DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Stratigraphy of the Murdama Formation between Afif, Halaban, and As Sawadah, Kingdom of Saudi Arabia

by

R. C. Greene [1/]

Open-File Report 84-327

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

1/ U.S. Geological Survey, Saudi Arabian Mission, Jiddah

1984

CONTENTS

ILLUSTRATIONS
[Plates are in pocket]

TABLES

STRATIGRAPHY OF THE MURDAMA FORMATION BETWEEN AFIF, HALABAN, AND AS SAWADHA, KINGDOM OF SAUDI ARABIA

by

Robert C. Greene[1]

ABSTRACT

The principal outcrop-area of the Murdama Formation, a synclinorium, extends from lat 23°00' N., long 43°00' E. near Afif to lat 22°00' N., long 45°00' E. in the As Sawadah area. Outcrops extend further to the northwest, but to the southeast Murdama is buried under Paleozoic rocks.

Measured sections in the west limb of the synclinorium include Jabal Murdama, 5287 m thick, Jabal Raqabah, 5652 m thick, and As Sawadah, where the thickest measurable sequence is 3938 m. Most of the rocks in these sections are sandstone, commonly greenish gray, fine to coarse grained, and composed of poorly sorted angular grains of quartz, plagioclase, and silicic volcanic rock fragments. Interbedded volcanic rock and conglomerate, some containing pebbles of granitic rock, are minor constituents.

Measured sections of the main part of the Murdama in the east limb of the synclinorium include Jabal Zaydi, 12,361 m thick, and Wadi Sirrah, 25,751 m thick, which are also composed of sandstone with minor volcanic rock and conglomerate. Sections of the lower part of the Murdama include Jabal Farida, 2497 m thick, Jabal Damkh, 3596 m thick, and Jabal Qatar, 200 m thick. Sections at Jabal Farida and Jabal Damkh each contain 600 m of marble in their lower parts. Above the marble lie rocks similar to those in the other sections.

Recent radiometric dating of plutonic rock underlying the Murdama and rock correlative with intrusives into it has shown that the Murdama strata were deposited between 600 and 640 Ma ago.

On the basis of this study, I conclude that the Murdama is a single lithostratic unit that should be formalized as the Murdama Formation. I also recommend that the unit heretofore referred to as the Farida formation be formallized as the Farida Marble Member of the Murdama Formation and that the term "Zaydi formation" be abandoned.

1/ U.S. Geological Survey, Saudi Arabian Mission, Jiddah.

INTRODUCTION

The first stratigraphic classification for rocks of the Arabian Shield was derived from the compilation over 20 years ago of a series of 1:500,000-scale geologic maps (e.g., Bramkamp and others, 1956, 1963; Brown and others, 1963a, b). This mapping largely separated gross lithologic types, but a few formation names were introduced.

Subsequently, mapping at 1:100,000-scale has resulted in the erection of a debatable stratigraphic scheme of considerable complexity. Lithostratigraphic units of group, formation, and member rank have been named informally and correlated with each other, often without benefit of either precise definitions or detailed descriptions.

The names of the stratigraphic units that have appeared in published maps and reports have been assembled in the Saudi Arabian Stratigraphic Lexicon (Fitch, 1980), which contains over 1500 entries. A Joint Stratigraphic Team of the Saudi Arabian Deputy Ministry for Mineral Resources has been assembled to review and revise the present stratigraphic classification. The team's first objective is to define and describe already-named units in accordance with the Saudi Arabian Code of Lithostratigraphic Classification and Nomenclature (Stratigraphic Committee, 1979). Initially, the units are to be studied in their type localities or areas and subsequently in areas to which they have been extended. This report, the first of a series to be produced by the team, describes the results of a study of the Murdama in its principal area of outcrop (figs. 1, 2.), the belt containing the type locality and the type localities of two of its constituent parts. It reports the lithologic content of several measured sections and relates the lithologies to those of underlying rock. Its purpose is to establish a firm answer to the question 'What is Murdama?' so that rocks elsewhere may be compared.

This report is in accordance with the work agreement between the U. S. Geological Survey and the Saudi Arabian Ministry of Petroleum and Mineral Resources.

Murdama formation and group

The name Murdama was first used by Brown and Jackson (1960) in their report on the Arabian Shield. They named slate, phyllite, graywacke, and conglomerate at Jabal Murdama the Murdama formation. The Murdama formation appeared on several 1:500,000-scale geologic maps of parts of the Shield--Southern Najd (Jackson and others, 1963), Southern Hijaz (Brown and others, 1963a), Northeastern Hijaz (Brown and others, 1963b), and Wadi ar Rimah (Bramkamp and others, 1963). The Murdama was first raised to group status in the Bir Ghamrah quadrangle (Overstreet and Whitlow, 1972); this quadrangle lies directly east of the As Sawadah section of the present report. Geologists of the Bureau de Recherches

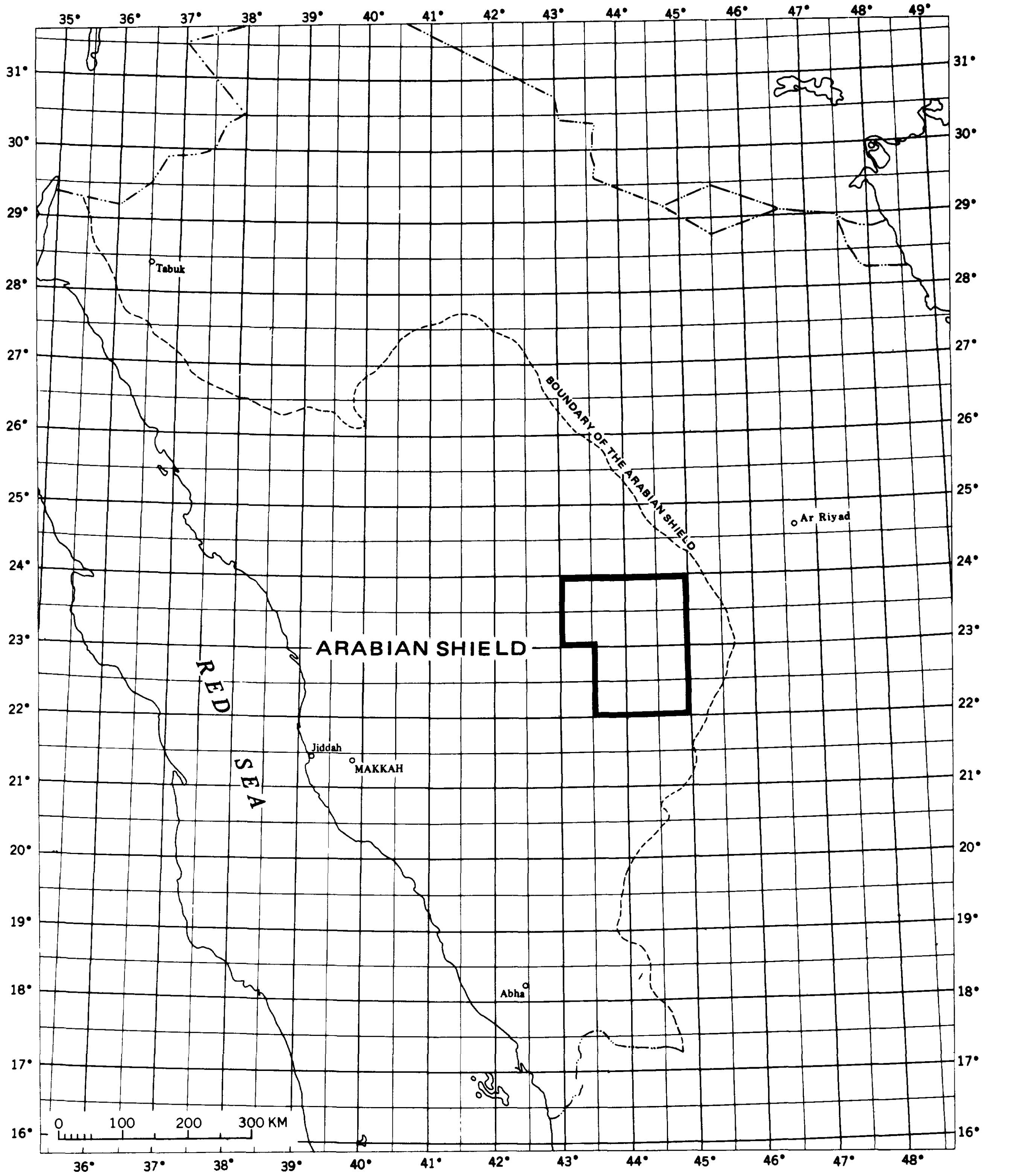


Figure 1.--Index map of western Saudi Arabia showing location of the central and southern parts of the principal outcrop belt of the Murdama formation.

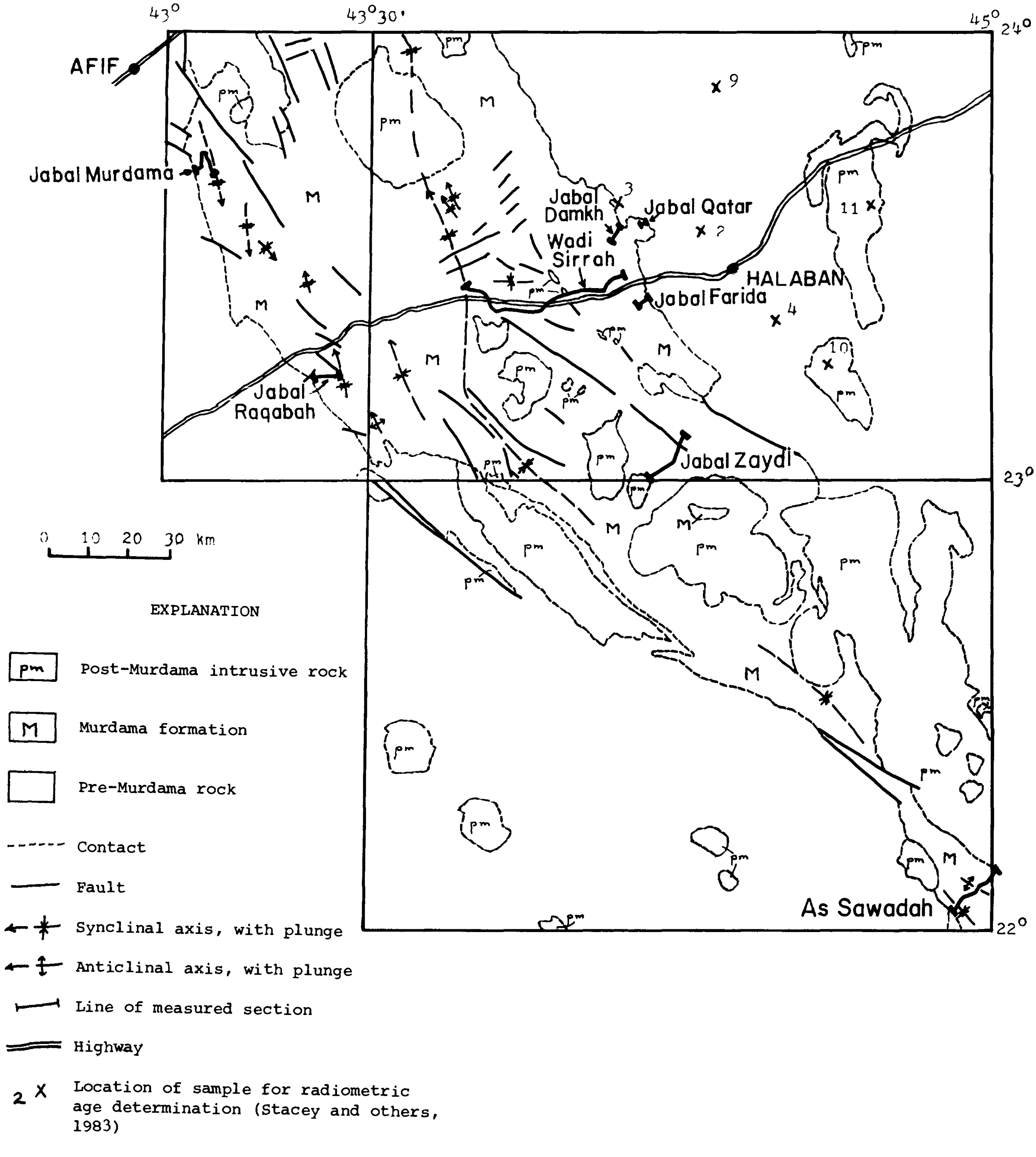


Figure 2.--Structure map showing the central and southern parts of the principal outcrop belt of the Murdama formation. Based on structural sketch maps of Afif (Letalenet, 1979), Halaban (Delfour, 1979), and Wadi ar Rika (Delfour, 1980) quadrangles.

Geologiques et Minieres (BRGM) continued to refer to the Murdama formation in its principal outcrop belt between Jabal Murdama and Halaban (Leca and others, 1972; Letalenet and others, 1972; and other authors). Schmidt and others (1973) adopted the name Murdama group for some rocks in the southern part of the Shield, principally the Jabal Yafikh quadrangle (20/43 B), that were believed by them to be correlative with those in the principal outcrop belt. The name Murdama, commonly as a group but locally as a formation, has continued to be applied to areas extending the principal outcrop belt to the north (Delfour, 1977, 1981). It has also been used for rocks lying across the strike to the west in the 1:100,000-scale maps prepared by BRGM geologists, for example 24/41 C (Aguttes, 1971), 24/40 D (Letalenet, 1976a), 24/40 C (Letalenet, 1976b), and 24/39 C (Brosset, 1979). However, later, in the 1:250,000-scale compilations of the Al Hissu (Delfour, 1981) and Al Madinah (Pellaton, 1981) quadrangles, these rocks were given another group name. The Murdama group has also been extended further in the southern Shield (Cornwall, 1973; Hadley, 1976; Schmidt, in press).

Farida member and formation

The name Farida marble was introduced in the southern Najd and Wadi ar Rimah 1:500,000-scale quadrangles (Bramkamp and others, 1963; Jackson and others, 1963). It was not originally part of the Murdama formation or group. The type locality is Jabal Farida, which lies about 25 km southwest of Halaban. Later (Bois, 1971), the Farida was made a member of the Murdama formation. Still later (Delfour, 1979), the Farida was made a formation and a part of the Murdama group.

Zaydi formation

The Zaydi formation is a new unit, having been introduced during 1:250,000-scale compilation of BRGM mapping in the principal outcrop-area of the Murdama group (Delfour, 1979, 1980). According to these maps, the Zaydi formation constitutes the bulk of the Murdama group. The type locality is at Jabal Zaydi, about 50 km southwest of Halaban.

Selection of sections and field methods

Sections were selected for measurement in a given area for one or more reasons, including: to establish a type section for a named unit, to establish a reference section, to determine the extent to which changing depositional environments varied the lithology and thickness of the deposit along strike.

Once an area was selected, a study of aerial photographs revealed the exact place where outcrop is most nearly continuous across the strike. Enlarged photographs at a scale of about 1:12,000 were used as a base. Field work was done entirely by foot traverse across the section and involved the collection of rock samples (more extensive at first), the describing of lithologies and sedimentary features, and the recording of strike and dip.

In the office, a domain was assigned to each field station generally equal to half the distance to the preceding station plus half the distance to the succeeding station. Strike and dip were plotted or interpolated, scale and directional factors were applied, and the thickness of section traversed was calculated. Corrections for slope of the land were generally not necessary, but were applied in some places.

The sections presented in this paper were erected by combining the appropriate domains. Where strike and dip were obtained at every station, thickness must be quite accurate, where strike and dip are interpolated, it will be less so. The outcrops observed are on flat pediments and gentle to moderate slopes and ridge crests. Much can be seen, but these outcrops emerge irregularly through a mantle of weathered fragments and lack the clarity in detail of sections observed in stream cuts in areas with more humid climate or in the cliffs characteristic of areas underlain by flat lying rock.

Outcrops follow one another in close succession, but allowance should be made for the fact that finer grained rocks tend to be more poorly exposed. The possibility of undetected structural complexities is an important problem, especially when reporting a section (Jabal Zaydi) that is 12 km thick and another (Wadi Sirrah) that is 25 km thick. The lack of mappable faults and, principally, the lack of minor folds in the rock observed along the sections, are the main factors which rule against structural repetition of beds.

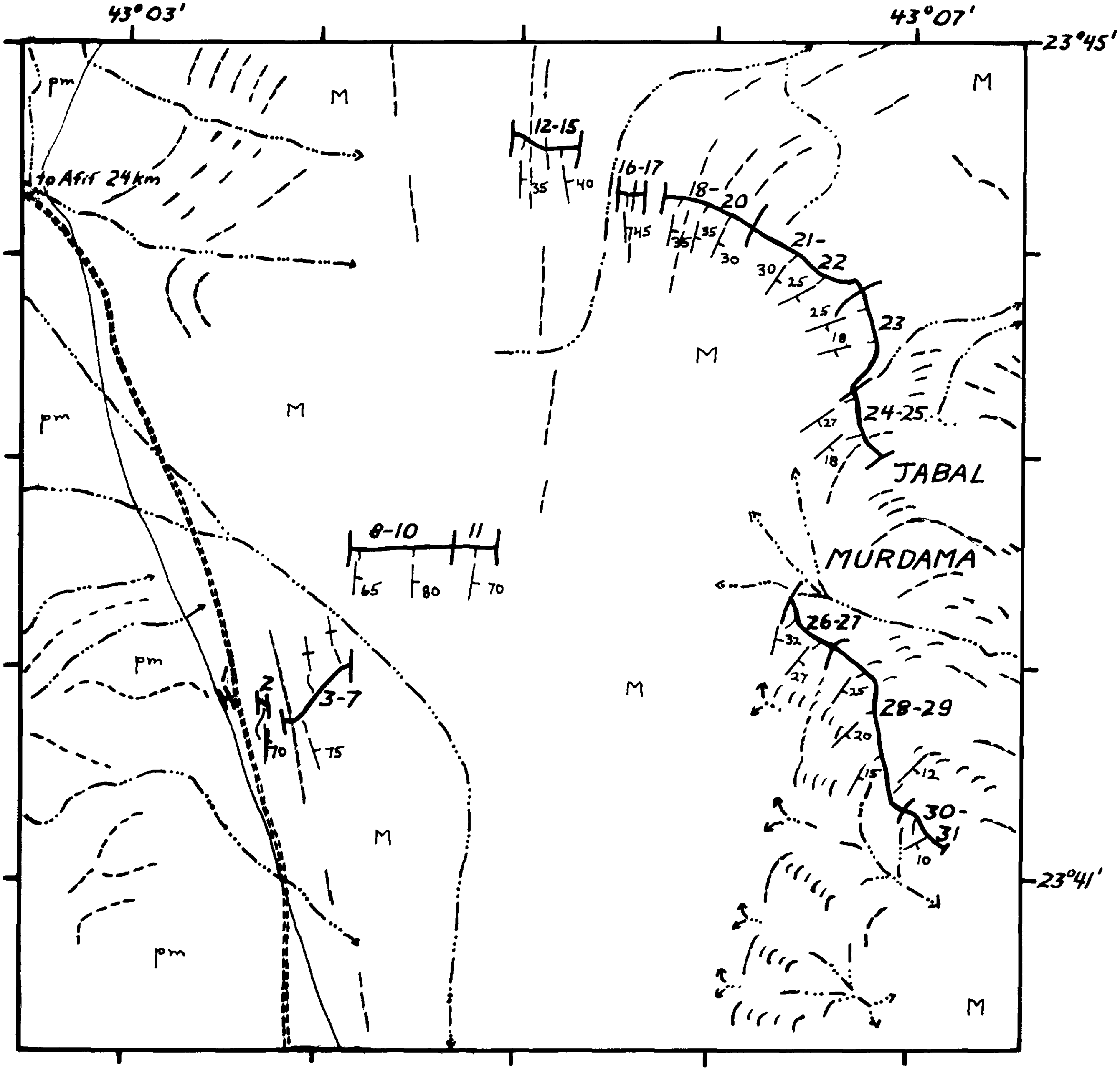
Acknowledgements

Assistance in the field provided by Benjamin Greene is gratefully acknowledged. Ahmed el Bazli helped with applying zip-a-tone patterns to the columnar sections. Charles Williams measured and calculated thicknesses and drafted location maps.

SECTIONS ON THE WEST LIMB OF THE MURDAMA SYNCLINORIUM

Jabal Murdama section

Jabal Murdama is located 32 km southeast of Afif (figs. 2, 3). It is accessible by a well-travelled ungraded track leading from the highway on the south side of Afif. Jabal



0 1 2 km

EXPLANATION

- M — Murdama formation
- pm — Pre-Murdama rock
- 8-10 — Measured section with numbered units
- Intermittent stream
- Ungraded track
- Crest of ridge; dashes parallel to bedding except in southwest part and near northeast corner
- 60 — Strike and dip of beds
- Strike and dip of vertical beds
- Contact

Figure 3.--Geologic map showing location of measured section at Jabal Murdama. Contact after Letalenet (1979).

Murdama is the type locality of the Murdama formation, as first described by Brown and Jackson (1960). Letalenet (1974) mapped the Jabal al Murdama 30-minute quadrangle and measured a section "on the west flank of the Jabal Murdama syncline" totaling 2,700 m.

The structure at Jabal Murdama is a rather complex south-plunging syncline (Letalenet, 1979). The synclinal axis bends to the southeast and back again to the south, suggesting multi-stage folding. South of Jabal Murdama the large syncline ends and there are a number of smaller folds.

The section was measured starting at the contact with underlying rock on the west side of a broad valley lying west of Jabal Murdama (fig. 3). The underlying rock was mapped by Letalenet (1974) as Afif formation, Jabal al Atulah facies. At this locality, the rock is dark gray, porphyritic andesite consisting of 40 percent plagioclase phenocrysts in a groundmass of plagioclase, clinopyroxene, opaque mineral and secondary epidote, chlorite, and actinolite. Although not observed, the contact may be located within a few meters of the mapped position. It is probably a fault, since none of the andesite appears as clasts in basal Murdama sedimentary rock.

The rock of the Jabal Murdama section (plate 1) consists of sandstone, siltstone, and conglomerate, with local ash tuff. The dominant type of rock is sandstone, which grades from very fine to very coarse grained. It further grades into siltstone and pebbly sandstone and conglomerate.

Observed in the field, the sandstone is rather colorful. The predominant color is green, with black surface patina. Other colors include brown and gray. When specimens are compared with the Rock Color Chart (Rock Color Chart Committee, 1975), however, it is seen that green rocks are actually greenish gray to dark greenish gray (5GY6-4/1) and light olive gray to olive gray (5Y6-4/1).

Bedding is not a very prominant feature in most of the rocks of this section, and indeed throughout the Murdama sections measured. Generally, bedding can only be described as "thick", "massive", or "obscure". The problem in describing bedding is compounded by the fact that weak materials in horizontal exposures of steeply dipping beds do not have protection from erosion and are easily lost.

Bedding is further obscured by a pervasive cleavage which is mostly vertical or nearly so. The fine-grained sandstone is mostly in massive beds a meter or more thick, though they locally contain faint laminae only a few millimeters thick which appear as dark lines. Some fine- and medium-grained sandstones are flaggy-bedded (beds a few centimeters thick along which the rock tends to cleave), but this is not commonly distinct from non-bedding cleavage, as little grain-size change is present. Coarse-grained sandstone, pebbly sandstone, and conglomerate have little planar bedding. Locally, they have irregular current bedding, grading, and scour features. These features are prominent in the uppermost part of the section (units 28 to 31). Distinct upward-fining sequences of beds were rarely observed.

The sandstone is rather poorly sorted and consists of angular grains. This applies to all grain-size classes of sandstone in this section. Measurements of grain size in thin section commonly reveal the presence of a size range of one-third or more of an order of magnitude, far more than a Wentworth size class (Pettijohn, 1975, p. 29). Mineral grains, mostly quartz and feldspar, commonly have a smaller upper limit than rock fragments, and stray rock fragments may extend the range even more. For example, sample MU-75 has mineral fragments at 0.1 to 0.3 mm, rock fragments at 0.1 to 0.5 mm and rare rock fragments as large as 0.8 mm. In the columnar section, the sandstones are placed in grain size classes according to the Wentworth scale, but most include grains of more than one size class.

The cause of the color variations in the bulk rock is elusive at the microscopic scale. If any correlation exists between the greenness of the rock and the composition of the matrix it is that the greenest rock has a murky irresolvable matrix and the rock with well-crystallized epidote or chlorite in its matrix is gray.

Very fine grained sandstone grades into siltstone by decrease in grain size. While the composition of framework grains and matrix material is less easily deciphered in this rock, it is apparently much the same as in the sandstone. Clay minerals may be more abundant, but the bulk of the fine particles are rock fragments.

Pebbly sandstone and conglomerate form only a small part of the section (plate 1) but are of considerable interest. The matrix of these rocks is coarse to very coarse sandstone similar to that described above. Pebbles of silicic volcanic rock and rare granite constitute a few percent to about 50 percent of the rock. Smaller pebbles are subangular, larger ones subrounded to well rounded. Pebble sizes range commonly to 2 cm, rarely to 10 cm (cobbles by definition if over 6.4 cm).

Yellow-green, aphanitic, ash tuff beds are randomly present in the section. These distinctive rocks are hard and resistant. A prominent ash bed (unit 27B) caps Jabal Murdama. The rock consists of devitrified glass shards in a finer matrix.

The composition of the sandstone is remarkably uniform, from base to top of the section and through the full range of grain sizes. The framework grains in most samples consist of the same rocks and minerals, though proportions vary. Quartz and plagioclase commonly range from 5 to 30 percent each; a few samples contain as much as 50 percent plagioclase. Potassium feldspar is present in about half of the samples studied and ranges from trace amounts to 10 percent, rarely to 25 percent. No samples contain more than 50 percent total feldspar. Heavy minerals, commonly present in trace amounts, may be as much as 1 percent of the sample. They include, in approximate decreasing order of abundance, epidote, opaque minerals, hornblende, chlorite, muscovite, clinopyroxene, biotite, sphene, and zircon.

The rest of the framework grains, 30 to 85 percent of the total rock, consist of rock fragments. The rock fragments consist mostly of silicic volcanic rocks. Many are murky under the microscope and their composition is thus indeterminate. Some have eutaxitic texture or collapsed pumice tubes and thus are clearly welded tuffs. Those few having aligned plagioclase grains are andesite. Rare grains show intergrowths of quartz and potassium feldspar and thus are granite.

One to about 10 percent, rarely as much as 20 percent, matrix or cementing material lies between the framework grains. This may consist of epidote, chlorite, calcite, clay minerals or unidentifiable material, probably ground rock fragments. In some sandstones, rock fragments merge with matrix, and grain boundaries are indistinct.

The sandstones described above are mostly lithic arenites, according to the classification of Pettijohn (1975, p. 211). The few which contain more total feldspar than rock fragments are arkosic arenites. Likewise, the very few which contain 15 or more percent matrix are lithic or feldspathic graywackes.

Jabal Raqabah section

Jabal Raqabah lies near the southwestern side of the Murdama belt of outcrop, between 6 and 13 km south of the highway connecting Zalim and Halaban (figs. 2, 4). It is readily accessible from that highway via a major ungraded track which crosses at a point about 115 km west of Halaban. A section was measured here to provide information on the lateral facies changes in the lower Murdama, as exemplified by this locality lying 60 km southeast of Jabal Murdama.

Letalenet and others (1972) mapped the Jabal Raqabah quadrangle at 1:100,000 scale and recorded brief descriptions

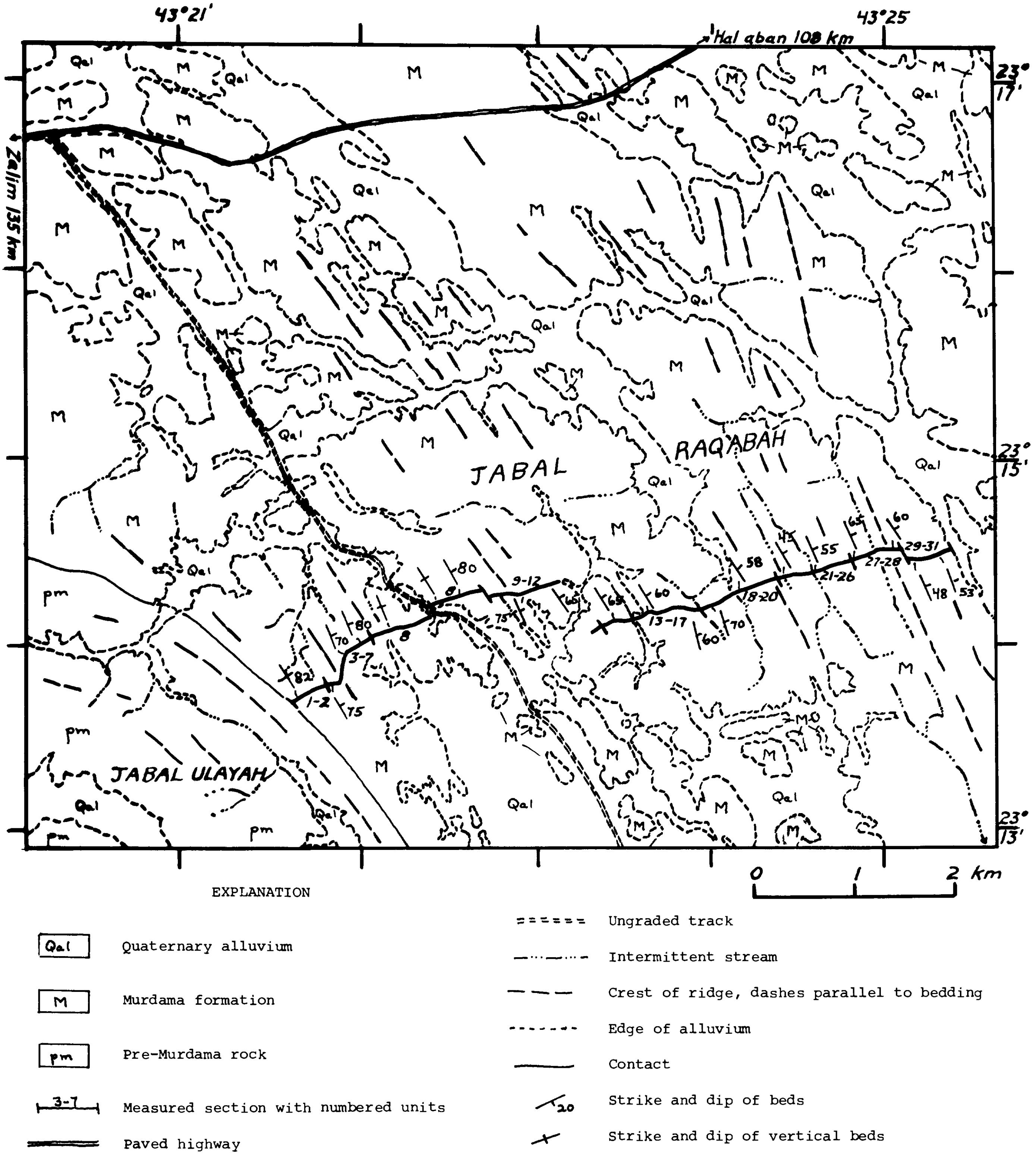


Figure 4.--Geologic map showing location of measured section at Jabal Raqabah. Contact after Letalenet (1979).

of the Murdama group rocks. The dominant structure in the Jabal Raqabah area is a north-plunging syncline (fig. 2; Letalenet, 1979). A steeply dipping homocline with remarkably straight strike forms the west flank of the syncline, and it is across this that the section was measured. A series of northwest-trending faults cut across the homocline, however, and other faults slightly displace the synclinal axis.

Jabal Raqabah has classic valley and ridge topography consisting of a series of ridges of nearly equal height with parallel valleys lying between. Highest elevations are at the base of the section and at Jabal Ulayah to the southwest (fig. 4).

The underlying rocks are mapped by Letalenet (1979) as Afif formation, Jabal al Atulah facies. At this locality the rocks are medium to dark, brownish-gray rhyolite with faint flow-banding and a few percent plagioclase phenocrysts. This is the sole type of rock underlying a substantial area extending several kilometers southwest of the base of the section.

The Jabal Raqabah section is characterized by the presence of coarse- and very coarse grained sandstones, pebbly sandstones, and local conglomerates (plate 1). Brecciated rocks including rhyolite fragments at the well-exposed base suggest that the base of the section is an unconformity along which there has been some fault movement. Following a few hundred meters of fine- and medium-grained sandstone, the rest of the section consists almost entirely of coarse materials. Colors are mostly greenish gray, light olive gray, and brownish gray. Planar bedding is not prominent and is commonly obscured by cleavage, a feature even more pervasive here than at Jabal Murdama. Strike and dips were mostly obtained on local finer-grained beds. The sandstones are poorly sorted and consist of angular grains. The sandstones contain 5 to 10 percent quartz, and 1 to 10 percent, rarely as much as 30 percent, plagioclase. Potassium feldspar, present in less than half of the samples studied, ranges from 0 to 10 percent. Trace amounts of heavy minerals are also present. The rest of the framework grains, 60 to 95 percent of total rock, are rock fragments, mostly silicic volcanic rocks. Matrix constitutes 1 to 10 percent of the sandstones. That these rocks have a narrower compositional range than those at Jabal Murdama is of doubtful significance. All are lithic arenites (Pettijohn, 1975, p. 211).

Conglomerates occur at scattered intervals throughout the lower two-thirds of the section, giving way to local pebbly sandstones above (plate 1). They constitute only a very small proportion of the section but are significant because they represent the record of pulses of high-energy deposition by currents carrying materials from a considerable distance. Pebbles and cobbles range to 30 cm in diameter in the lower units but decrease in size in higher units. They consist mostly of granite, rhyolite similar to that at the base of the section, and local andesite. High in the section, some are of sandstone and siltstone.

Ash tuff with sparse phenocrysts of quartz and plagioclase occurs at two horizons (plate 1, units 2A and 24). Near the top of the section there is a ridge-forming rhyolitic ash-flow tuff (unit 31). This rock contains abundant phenocrysts of potassium feldspar, plagioclase, and quartz, and trace amounts of hornblende and fayalite(?) in shard matrix. Letalenet and others (1972) mapped this tuff (which they called "arkose") for a strike length of 15 km.

As Sawadah section

The As Sawadah region lies near the southeastern end of the principal outcrop belt of the Murdama group (fig. 2). The name As Sawadah has been applied to a series of ridges east of Jabal Sahah (Delfour, 1980), to an area northwest of Jabal Sahah (Jackson and others, 1963), and to a very large area including both of the above and extending from lat 22°00' to about 23°20' N. (USGS and ARAMCO, 1963).

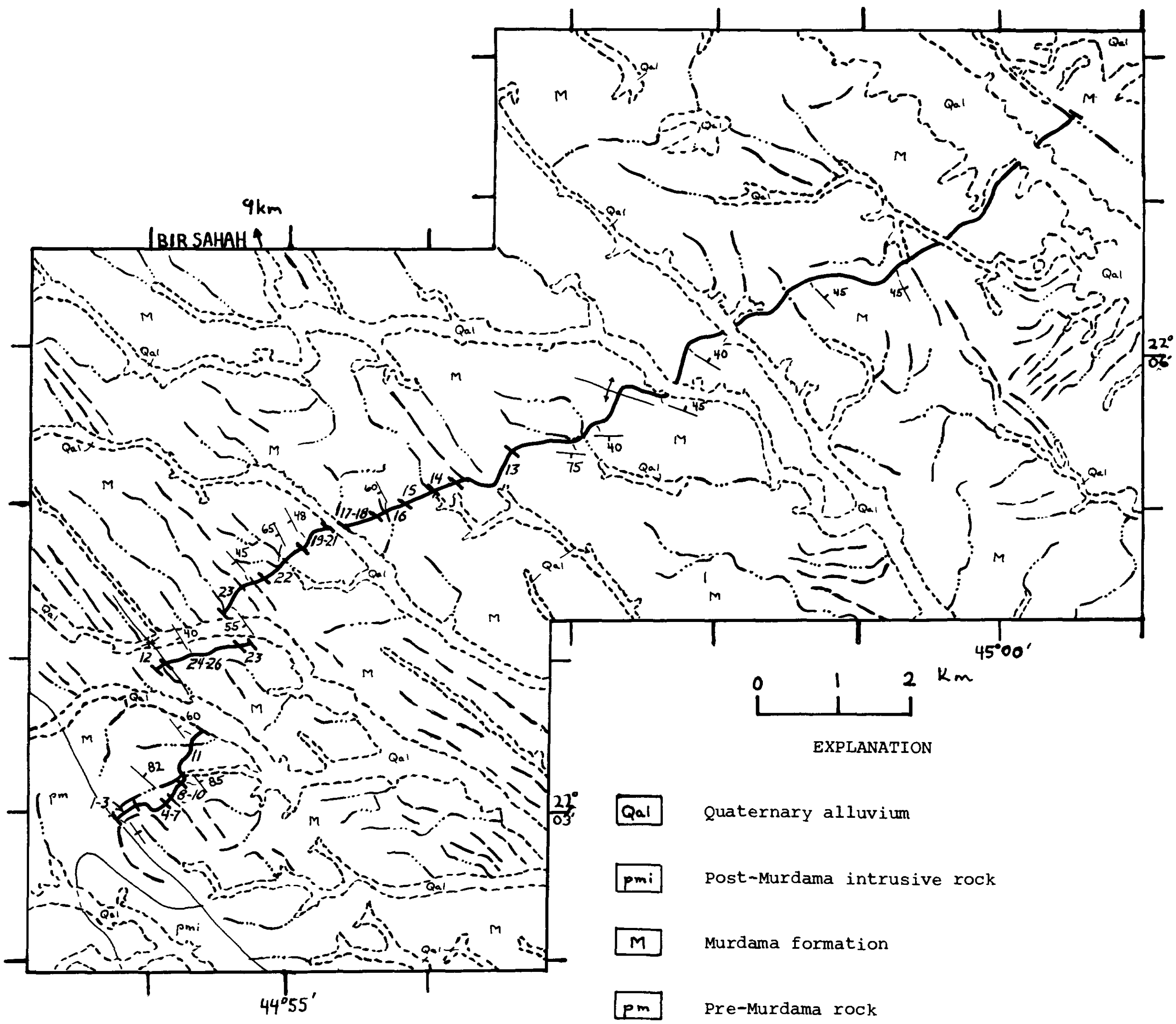
The As Sawadah section lies southeast of Jabal Sahah and Bir Sahah (fig. 5). The Murdama belt disappears under alluvium, dune sand, and Paleozoic rock only 30 km southeast of the measured section (Bramkamp and others, 1956, Southern Tuwayq quadrangle).

Access to the area by vehicle is difficult. A series of ungraded tracks must be followed for about 190 km from the Zalim-Halaban highway near Jabal Farida (fig. 2). Other routes are possible but are probably more difficult.

The As Sawadah section is on the southwestern side of the Murdama outcrop belt, 200 km southeast of Jabal Raqabah (fig. 1). It was measured to provide additional information as far to the southeast on strike with Jabal Murdama and Jabal Raqabah as possible, near the last outcrops of Murdama group rocks.

The 1:100,000-scale map of the area was prepared by Leca (1970), and the 1:250,000-scale compilation was done by Delfour (1980).

The belt of Murdama group rocks is only 14 km wide at the As Sawadah section, compared to 95 km between Jabal Farida and Jabal Raqabah (fig. 2). The rocks are broadly folded into a syncline and complementary anticline. Delfour (1980) shows another, parallel, syncline to the northeast and a



EXPLANATION

Symbol	Explanation
Qal	Quaternary alluvium
pmi	Post-Murdama intrusive rock
M	Murdama formation
pm	Pre-Murdama rock
3-7	Measured section with numbered units
	Intermittent stream
	Crest of ridge, dashes parallel to bedding
	Edge of alluvium
60	Strike and dip of beds
	Strike and dip of vertical beds
	Anticline
	Syncline
	Contact

Figure 5.--Geologic map showing location of measured section at As Sawadah. Contacts after Delfour (1980).

major fault, apparently strike-slip, in a valley near the northeastern edge of the belt. Field observations were made to extend the section completely across the outcrop belt (fig. 5). However, there is a dearth of measurable strike and dip in the northeastern half of the traverse, and folds repeat the section. Therefore, two partial-sections only are reported: A--from the base to the synclinal axis, and B--from the synclinal to the anticlinal axis.

The topography of this area is typical valley and ridge with accordant crests. The ridge crests have probably not been lowered very much since the removal of Paleozoic rocks, still preserved 30 km to the southeast. Jabals underlain by granite, such as Jabal Sahah, however, are much higher, and apparently were monadnocks at the onset of the deposition of Paleozoic rocks.

The base of section A lies at a well-exposed, little-disturbed unconformity. The rock immediately below the base is mapped as Hulayfah Group, Nuqrah formation by Delfour (1980). This unit is mapped as continuous, however, with the Afif formation, Jabal al Atulah facies of the Jabal Murdama and Jabal Raqabah areas (Delfour, 1979; Letalenet, 1979). At this locality the rock is rhyolite, some being pale red with uniform, aphanitic texture and very sparse minute phenocrysts of plagioclase and quartz. Other rhyolite is brownish-gray with lighter streak and mottle with about 5 percent plagioclase phenocrysts and trace amounts of fayalite(?) and opaque minerals. Other underlying rocks, as mapped by Delfour (1980), include a unit containing assorted plutonic rock and "Older basement". A traverse by the writer for about 7 km to the southwest of the base of the section crossed rhyolite, rhyodacite, and andesite followed by alkali-feldspar granite with graphic texture, and then by metabasalt.

Section A (plate 1) consists of coarse- and medium-grained sandstone with abundant conglomerate for the first 350 m above the base. Pebbles and cobbles in the conglomerate consist mostly of volcanic rock similar to that immediately underlying the section. Higher in section A, fine- and very fine grained, mostly greenish-gray sandstone predominates. Rare conglomerate beds contain granite and sandstone pebbles in addition to those of volcanic rocks.

Section B (plate 1) consists almost entirely of sandstone, fine grained in the upper part, and fine, medium, and locally coarse grained in the middle and lower parts. A small thickness of andesite constitutes the only volcanic rock in either section.

Comparing the two sections, it is noteworthy how much the thickness has increased in section B, which lies further away from the edge of the outcrop belt. Five hundred meters of fine- and very fine grained sandstone near the top of section A (unit 11) has increased to 1140 m in section B (units 23-25). Seven hundred meters of sandstone and conglomerate in the lower part of section A (units 3-10) are the approximate equivalent of 2740 m of sandstone in section B (units 13-22). Conglomerates may have pinched out or may be present in an additional unexposed section lying between the crest of the anticline and basement, the thickness of which is unknown.

The sandstones in these sections are very much like that at Jabal Murdama. They are nearly all greenish gray and poorly bedded. They consist of angular grains, poorly sorted. Framework-grains consist of quartz and plagioclase in part but are predominantly rock fragments. Potassium feldspar is rare. Rock fragments are mostly silicic volcanic rocks but some are andesite. The sandstone contains 5 to 10 percent matrix.

SECTIONS ON THE EAST LIMB OF THE MURDAMA SYNCLINORIUM

Jabal Zaydi section

Jabal Zaydi is the name given to a mountainous area of substantial size lying between lat 23°00' and 23°15' N. and long 43°50' and 44°20' E. (Jackson and others, 1963; Delfour, 1979). Jabal Zaydi has two parts that are separated by an intervening lowland. The section was measured in the southeastern part, which lies between 32 and 55 km south-southwest of Halaban (figs. 2, 6).

The section is accessible via a series of ungraded tracks from the Zalim-Halaban highway. Turn off the highway onto a major track heading southeast in the middle of a broad valley near Wadi Ghaghah. The track lies 2 km southwest of the position shown on the map of Delfour (1979). Turn southwest onto a minor track between two large dunes 37 km from the highway. From there, it is 8 km to the base of the section (fig. 5). The southwesternmost part, however, can only be reached from the broad valley lying to the southwest.

A section was measured at this locality to provide a type section for the Zaydi formation, should it be desirable to retain this name, and to provide an additional reference section for the thick sequence exposed in the northeastern flank of the Murdama synclinorium.

Geologic mapping in the Jabal Zaydi area at 1:100,000 scale was compiled by Vincent (1968). The 1:250,000-scale compilation and initial description of the Zaydi formation is by Delfour (1979).

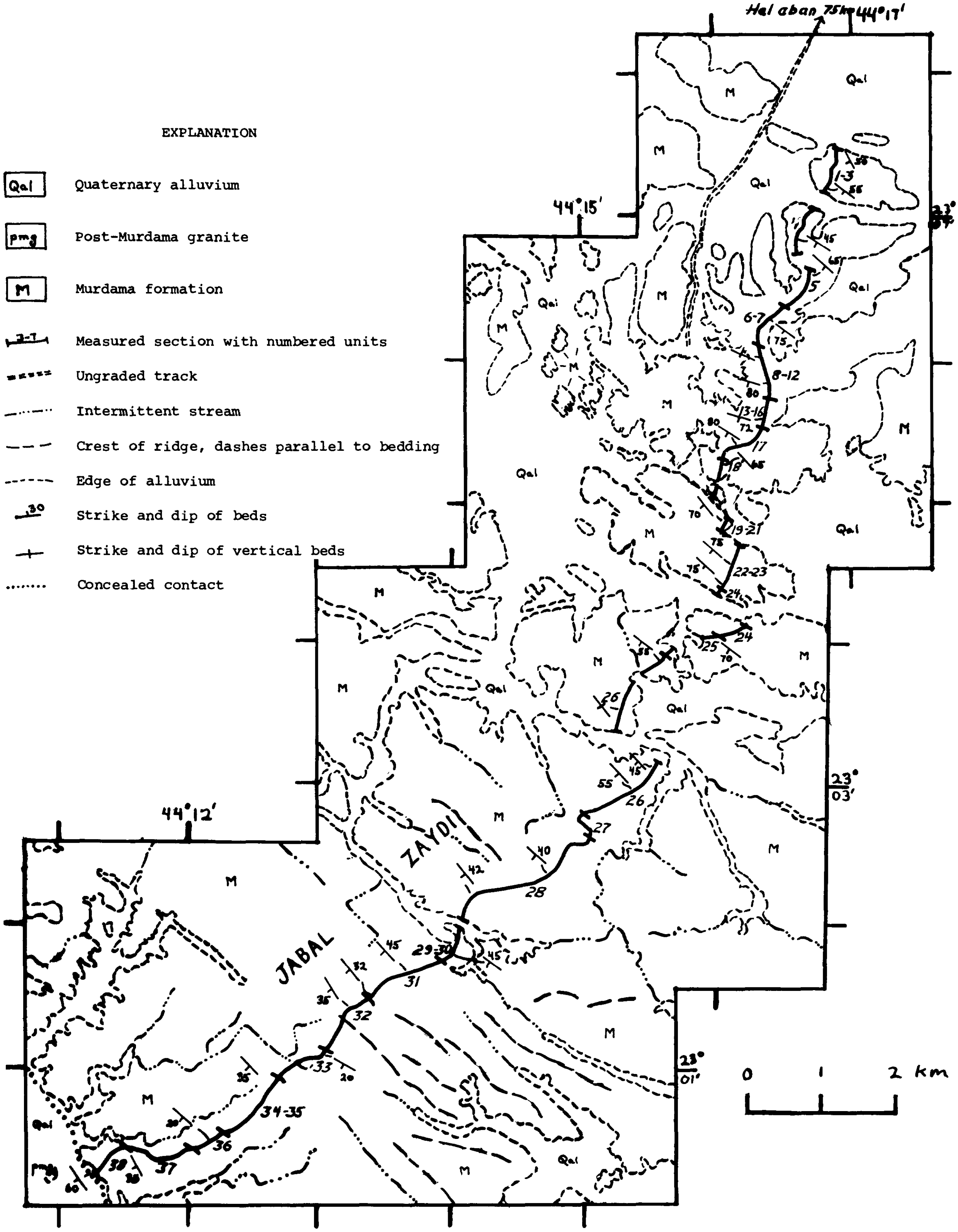


Figure 6.--Geologic map showing location of measured section at Jabal Zaydi. Contact after Delfour (1979).

The structure of the southeastern part of Jabal Zaydi is that of a southwest-dipping homocline, though the dip varies considerably. For the northern two-thirds of the section, the dip ranges from 50° to vertical, in the southern one-third it decreases irregularly to 20° near the southwestern end, then it increases abruptly to 50° in the last few hundred meters before the end of outcrop. In the northwestern part of Jabal Zaydi (not measured) dips are principally to the southwest at low angles. A terrace, or area of flat-lying beds, occupies the central part, and beds dip steeply toward intrusive bodies flanking the jabal. All these structures are part of the northeastern flank of the Murdama synclinorium.

The topography of the area is valley and ridge that is substantially modified by irregular and cross-cutting drainages. The northernmost part of the section (units 1-4) underlies small isolated hills that are partially buried with windblown sand. Units 5 to 18 underlie one of several ridges of substantial height that trend across the strike of bedding. The rest of the section underlies the main part of the jabal, which reaches its maximum altitude at the ridge forming the drainage divide. Unit 31 of the measured section underlies this ridge (fig 6).

The section starts at the first exposures on the southern side of a wide gravel plain and sand dune field (Nafud as Sirrah). There is no exposed base to the section, and structural complexities plus surficial cover render the position of the base in this area uncertain (Delfour, 1979). The nearest basement rock is shown on Delfour's map as "Ajal group" and "Older basement". The writer's traverse in this area encountered the following types of rock: 1) plutonic breccia consisting of coarse-grained quartz diorite intruding a darker, medium-grained diorite; 2) metabasalt rich in hornblende and biotite; 3) syenogranite with muscovite and biotite; and 4) hornblende diorite.

The Jabal Zaydi section consists almost entirely of sandstones (plate 1). Color, as elsewhere, is predominantly greenish gray but is locally medium light to medium dark gray. Medium- and coarse-grained sandstones are most abundant in the lowermost 4200 m (units 1-20B). A 100-m-thick unit (2) of conglomerate is present near the base, and a few thin conglomerates are farther up the section. Most of the pebbles are rhyolite, rhyodacite, and granite. The granite pebbles studied are perthite granite containing muscovite and biotite or chlorite. Pebbles of tonalite and of quartz are also present. The middle part of the section (units 21-26, 3700 m) consists almost entirely of medium-and fine-grained sandstones. There are local very fine grained sandstone, siltstone, and minor limestone. The upper part of the section (units 27-37, excluding contact rock at the top) contains a mix of mostly medium- and coarse-grained sandstone with local fine- or very fine grained types and no conglomerate.

The uppermost rocks of the Jabal Zaydi section (plate 1, unit 38) constitute a contact aureole adjacent to post-Murdama granite. The rocks are hornfels and amphibolite, the latter apparently derived from andesite, a rock type not present lower in the section.

The sandstones in the Jabal Zaydi section, like those at Jabal Murdama, are composed of poorly sorted, angular grains. Samples studied contained 10 to 25 percent quartz and 20 to 50 percent plagioclase as framework grains. Potassium feldspar is rare. Heavy minerals consist of minute amounts of epidote and opaque minerals. The remainder of the framework grains, 20 to 65 percent of total rock, consists of rock fragments, mostly silicic volcanic rocks and minor andesite. Matrix, 5 to 30 percent, consists in part of finely ground rock fragments and other murky unidentifiable material and in part of well-crystallized epidote, chlorite, calcite, biotite, and muscovite. These figures show that some of the Jabal Zaydi rocks contain more feldspar or more matrix than those from the other sections. However, the figures are based on visual estimates only and are of doubtful significance. The rock is lithic and arkosic arenite, and lithic and arkosic graywacke (Pettijohn, 1972, p. 211).

Jabal Farida section

Jabal Farida is located 25 km west of Halaban. The northern end of the jabal is only 1 1/2 km south of the highway leading toward Zalim (fig. 2). A section was measured here to establish a type section for the Farida formation or member.

As for the Jabal Zaydi section, 1:100,000-scale geologic mapping in the area was compiled by Vincent (1968) and 1:250,000-scale mapping by Delfour (1979).

Jabal Farida lies at the base of the northeastern flank of the Murdama synclinorium (fig. 1). Mapping by Jackson and others (1963) showed Jabal Farida and several other areas underlain by Farida marble as klippen (outliers of thrust sheets). The map by Vincent (1968) shows a thrust fault, apparently dipping southwest, along the northeastern flank of Jabal Farida, and a rhombic pattern of normal faults striking about N. 55° W. and N. 30° W. in both hanging and footwall blocks. No faults are shown in the vicinity of Jabal Farida on the map of Delfour (1979). The writer's observations at Jabal Farida and elsewhere at and near the base of the Farida formation indicate that the contact is an unconformity along which there has been some movement, probably during the folding that produced the Murdama synclinorium.

The structure of Jabal Farida itself is apparently that of a southwest-dipping homocline, though reliable strike and dips are not abundant. Additional outcrop in the flats southwest of the jabal was included in the measured section. There, the dip steepens to vertical.

Jabal Farida (fig. 7) is a striking topographic feature, visible almost any day from 20 km or more. It is an isolated strike ridge, 4 1/2 km long, and formed primarily of the brown-weathering marble, a resistant rock in a desert climate. Its height above base is unknown, as survey results are not available.

Rock underlying the section is mapped by Delfour as "Older basement". At this locality it consists of dacite with light-olive-gray aphanitic groundmass, about 30 percent plagioclase phenocrysts and 2 percent hornblende phenocrysts.

The rocks at the base of the section are highly disturbed and consist of marble, sandstone, and dacite (plate 1, unit 1). These are overlain by a small amount of stretched-pebble conglomerate and by coarse, cataclasized sandstone (units 2, 3). The ridge forming marble follows; at this locality it consists of lower and upper units of the light-gray, brown-weathering type with a small thickness of the dark-gray type between them (units 4-7).

The brown-weathering marble is composed of calcite, mostly recrystallized, with trace amounts of quartz the only other visible mineral. The brown surface is apparently caused by the weathering out of minute amounts of clays and iron oxides. It is characterized by the local presence of algal structure. This feature is best viewed on a weathered surface, where it consists of a series of troughs and ridges in a curved pattern resembling a sliced head of cabbage. Distance from ridge to ridge is quite uniform and is 1 1/2 to 2 mm. Good observations of whole colonial growths are hard to obtain; however, the growths appear to expand in a fan pattern with decreasing curvature until they interfere with a neighboring growth.

A covered interval separates exposures at the southwestern base of Jabal Farida from exposures further to the southwest (fig. 7). It is possible there is a fault here, but it probably has little stratigraphic displacement.

Olive-gray, medium-grained sandstone with abundant interbedded conglomerate forms the next 600 m of the section (plate 1, units 8-13). Pebbles and cobbles consist of

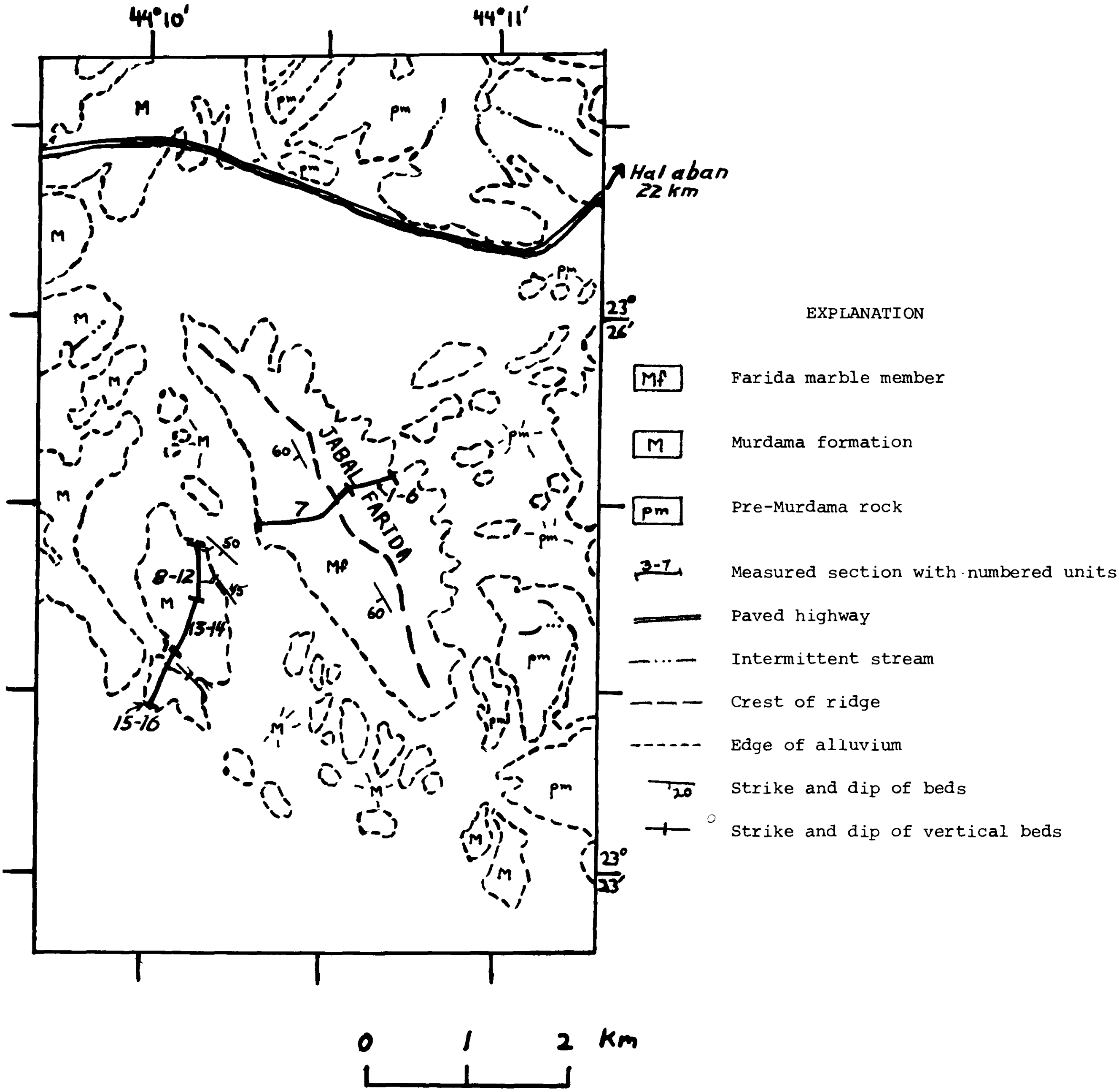


Figure 7.--Geologic map showing location of measured section at Jabal Farida. Geology modified from Delfour (1979).

andesite, dacite, quartz diorite, and trondhjemite. Granite and rhyolite are absent. The next unit contains abundant altered andesite, which consists of plagioclase, quartz, chlorite, and calcite. The rest of the section consists of sandstone.

Some of the sandstone in this section, both at the base and near the top, has cataclastic texture; otherwise, it is similar in texture and mineralogy to those in the other sections.

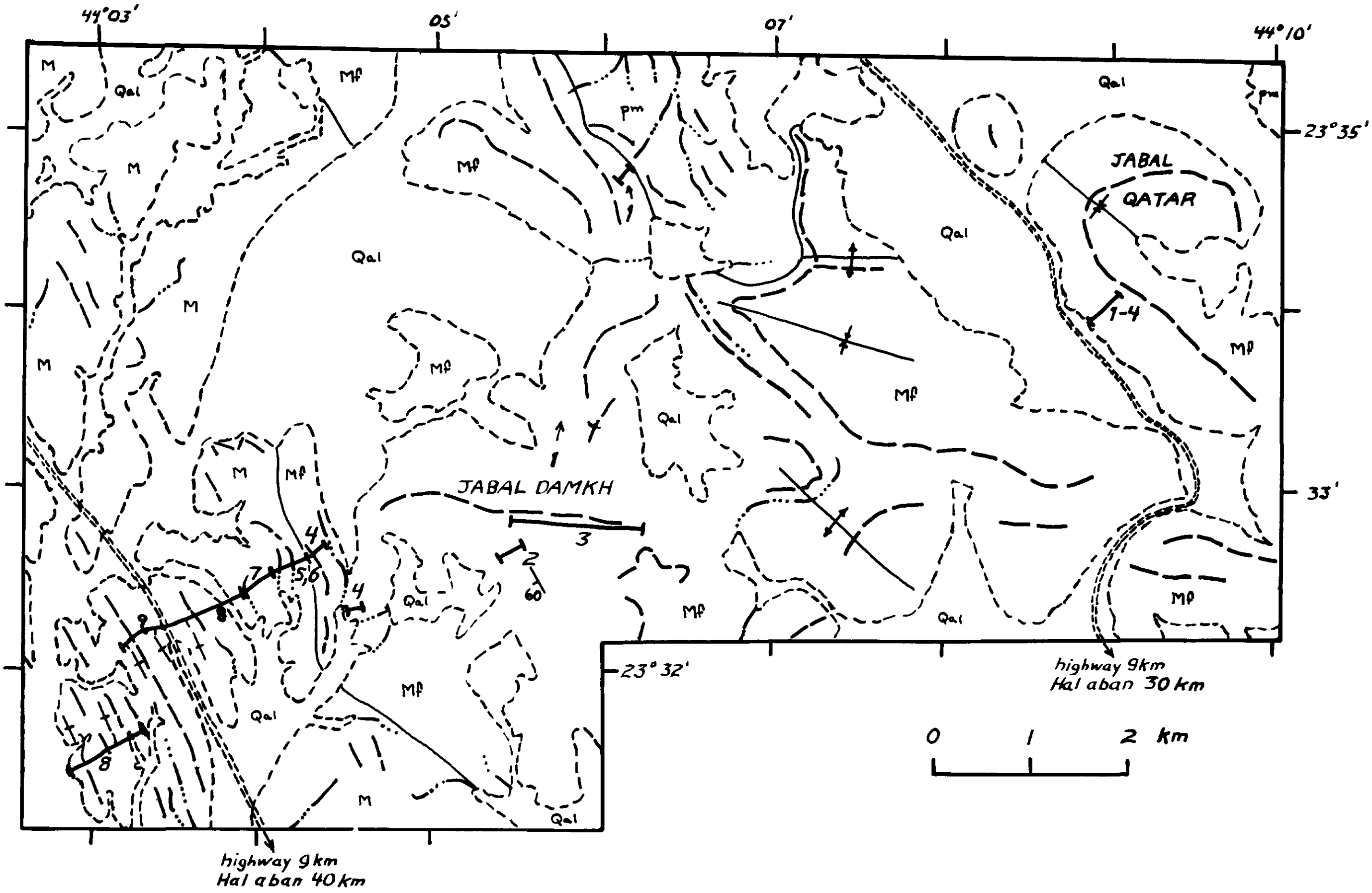
Jabal Damkh section

Jabal Damkh is located in the northeastern flank of the Murdama synclinorium, about 15 km northwest of Jabal Farida and 30 km west of Halaban (figs. 2, 8). Access to the main part of the section is by an ungraded track leading north from the Halaban-Zalim highway 31 km west of Halaban. Access to unit 1 is by another track leaving the highway 21 km west of Halaban (fig. 8).

A section was measured in this area in order to obtain additional information about the Farida formation and the rock immediately above it, where these units are apparently thickest. The section was also chosen to form a near-continuum with the Wadi Sirrah section, which begins on the western side of Wadi Ghaghah, 7 km southeast on strike with the end of the Jabal Damkh section.

Leca and others (1972) named a different mountain "Jabal Damkh". It is located 20 km farther northwest in the Maslum quadrangle, and a sketch section of Farida formation was recorded from the locality. This mountain, on strike with the Jabal Damkh of current usage, is identified as Jabal Ghurur on the map of Delfour (1979). Geologic mapping in this area was compiled at 1:100,000 scale by Eijkelboom (1966) and at 1:250,000 scale by Delfour (1979). The structure in the Jabal Damkh area is somewhat complex. Delfour indicates a southwest-dipping homocline in the immediate vicinity of the measured section and a series of anticlines and synclines both to the north and south. The 1:500,000-scale map by Jackson and others (1963) shows Jabal Damkh and other outcrops of Farida marble as klippen. Folding and brecciation near the base of the section suggest that these rocks have been thrust faulted somewhat to the northeast over older rocks.

Jabal Damkh, like Jabal Farida, is a striking topographic feature. From the highway northwest for 35 km, Jabal Damkh and other jabals form a broken and discontinuous ridge, with similar summit altitudes. The measured section continues southwest from Jabal Damkh across low ridges to flats at Wadi Ghaghah.



EXPLANATION

Symbol	Explanation	Symbol	Explanation
Qal	Quaternary alluvium		Intermittent stream
Mf	Farida marble member		Crest of ridge
M	Murdama formation		Edge of alluvium
pm	Pre-Murdama rock	30	Strike and dip of beds
3-7	Measured section with numbered units		Strike and dip of vertical beds
	Ungraded track		Anticline
			Syncline
			Contact

Figure 8.--Geologic map showing location of measured section at Jabal Damkh and Jabal Qatar. Geology modified from Delfour (1979).

The Jabal Damkh section is a composite of parts whose "fit" and thicknesses (particularly units 1 to 3) are less certain than those of the other sections reported in this paper. This is largely because dips are low and bedding is obscure in the marble units. Unit 1 (north-central part of fig. 8) rests directly on a basement of gneissic quartz diorite. The quartz diorite consists of the following minerals: plagioclase, 80 percent; quartz, 8 percent; hornblende, 12 percent; and trace amounts of biotite, chlorite, epidote, calcite, apatite, and opaque mineral.

Unit 1 (fig. 8) consists of a variety of weak sedimentary rocks, all highly deformed. Unit 2 is light-gray, brown-weathering marble, and unit 3 is dark-gray marble; thicknesses of these units are estimates. A few meters of conglomerate are followed by more marble (unit 4) and by sandstone with minor conglomerate (units 5-7). Some interbedded marble and sandstone is followed by over 2000 m of sandstone. It is significant that although most of the marble is in massive units underlying the jabals, some also underlies lowlands where it is interbedded with sandstone and conglomerate (units 4 and 8). Upper and lower clastic portions of this section bear only small resemblance to those at Jabal Farida (plate 1), which contain more coarse sandstone and conglomerate and some volcanic rocks, both above and below the marble units.

Sandstones are light olive or greenish gray and consist of angular grains with sparse matrix, as in the other sections. Framework grains are quartz, plagioclase, rock fragments and sparse heavy minerals. The two types of marble are similar to those in the Jabal Farida section.

Jabal Qatar section

The Jabal Qatar section is located 6 km east of the main part of Jabal Damkh and is accessible by the ungraded track leading north from the highway 21 km west of Halaban, which also leads to unit 1 of the Jabal Damkh section (figs. 2, 8). The section was measured to show the variety of rock types present in different sections in the short interval between the massive marble units and the basement.

Jabal Qatar is shown on the same geologic maps as Jabal Damkh. It is synclinal in structure, underlain mostly by massive marble, and rises to a substantial height above the surrounding lowlands. No basement rock is exposed beneath the measured section.

The 150 m of section exposed at Jabal Qatar beneath the marble consists entirely of conglomerate. The maximum cobble size increases up the section to as much as 40 cm. Diorite, quartz diorite and tonalite with some andesite are the cobble rock types. Quartz diorite and tonalite are similar to those at the base of the Jabal Damkh section and to basement rock exposed 5 to 6 km south of Jabal Qatar.

Wadi Sirrah section

The Wadi Sirrah section is located near the Halaban-Zalim highway and extends from a point 35 km west of Halaban to one 70 km west of Halaban (fig. 1, plate 2). The section is named for Wadi Sirrah, a major drainage parallel to the section a few kilometers to the south (plate 2; Delfour, 1979). The base of the section is at Wadi Ghaghah, 7 km on strike southeast of the top of the Jabal Damkh section.

Access to the base of the section is by obscure tracks on the Wadi Ghaghah flat, leaving the highway 33 km west of Halaban. The first part of the section consists of low outcrops; these can be driven over as far as unit 23. From there on, access is by tracks following the north-trending valleys; most of the section, however, lies within 3 km of the highway (plate 2). The 1:250,000-scale maps of the Halaban and Afif quadrangles (Delfour, 1979; Letalenet, 1979) do not show the position of the Halaban-Zalim highway, an important reference point in this report. However, the reader may sketch in a good deal of it with the aid of figures 4 and 7, and plate 2.

The Wadi Sirrah section was measured in order to provide, in conjunction with the Jabal Damkh section, a reference section for the entire Murdama. The Wadi Sirrah area is exceptionally well suited for this purpose as rocks are nearly continuously exposed across the entire east limb of the Murdama synclinorium, and structural complexities are at a minimum. Also, thickness is almost certainly at a maximum here.

Map compilation at 1:100,000 scale for the part of the section east of long 44°00' E. is by Vincent (1968), as for the Jabal Farida section. West of long 44°00' E., mapping at 1:100,000 scale is by Letalenet and others (1972). The 1:250,000-scale compilation for the entire area is by Delfour (1979).

The structure of the east limb in the vicinity of this section is apparently homoclinal, despite the fact that the rather large thickness of strata (over 25 km) invites scrutiny for structures causing repetition. Dips in the east part of the section (units 1-20) are vertical or nearly so, and strike is northwest. In the next part (units 20-34), dips are 70 to 80° southwest and the strike shifts to north-northwest. Next (units 35-37), dip decreases to 45° to 65° and strike shifts to the north. In the western part of the section, dip decreases irregularly to about 20°, and strike shifts to the northeast near the axis of the synclinorium. The map by Delfour (1979) shows a similarly simple picture of the east limb of the Murdama synclinorium from Wadi Sirrah north to Nafud al Hasraj. However, a cross fold bends the strike near Wadi al Khasirah, and decreasing outcrop breadth probably means decreasing thickness to the north.

The eastern part of the section, from Wadi Ghaghah to Wadi Sirahi (plate 2) underlies a pediment of abundant outcrop. The rest of the area has valley and ridge topography of considerable relief. Strike-ridges are separated by parallel valleys, presumably underlain by weaker rocks. Ridge crests are not accordant; however, Jabal Nidyan (unit 38) rises considerably higher than the rest, as do the ridges at the end of the section (units 48-51). Thus the ridge elevations are controlled by rock resistance and the current position of drainages, rather than by an exhumed peneplain, as at the As Sawadah section.

The base of the Wadi Sirrah section is at the edge of the Wadi Ghaghah flats. Basement rocks further east have been described along with the Jabal Farida, Jabal Damkh, and Jabal Qatar sections. The top of the section is at the axis of the Murdama synclinorium.

The bulk of the Wadi Sirrah section consists of a remarkably monotonous sequence of sandstone. It is greenish gray, olive gray, and medium gray; mostly fine and medium grained, but locally coarse grained. Interbedded volcanic rocks consist of a small amount of andesite at the base, some dacite porphyry in unit 23, a bed of ash in unit 39, and several layers of andesite in the top 1200 m, units 48-51. Estimated modes of some of these rocks are given in table 1. Conglomerate and pebbly sandstone are confined to a few meters each in units 24, 25, 27, 29, 31, and 33; all are between 11,000 and 13,600 m above the base of the section. Conglomerate is depicted rather generously in this interval on the map of Delfour (1979).

Like that in the other sections, the sandstone is poorly sorted and consists of angular grains. Framework grains consist of quartz (5 to 30 percent of the total rock), plagioclase (1 to 35 percent), and rock fragments (40 to 70 percent) of mostly silicic volcanic rocks. Potassium feldspar is rare. Heavy minerals in trace amounts include epidote, hornblende, and chlorite. The sandstone also contains 5 to 20 percent matrix, which consists of well-crystallized epidote, calcite, chlorite and other micas in some and of murky, unidentifiable material in others. Thus the sandstones are lithic arenite and lithic graywacke (Pettijohn, 1975, p. 211).

Table 1.--Estimated modes of some volcanic rocks from the Wadi Sirrah section. [p=phenocrysts; tr=trace.]

Sample No.	479	487	538	678	682
Unit No.	1	6	23	49	51
Rock type	altered andesite	altered andesite	dacite porphyry	andesite porphyry	andesite
Color	medium dark-gray	medium light brownish-gray	light olive gray	dark greenish-gray	medium gray
Texture	fine grained	fine grained	p to 3 mm aphanitic groundmass	aphanitic groundmass	fine grained
Quartz	5	5			
Plagioclase	45	55	p-35	p-25	85
Clinopyroxene					10
Hornblende	20				
Actinolite			p-10		
Chlorite	15	20	tr		3
Epidote	tr		tr		
Calcite	15	20	tr		
Opaque	tr	1	tr		2
Groundmass			55	75	

Pebbles and cobbles in conglomerate and pebbly sandstone consist of granites, volcanic rocks, cherts, and sandstones. Estimated modes of some of these clasts are given in table 2.

GEOCHRONOLOGY

Recent work by Stacey and others (unpub data) has established a firm basis for interpreting the age of the Murdama in its type area. These authors sampled four different terrains of plutonic rock lying to the northeast of the Murdama synclinorium that are pertinent to the age of the Murdama. Also sampled by them, but not pertinent to the present discussion, are several plutonic rocks lying east of the Al Amar fault (east of long 45°00' E.). These authors determined U-Pb model ages from zircon fractions separated from samples collected. They state that they prefer their "Model 2" ages as presented in their table 2, and only these are quoted and discussed in the present report.

A sample of hypersthene gabbro of the Urd group "ophiolitic complex" from locality 2 (fig. 2) has an age of 700 Ma. This is the oldest well-established age for the region. Reconnaissance by the present author suggested that mafic-ultramafic rocks are far less extensive in this area than shown on the map of Delfour (1979), nevertheless, their presence is significant for regional interpretation.

A sample of biotite-hornblende tonalite of the Sawda domain (Delfour, 1979, tectonic map) from locality 3 near the base of Jabal Damkh has an age of 680 Ma. The description of this rock matches that of tonalite collected by the present author directly under basal Murdama strata nearby, and is close to that of cobbles in the lower Murdama at Jabal Qatar.

A sample of two-mica monzogranite from the Ar Rukhamah domain (Delfour, 1979, tectonic map) from locality 9 (fig. 2) north of Halaban has an age of 643±12 Ma. Stacey and others (unpub data) believe that this granite was intruded into the Abt formation during a period of compressional orogeny and syntectonic intrusion that occurred about 660 to 645 Ma ago. A sample from the Abu Isnun biotite leucomonzogranite at locality 4 may be in this age range, but it has a maximum age of only 725 Ma, probably because of the presence of inherited zircons.

A sample of two-mica monzogranite from Jabal Sabhah south of Halaban (locality 10) has an age of 605±5 Ma, and one from Wadi Khurs east of Halaban (locality 11) has an age of 597±10 Ma. These are believed to be post-orogenic granites, and they reflect the Pan African thermal event that affected the entire Arabian Shield (Fleck, 1976).

Table 2.--Estimated modes of some cobbles from conglomerates in the Wadi Sirrah section. [p=phenocrysts; g=groundmass; tr=trace; X=present.]

Sample No.	546-1	546-2	553-3	556-4	556-1	556-2
Unit No.	25	25	27	29	29	29
Rock type	granite	alkali-feldspar granite	alkali-feldspar granite	alkali feldspar granite	rhyolite	andesite porphyry
Color	grayish orange-pink	light olive-gray	light brownish-gray	light brownish gray	medium gray	dark greenish gray
Texture	graphic, irregular	graphic	fine granular	graphic	porphyritic with micrograined groundmass	
Quartz	30	p-1 g-35	35	35	p-10	p-5
K-feldspar	30	p-2 g-60	65	p-1 g-65	p-20	
Plagioclase	40					p-50
Chlorite	tr			tr	3	X
Epidote	tr	2	tr	tr	2	X
Calcite			tr	tr		X
Opaque	tr	tr	tr	tr	tr	X
Groundmass					65	45

These data establish a firm maximum age of 680 Ma and a probable maximum of 640 Ma for the beginning of Murdama sedimentation and accompanying volcanism.

Plutonic rocks directly intrusive into Murdama rocks were not sampled by Stacey and others (unpub. data). However, Delfour (1979) believes that several large bodies of granite intrusive into the Murdama, including Maslum, Hasraj Ad Darah, and Jumaymiyah plutons, are correlative with the Jabal Sabhah and Wadi Khurs granites, whose ages are given above. Delfour's chemical data (table 1) and variation diagrams (figs. 4 and 9) tend to confirm this.

Therefore, 600 Ma is a respectable minimum age for Murdama sedimentary and volcanic rocks, and the unit has been bracketed at 640 to 600 Ma.

SUMMARY AND RECOMMENDATIONS FOR STRATIGRAPHIC NOMENCLATURE

The measured sections (plate 1) show that the bulk of the Murdama is a remarkably uniform sequence of sandstone that is gray, olive, and greenish gray, very fine to very coarse grained, and is composed of angular fragments of quartz, plagioclase, and silicic volcanic rock. Conglomerate, often with pebbles of granitic rock, and intermediate to silicic volcanic rock are locally interbedded but are volumetrically insignificant. Marble is a significant component near the base of the Murdama on the northeastern flank of the synclinorium, but conglomerate is minor.

In view of the above, it is evident that the Murdama should be a formation, not a group. It is mostly a single lithologic entity from which variants can locally be split off as members. It is not an aggregate of formations. The type section for the Murdama Formation should be at Jabal Murdama, as this is the locality from which the name comes and the typical lithologies are well represented there (plate 1). However, in view of the fact that the thickness of section exposed at Jabal Murdama (5287 m) is much less than that exposed elsewhere, particularly on the eastern flank of the Murdama synclinorium, reference sections are needed. I propose that the Jabal Raqabah (5652 m), Jabal Zaydi (12,361 m), and Jabal Damkh (3596 m) combined with Wadi Sirrah (25,751 m) sections be designated reference sections, as shown.

The Halaban 1:250,000-scale quadrangle (Delfour, 1979) shows the Murdama as a group divided into three formations: Hibshi, Farida, and Zaydi. The first two names are well established in the literature (Bramkamp and others, 1963; Jackson and others, 1963; Delfour, 1977) and all deserve comment.

The type locality of the Hibshi formation is at Jabal Hibshi, lat 26°35' N., long 42°20' E., 400 km north-northwest of Halaban (Bramkamp and others, 1963). Delfour (1977) placed the Hibshi formation as the basal unit of the Murdama group in the Nuqrah 1:250,000-scale quadrangle. Later, Delfour (1979) extended the name, mapping Hibshi formation below Farida formation in the Jabal Farida-Jabal Damkh area of the Halaban quadrangle.

Recent geologic mapping in the Jabal Hibshi area by P. L. Williams (USGS, written commun., 1982) has included measurement of a section at Jabal Hibshi. The section is 1100 m thick and includes 200 m each of basal and intraformational conglomerate. Properly defined, the Hibshi may prove useful as a member in the area between Nuqrah and Jabal Hibshi.

Sections measured by the writer show: 100 m of deformed clastic sediments beneath the marble at Jabal Damkh (plate 1); 300 m of the same with a little conglomerate at Jabal Farida (plate 1); and 150 m of cobble conglomerate at Jabal Qatar (plate 1). In view of the facts that these basal clastic sediments are thin and irregular, poorly exposed, and not mappable except at very large scale, I recommend that the name Hibshi not be used in the Halaban area.

A brief history of the use of the name Farida is given in the introduction to this report. Since the marble is a distinctive, mappable rock unit that can be separated from the main mass of the Murdama, I recommend that it be made the Farida Marble Member of the Murdama Formation, as used by Bois (1971). The type section is at Jabal Farida, and the member includes units 1 to 7 of the Jabal Farida section (plate 1) and units 1 to 4 of the Jabal Damkh section (plate 1). I am including the basal clastic sediments in the Farida Marble Member.

The Zaydi formation, as introduced by Delfour (1979, 1980), includes the bulk of the Murdama. If this name were retained as a member, included in it would be all of the Jabal Murdama, Jabal Raqabah, As Sawadah, Jabal Zaydi, and Wadi Sirrah sections, and over one-half of the Jabal Farida and three-fourths of the Jabal Damkh sections. The Zaydi formation in the Afif, Halaban, and Wadi ar Rika 1:250,000-scale quadrangles includes about 98.5 percent of the area of Murdama outcrop. The name serves little useful purpose, and I recommend that it be abandoned.

DATA STORAGE

A base data file USGS-DF-03-11 was established as a result of this study, but no entries or updates were made to the Mineral Occurrence Documentation System (MODS) data bank.

REFERENCES CITED

Aguttes, J., 1971, Geology and mineral exploration of the Jabal ash Sheba quadrangle, Photomosaic 104 West: Bureau de Recherches Geologigues et Minieres (Saudi Arabian Mission) Report 71-JED-6, 35 p.

Bois, J., 1971, Geology and mineral exploration of the northwestern part of the Jabal Damkh quadrangle, Photomosaic 115 West: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 71-JED-2, 27 p.

Bramkamp, R. A., Gierhart, R. D., Brown, G. F., and Jackson, R. O., 1956, Geologic map of the southern Tuwayq quadrangle, Kingdom of Saudi Arabia: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-212 A, scale 1:500,000.

Bramkamp, R. A., Ramirez, L. F., Brown, G. F., and Pocock, A. E., 1963, Geologic map of the Wadi ar Rimah quadrangle, Kingdom of Saudi Arabia: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-206 A, scale 1:500,000.

Brosset, R., 1979, Geology and mineral exploration of the Bi'r al Furaysh quadrangle 24/39 C: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 79-JED-3, 19 p.

Brown, G. F., and Jackson, R. O., 1960, The Arabian Shield: International Geological Congress, 21st, Copenhagen, 1960, Proceedings, sec. 9, p. 69-77.

Brown, G. F., Jackson, R. O., Bogue, R. G., and MacLean, W. H., 1963a, Geologic map of the southern Hijaz quadrangle, Kingdom of Saudi Arabia: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-210 A, scale 1:500,000.

Brown, G. F., Layne, N. M., Jr., Goudarzi, G. H., and MacLean, W. H., 1963b, Geologic map of the northeastern Hijaz quadrangle, Kingdom of Saudi Arabia: U. S. Geological Survey Miscellaneous Geologic Investigations Map I-205 A, scale 1:500,000.

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.

Delfour, J., 1977, Geology of the Nuqrah quadrangle, sheet 25E, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-28, 32 p., scale 1:250,000.

Delfour, J., 1979, Geologic map of the Halaban quadrangle, sheet 23G, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-46-A, 32 p., scale 1:250,000.

Delfour, J., 1980, Geologic map of the Wadi ar Rika quadrangle, sheet 22G, Kingdom of Saudi Arabia (with topographic base): Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-51-A, 34 p., scale 1:250,000.

Delfour, J., 1981, Geologic map of the Al Hissu quadrangle, sheet 24E, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources Geoscience Map GM-58-A.

Eijkelboom, G., 1966, The mineral resources and geology of the Jabal Damkh-Arwah region (Sheet 115, Zone II): Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report SG-JED-66-A-13, 21 p.

Fitch, F. H., Compiler, 1980, Saudi Arabian Stratigraphic Lexicon: Saudi Arabian Deputy Ministry for Mineral Resources Technical Record DM-TR-01-1, 273 p.

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.

Hadley, D. G., 1976, Geology of the Bi'r Juqjuq quadrangle, sheet 21/43 D, Kingdom of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-26, 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, U. S. Geological Survey Miscellaneous Investigations Map I-211 A, scale 1:500,000.

Leca, X., 1970, Mineral resources and geology of the Jabal Sahah quadrangle, Photomosaic Sheet 132 East: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 70-JED-7, 28 p.

Leca, X., Letalenet, J., and Shanti, M., 1972, Geology and mineral exploration of the Al Maslum quadrangle, Photomosaic 114 East: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 72-JED-13, 28 p.

Letalenet, J., 1974, Geology and mineral exploration of the Jabal Al Murdama quadrangle, 23/43 A: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 74-JED-10, 35.

Letalenet, J., 1976a, Geology and mineral exploration of the Jabal Abhah quadrangle, 24/40 D: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 77-JED-2, 22.

Letalenet, J., 1976b, Geology and mineral exploration of the Wadi ash Shaqrah quadrangle, 24/40 C: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 77-JED-3, 20 p.

Letalenet, J., 1979, Geologic map of the Afif quadrangle, sheet 23F, Kingdom of Saudi Arabia (with topographic base): Saudi Arabian Directorate General of Mineral Resources Geologic Map GM-47-A, 20 p. scale 1:250,000.

Letalenet, J., Bois, J., Arinan, A., Gazzaz, A. R., Pflaum, J., Shanti, M., 1972, Geology and mineral exploration of the Jabal ar Raqabah quadrangle, Photomosaic 119 West: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 72-JED-20, 28 p.

Letalenet, J., Bois, J., and Pflaum, J., 1972, Geology and mineral exploration of the Ad Darah quadrangle, Photomosaic 119 East: Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 72-JED-18, 35 p.

Overstreet, W. C., and Whitlow, J. W., 1972, Reconnaissance geology of the Precambrian rocks of the Bi'r Ghamrah quadrangle, Kingdom of Saudi Arabia: U. S. Geological Survey Saudi Arabian Project Report 128, 33 p.; also 1972, U. S. Geological Survey Open-File Report (IR) SA-128.

Pellaton, C., 1981, Geologic map of the Al Madinah quadrangle, sheet 24D, Kingdom of Saudi Arabia (with topographic base): Saudi Arabian Deputy Ministry for Mineral Resources Geoscience Map GM-52-A, 19 p., scale 1:250,000.

Pettijohn, F. J., 1975, Sedimentary rocks, 3rd: New York, Harper and Row, 628 p.

Rock Color Chart Committee, 1975, Rock Color Chart: Boulder, Colorado, Geological Society of America.

Schmidt, D. L., , Geology of the Jabal Yafikh quadrangle, sheet 20/43 B, Kingdom of Saudi Arabia: Saudi Arabian Deputy Ministry for Mineral Resources map series.

Schmidt, D. L., Hadley, D. G., Greenwood, W. R., Gonzalez, L., Coleman, R. G., and Brown, G. F., 1973, Stratigraphy and tectonism of the southern part of the Precambrian Shield of Saudi Arabia: Saudi Arabian Directorate General of Mineral Resources Bulletin No. 8, 13 p.

Stratigraphic Committee, Directorate General of Mineral Resources, 1979, Saudi Arabian code of lithostratigraphic classification and nomenclature, Deputy Ministry for Mineral Resources Technical Manual TM-1979-1, 15 p.

U.S. Geological Survey and Arabian-American Oil Companay (ARAMCO), Compilers, 1963, Geologic map of the Arabian Peninsula: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-270-A, scale 1:2,000,000.

Vincent, G., 1968, Geology and mineral resources of the Halaban-Sabhah region (Sheet 118, Zone 2): Bureau de Recherches Geologiques et Minieres (Saudi Arabian Mission) Report 68-JED-1, 47 p.