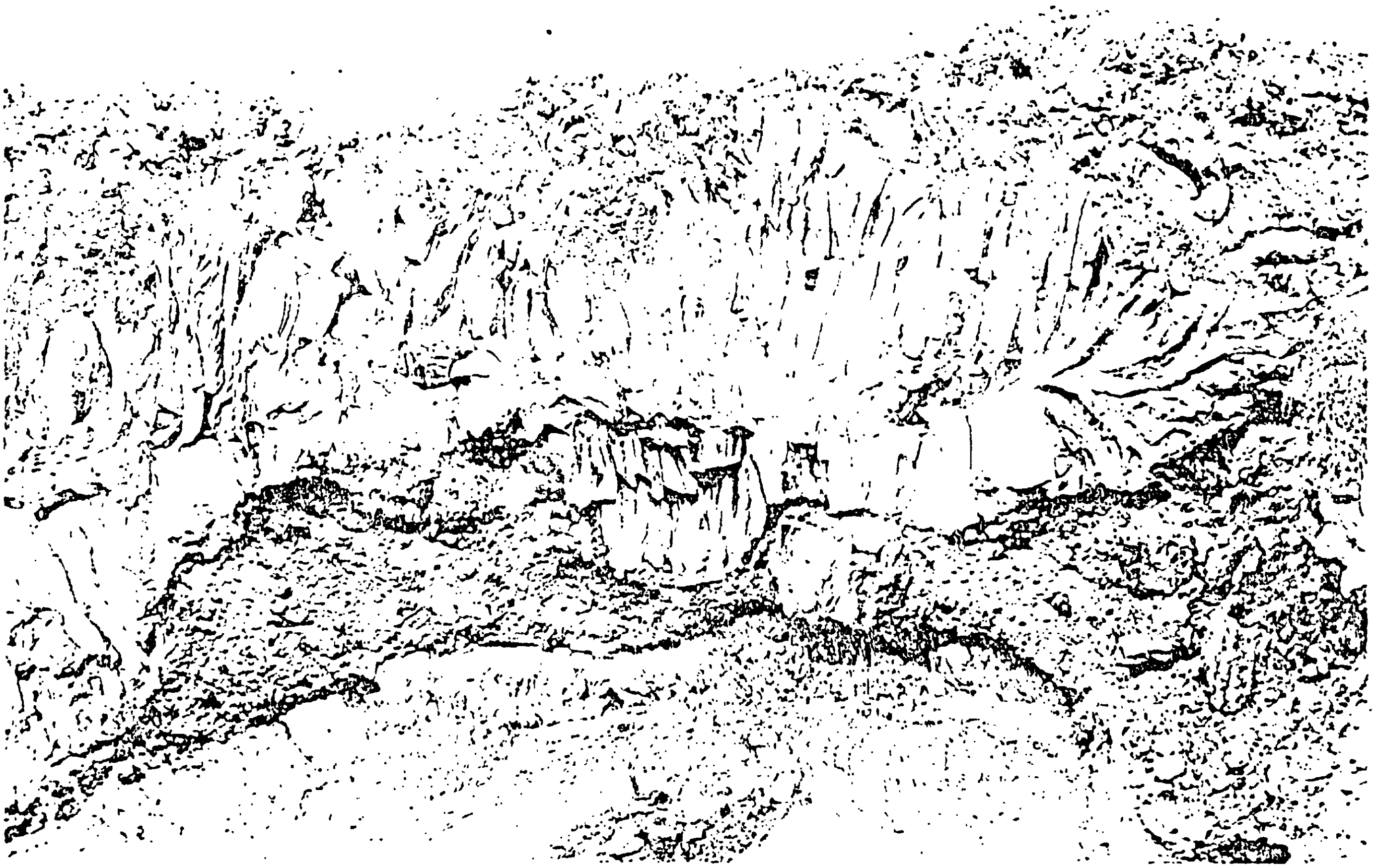

Figure 4.– Photograph showing columnar-jointed Quaternary basalt molded over ridges of alluvium near Wadi Dhahaban in the north-central part of the quadrangle.

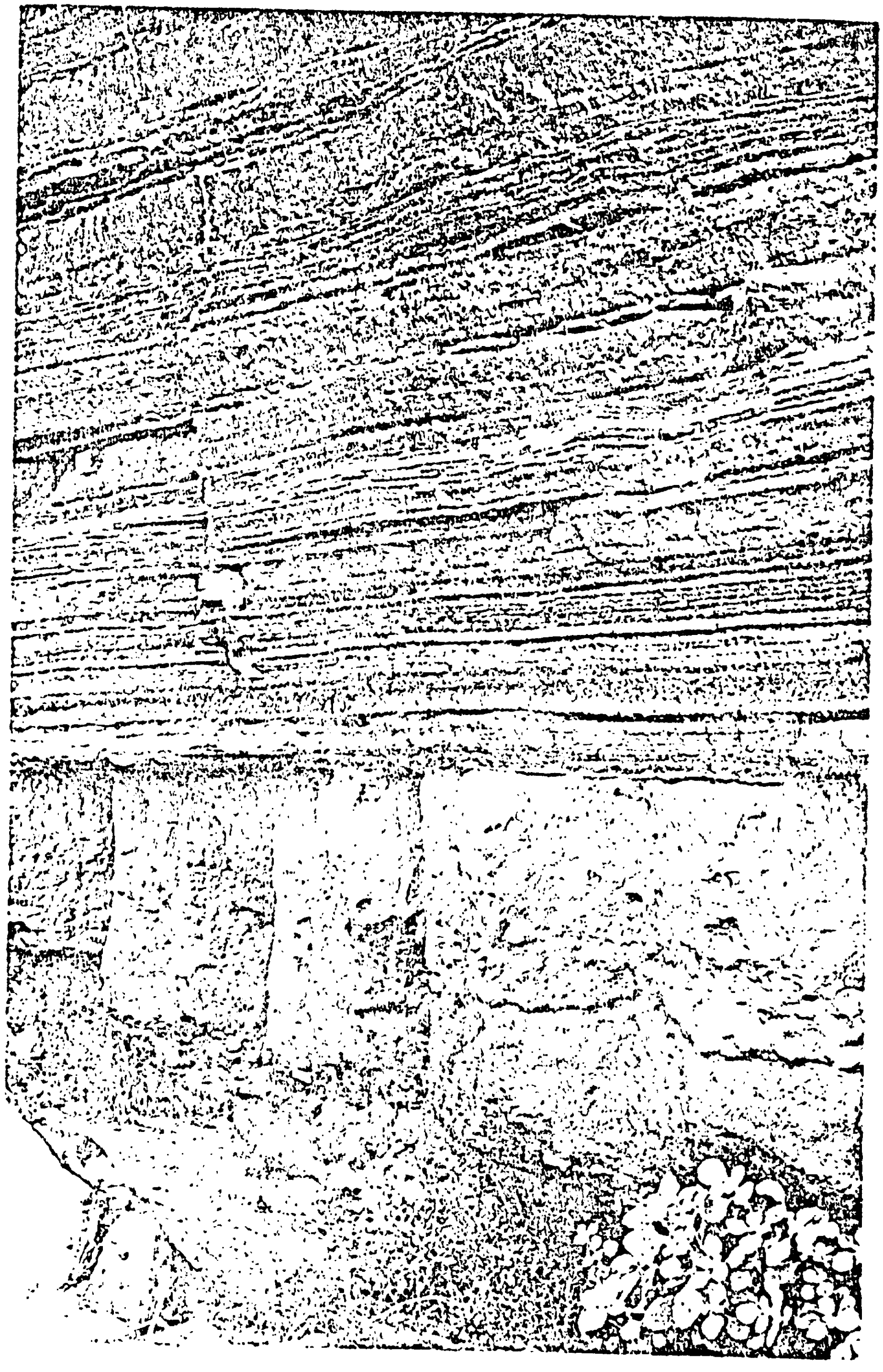

Figure 5.– Photograph of tephra overlying alluvium near the center of the southern margin of the quadrangle.

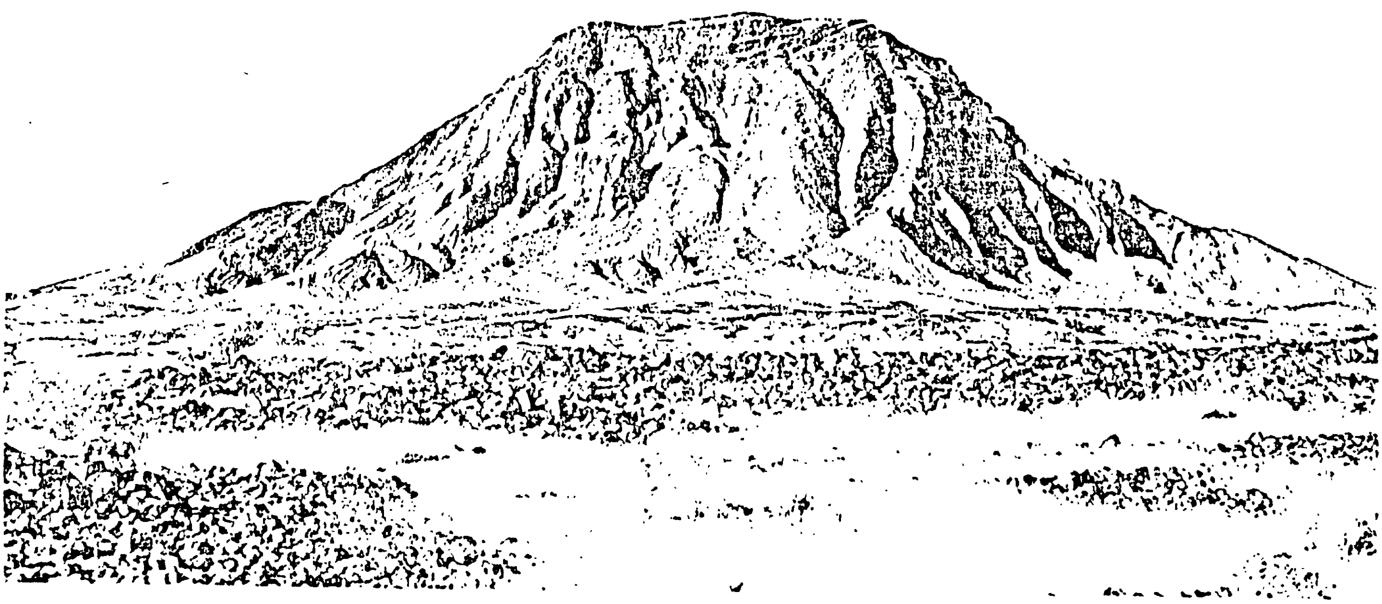

Figure 6.– Cinder cone photographed from near the center of the southern margin of the quadrangle.

Table 1.--*Chemical analysis of two basalt samples from Wadi Amq*
[results in percent]

Oxide	932A	932B
SiO_2	43.5	44.1
Al_2O_3	15.6	14.5
Fe_2O_3	7.9	6.3
FeO	3.8	5.8
MgO	7.0	10.0
CaO	10.3	9.5
Na_2O	2.3	2.5
K_2O	.83	.67
H_2O+	1.8	1.3
H_2O-	1.4	1.0
TiO_2	2.4	2.2
P_2O_5	.35	.32
MnO	.23	.18
CO_2	1.7	.70
TOTAL	99.11	99.07

The tephra occur as black, flat-lying, well-stratified layers with beds 2 to 25 cm thick (fig. 5), but similar material on the cinder cones is dark red. The beds are graded and consist of ejecta ranging up to 3 mm in diameter.

Surficial deposits

Shallow bank and coral reef deposits

Shallow banks and coral reefs are present along the coast and around small offshore islands. The banks consist of a mixture of calcareous and terrigenous muds, the latter dominating those along the coastal margins. The reefs consist of many types of coral, gastropods, brachiopods, and pelecypods, and are still being built by living organisms on cemented accumulations of the skeletons and shells of former generations. The water depth above the banks and the crests of the coral reefs is from 0.5 to 10 m.

Carbonate sand deposits

An island located about 2 km offshore is about 1.5 km long and 0.5 km wide and consists primarily of fine- to coarse-grained carbonate sand deposits, composed of broken shells, coral fragments and subordinate amounts of eolian silt, which rest on coral reef and are surrounded by shallow banks. A similar but smaller island occurs off the mouth of Wadi Najla, in the southwestern part of the quadrangle.

Pediment and plains deposits

Pediments and derived deposits cover an extensive area between the basalt and Precambrian outcrops and the flood plain deposits that are present along wadis draining the basalt fields. They consist of boulder- and cobble-sized material on the steep flanks of the outcrops, and of gravel, sand and silt washed from the coarse material onto flat areas below the steep slopes. These abundant deposits have resulted from rapid erosion caused by disturbance of the balance of coastal-plain drainage by the eruption of great thicknesses of basaltic rocks.

Alluvial sand and gravel deposits

Sand and gravel deposits form the floors of all the main wadis and their tributaries and consist of tan to brown, subangular to well-rounded, unstratified to well-stratified material that is commonly crossbedded and fills channels.

Wadi flood-plain deposits

Extensive flood plains have formed along the major wadis, and consist of tan silt with subordinate amounts of fine-grained sand and clay. These deposits are as much as 4 m thick and are generally unstratified. New material is deposited during periods of intermittent flooding in the low-energy environments of high ground within the wadis and marginal to the main channels.

Tufa deposits

Tufa or secondary carbonate enclosing basalt boulders (fig. 7) is present in wadis in a few places. In the northwestern part of the quadrangle a 15-m-thick deposit of basalt boulders enclosed in tufa is overlain by 5 to 10 m of buff tufa. The tufa appears to have formed by deposition of calcium carbonate, possibly derived from volcanic waters or from the basalt itself, while a wadi was dammed by a lava flow and then was partly eroded when the dam was breached.

Sabkhah deposits

Sabkhah deposits are present along the coast, between the edges of the basalt outcrops and the shallow bank and coral reef deposits of the shoreline. They are flats composed of brown and white saline silt with partly indurated crusts 1 to 3 cm thick.

STRUCTURE

North to north-northwest trends dominate the structure of the Precambrian rocks in the Wadi Dhahaban quadrangle, mainly in the form of wrench faults, some of which can be traced for tens of kilometers; only a few folds have been recognized in these rocks. Most schistosity strikes north and dips steeply; however dips as shallow as 30° east or west, and even north or south, are present.

Work in nearby quadrangles suggests that the Baish and Bahah group rocks were folded and faulted during the first orogenic episode to regionally affect the area, then metamorphosed to greenschist facies, and finally unconformably overlain by the Ablah group (Schmidt and others, 1973; Ratte and Andreasen, 1974; Greenwood, 1975b; Hadley, 1975b, Prinz, 1975). The Ablah group rocks were subsequently folded and faulted about north-trending axes and were intruded syntectonically by granodiorite and granite batholiths that metamorphosed the Ablah and older groups locally to amphibolite facies. Posttectonic granodiorite stocks were emplaced later during the late Precambrian.

Emplacement of the Miocene dikes appears to have been associated with a fracture system that developed toward the close of first-stage lateral spreading of the Red Sea rift, probably in response to isostatic forces (Blank, 1978). Only two transform faults affecting the dikes have been mapped in the Wadi Dhahaban quadrangle, but such faults elsewhere may have been caused by sympathetic disruption in mechanical response of the Precambrian host rocks to the evolving stress field. The overall pattern of the dike and fault system suggests deep-rooted slump failure of the Precambrian rocks adjacent to the newly formed continental margin.

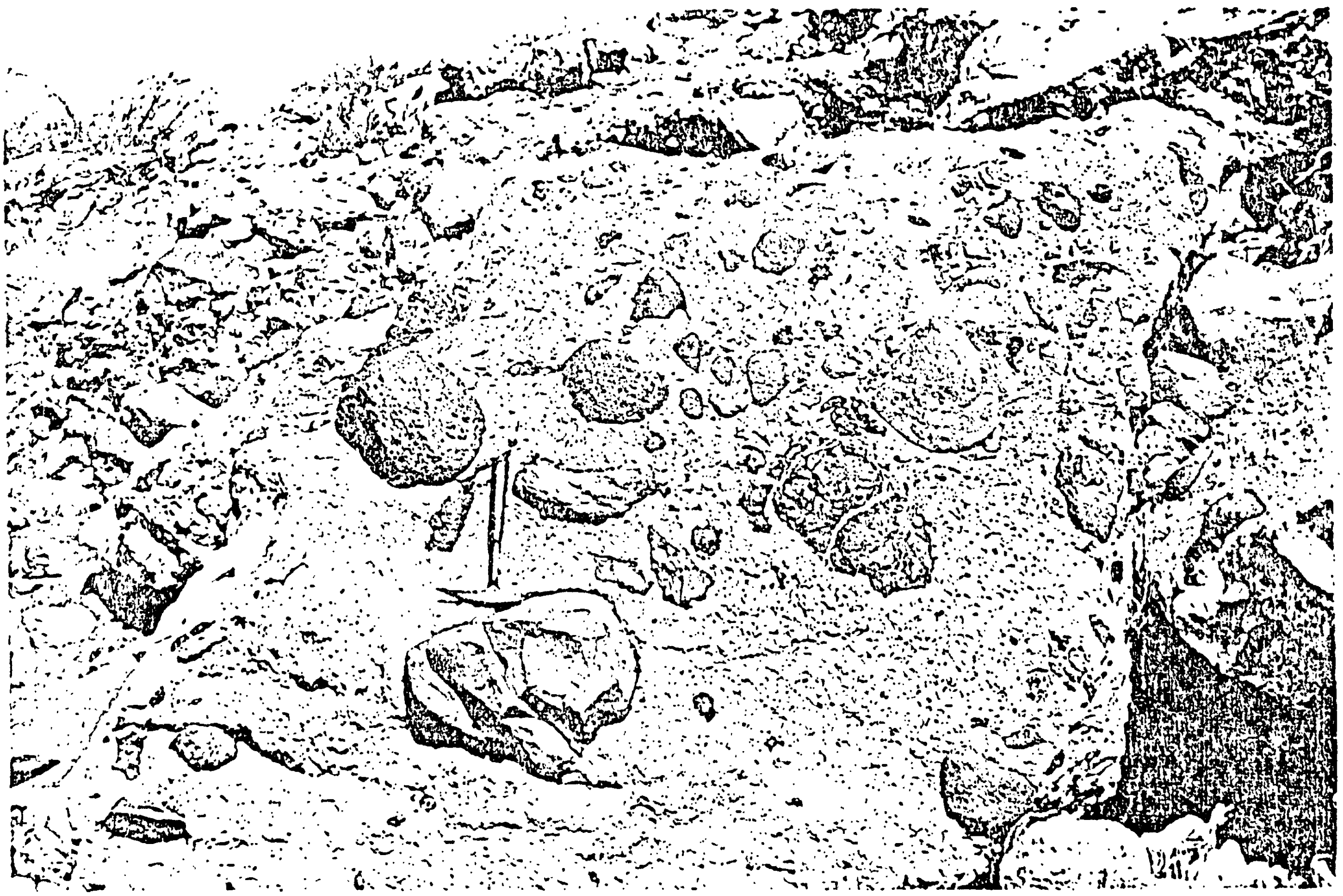

Figure 7.– Photograph showing secondary carbonate deposit enclosing boulders of basalt near Wadi Amq in the northern part of the quadrangle.

ECONOMIC GEOLOGY

Disseminated pyrite is common in many parts of the eastern half of the Wadi Dhahaban quadrangle, but no other signs of possible mineralization were observed during the reconnaissance mapping. Pyritic samples from several localities were analyzed, but the base metal contents were not sufficiently above background levels to justify further work.

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