I- INTRODUCTION

(I-1) Location and accessibility

The area around Wadi Umm Araka is located in the southern sector of the basement complex in the Eastern Desert of Egypt about 150 km southeast of Aswan (Fig. 1). The studied area lies in Wadi Jabjabah quadrangle sheet (No. NF 36 K) and covers about 1040 km^2 of the crystalline basement rocks. It is bounded by the following coordinates :

Longitude 33° 15′ 00″ - 33° 33′ 00″ E.

Latitude 22° 41′ 00″ - 22° 57′ 00″ N.

The study area became, to some extent, accessible after the construction of Aswan-Allaqi asphaltic road. It crosscuts Wadi Ashira and continues through the southern part of Wadi Umm Araka, Wadi Quleib then finally the southern part of Wadi Haimur till the border of the study area (Fig. 2). Other old desert tracks are accessible to light desert vehicles especially those running through Wadi Heisurbah and the western part of Wadi Quleib.

(I-2) Physical features

Morphologically, moderate to high hills and ridges are cropping out at the northeastern and southwestern sides of the present area. Both sides confine in the central part low lying country rocks which are predominated with the intrusion of granitoid rocks. Lately, these intrusions are severely eroded to give rise extensive intermittent sandy plains. The important positive topographic features comprise hogbacks and homoclinal ridges, cuestas, buttes and dyke ridges. Hogbacks and homoclinal ridges are well developed in marbles delineating the major anticline fold at the central part of the mapped area. Cuestas are mainly represented by the sheared ultramafic derivatives and sometimes adjoin

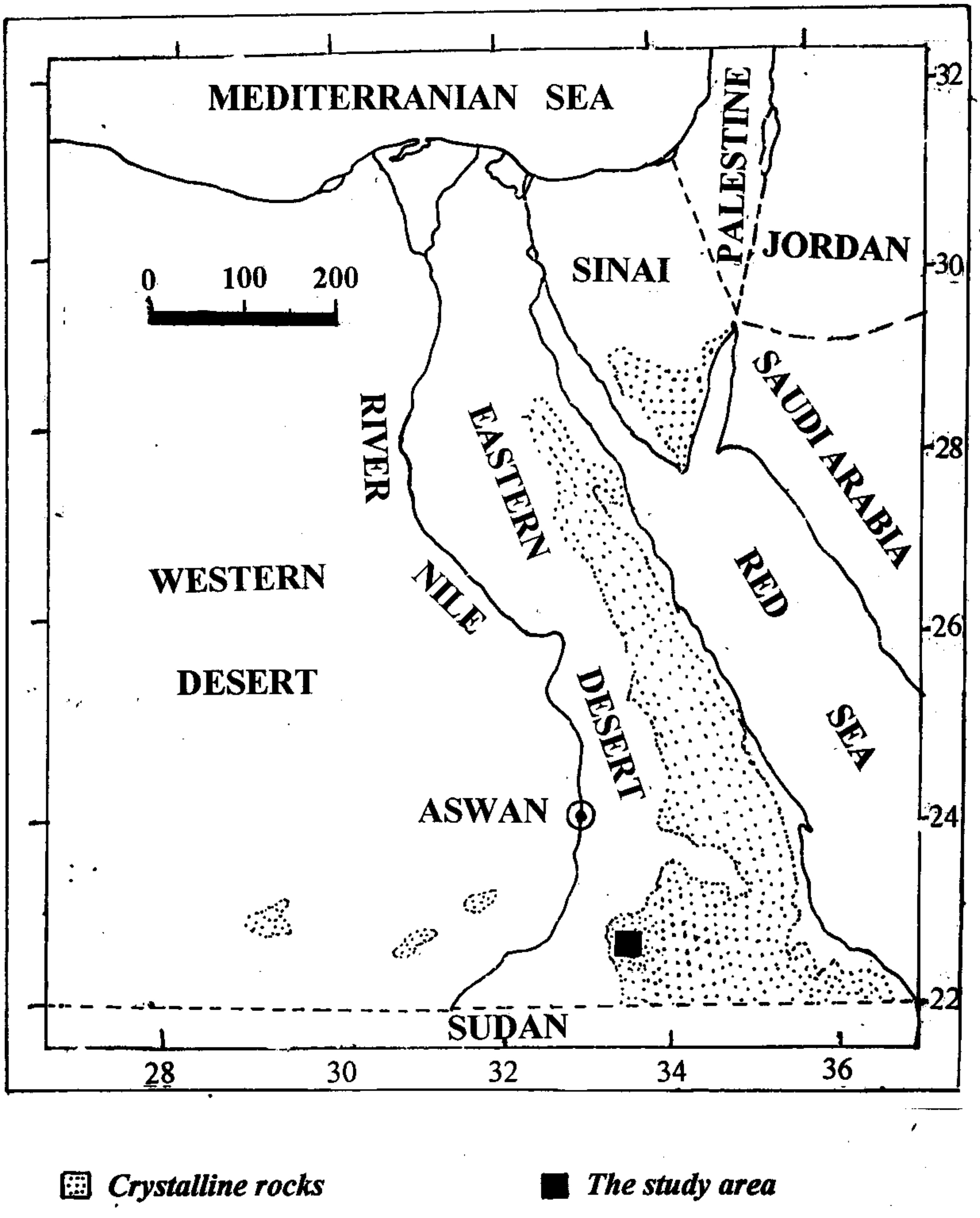

Fig. (1) **Index map showing the location of the study area.**

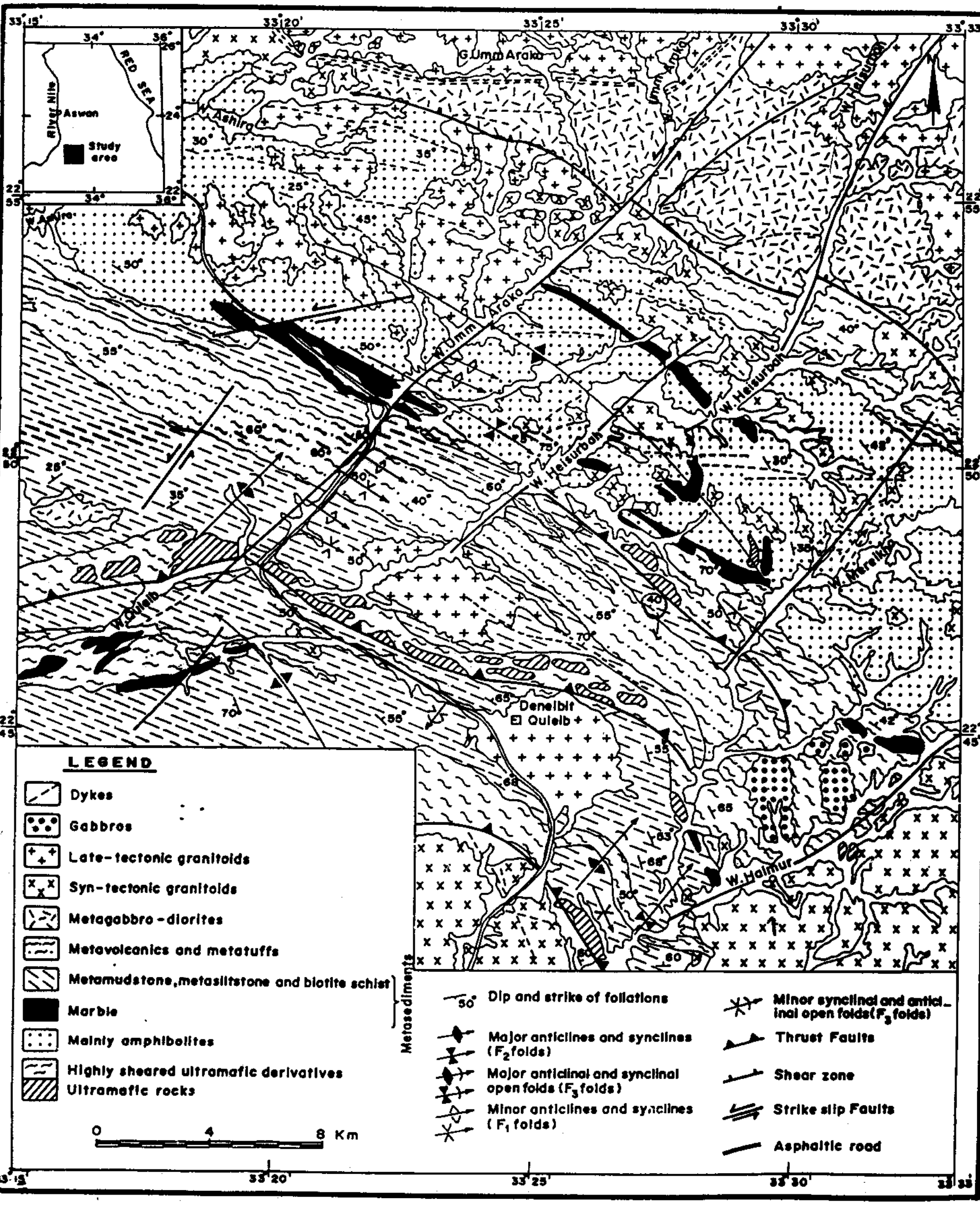

Fig. (2) **Geologic map of Umm Araka area** each other forming gentle terrain oriented NW-SE. Dyke ridges are less common and well represented by the acidic dyke oriented E-W near the northern border of the study area. Buttes are small to large isolated masses clearly displayed in the metavolcanic rocks at Wadi Umm Araka. The important dry valleys in the study area are Wadi Umm Araka, Wadi Heisurbah, Wadi Haimur, Wadi Mereikha, Wadi Quleib and Wadi Ashira.

(I-3) Scope of the present work

The present work deals with the geology and structural evolution of the area around Wadi Umm Araka aiming to add some information about the Pan-African crustal evolution of Wadi Allaqi region. The scope of the present work can be discussed in the following points:

1- Detailed geological mapping and assessment of the different rock units.
2- Clarification of the field relationships between and among the different rock units.
3- Detailed petrographic investigations of the exposed rock units.
4- Representation of the petrochemical characteristics for some selected samples of the intrusive rock units.
5- Detailed recognition and extensive accounts to the structure elements and metamorphic events developed in the study area.
6- Establishment a model for the tectonic setting and the evolution of the area under consideration.

(I-4) Methodology

In order to achieve the main topics of the present study, the following methods were completed:

1- Preparing the detailed geologic map of the study area using the vertical aerial photographs of scale (1: 40,000), photomosaics of scale (1:50,000) and landsat images (TM).

2- The fieldwork was accomplished during two field trips.

3- The lithology and contact relationships of the different rock units were studied through more than five traverses running across and along Wadi Umm Araka, Wadi Heisurbah and Wadi Haimur.

4- Through these traverses, more than 350 rock samples were collected for the petrographic and geochemical studies. Moreover, 1850 **measurements to strike and dip of the different structural elements** (including foliation, lineation, fold axes and kinking) were recorded. More than 150 photographs were also taken to represent some geologic features in the field.

5- Laboratory and office works were completed according to the following points:

   A) The petrography and metamorphism of the studied rock units were carried out by investigation of 200 thin sections of selected samples and more than 90 photomicrographs were also taken for documentation.

   B) For the geochemical analysis, 32 samples were selected in the intrusive rock units for major elements analysis using Shapiro method (1975) in Faculty of Science-Benha University. Of these samples, 21 samples were selected and analyzed for trace elements in the Central Laboratories of the Egyptian Geological Survey using XRF technique.

   C) The structural analyses were accomplished by plotting the measurements of strike and dip of the different structural elements on the equal area lower hemisphere projection in order to determine the alternated deformational phases and stresses affected the area.

D) The computer techniques were employed in the various calculations, statistical parameters, Niggli values and CIPW norms.

(I–5) Overview on the evolution of the basement rocks in the Eastern Desert of Egypt

The evolution of the basement rocks in Egypt as a part from the Arabo-Nubian Shield was interpreted in the light of two theories, the first is the classic geosynclinal theory which interpreted the Arabo-Nubian Shield as intercratonic ensialic geosyncline with basement of Sialic materials (e.g. Akaad and El Ramly, 1960; Sabet, 1961; El Shazly, 1964 and Akaad and Noweir, 1969). The second is the plate tectonic theory which considered that the Arabo-Nubian Shield was evolved on oceanic crust by welding of series of island arcs and cratonization processes (e.g. Greenwood et al., 1976 and Gass , 1977). Furthermore, Hashad and Hassan (1979), and El Gaby et al. (1984) considered that the Shield was developed as oceanic crust beneath continental plate margin.

During the last two decades, special emphasis has been put on the study of the tectonic setting of the basement rocks of the Eastern Desert on the basis of the plate tectonic concept (Garson and Shalaby, 1976; El Sharkawy and El Bayoumi, 1979; Shackelton et al. , 1980; Ries et al , 1983; El Ramly et al. , 1984 and El Gaby et al. , 1988). Accordingly, it is believed that the basement rocks of this region evolved through a horizontal crustal accretion during the Pan-African event from about 950 Ma to 550 Ma (Gass, 1981; Vail, 1983 and Kroner, 1984). These rocks are mainly represented with extensive ophiolites and volcanosedimentary rocks which in some places thrusted onto gneisses, migmatites and amphibolites.

Currently, the principal question that awaits answering is whether there are any Pre-Pan African (> 950 Ma) basement rocks in the Eastern Desert or not?. Most available works seem to favor such existence. Depending on age determinations, however, some authors (e. g.Kroner et al., 1988) stated that "there is as yet no conclusive evidences for the presence of Pre-Pan African crust underneath the Eastern Desert". Whereas the others (e.g. Garson and Shalaby, 1976; El Manharawy, 1977; Abdel Monem and Hurley, 1987 and El Gaby at al., 1988) substantiated the presence of such crust. Anyhow, there is a general consensus that the basement rocks in the Eastern Desert are structurally characterized by low angle thrusts and folds (Shackleton et al., 1980; Ries et al., 1983 ; Shimron, 1984; El Ramly et al., 1984; Greiling et al.,1984 ; Greiling,1987 and Bernau et al. 1987).

Kroner et al. (1987) suggested that the Pan-African structural domain with its ophiolitic melange and its low angle thrusts extends almost as far west as the Nile River, where the margin of the ancient African carton may be found. The entire domain in the farther east is characterized by newly accreted magmatic associations of late Precambrian age which might have evolved in tectonic settings similar to those presently observed in the Indonesian archipelago.

Local and regional shortening of the basement rocks inside the Eastern Desert had been taken place during the Pan-African Orogeny, but the directions of the shortening and nappe transportation are still debatable (Ries et al., 1983; Vail, 1983; Kroner, 1985 and Shackleton, 1986).

II- FIELD GEOLOGY

Based on the detailed field mapping and rock units relationships, the rocks exposed in the study area are arranged as follow beginning with the youngest.

Dykes and Veins

Gabbros -- (youngest)

Late-tectonic granitoids

Syn-tectonic granitoids

Metagabbro-diorites

Metavolcanics and Metatuffs

Metasediments

Amphibolites

Ultramafic rocks and their sheared derivatives --------- (oldest)

(II-1) Ultramafic rocks and their sheared derivatives

These are the oldest rock unit in the study area and exposed mainly along the western flank of Wadi Quleib, north of Deneibet El Quleib and, in places, at Wadi Haimur, Wadi Mereikha and Wadi Umm Araka (Fig. 2). They represent the disrupted, allochthonous and discontinuous oceanic remnants that are tectonically re-emplaced due to a compressive force and indicated by tectonic and thrust contacts with the amphibolites, metasediments, metavolcanics and metatuffs. Along their contacts with these rocks, talc-magnesite veinlets and sheaths of asbestos are developed.

The ultramafic rocks are dissected into elongated serpentinite masses of different sizes, which still preserve relics of dunites and pyroxenites. They cover an area 25 km^2 and topographically are characterized by ridges of high summits (reach up to 450 ms a. s. l.) with steep slopes because they are much more resistant to weathering than the surrounding rocks (Plate 1). They vary in size from small unmappable lenses to enormous ridges of more than 4 km length and 1.5 km width. In the present area, they are predominantly surrounded by highly sheared ultramafic derivatives.

The sheared ultramafic derivatives cover an area 85 km^2. They are common and consist of tremolite schist, talc schist, talc-graphite schist and talc carbonates. These rocks are developed between the serpentinite masses as a result of strong shearing processes. They form continuous and discontinuous tectonic sheets conformable with the other rock units. These sheets may extend in the area for 30-35 km in length and 1.0-2.3km width. They are very weak with well-developed foliation planes and the rocks split easily into separated plates through these planes. Occasionally, they contain small bands of marble, which are concordant with the strikes of the regional structure (Plate 2).

In general the ultramafic rocks and their sheared derivatives are tectonically alternated and intermingled with the metasediments and metavolcanics, and concordant with the regional structure elements in the study area.

(II-2) Amphibolites

They are relatively dominant in the study area and exposed within the low lands (about 180 km^2). They are scattered at the central part of the mapped area and drained by Wadi Heisurbah and Wadi Umm Araka (Fig. 2). Unmappable boudins of these rocks are also found concordant with the regional structure of the metasediments (Plate 3). Generally, the amphibolites are intruded by the Syn- and Late-tectonic granitoids which

Plate (1) High ridges of serpentinites (S) comformably interbedded within their sheared derivatives (H), Wadi Haimur. Photo looking NW.

Plate (2) Small boudins of marble (white colour) within the sheared ultramafic derivatives, Wadi Heisurbah. Photo looking SW. (Hammer gives scale).

Plate (3) Amphibolite boudine (black colour) embedded tectonically within marble (white colour), Wadi Umm Araka. Photo looking NE.

emplaced either across or along their foliations.

They show alternated leuco- and melanocractic bands nearby their contacts with the shear zones and, in parts, deformed into meso- and microscopic anticlinal and synclinal folds. The amphibolites show tectonic contacts and structurally are conformable with the sheared ultramafic derivatives, metasediments and metavolcanics. Although, these amphibolites don't show any intrusive contacts, however, they still have relic minerals advocating the gabbroic parentage as such observed by Takla et al. (1987), El Ramly et al. (1993) and Noweir and Al Amawy (1999).

(II - 3) Metasediments

The metasediments are mainly cropped out in the southwestern corner of the mapped area between Wadi Haimur and the southern sector of Wadi Ashira. They cover an area 200 km^2 are classified into marble, biotite-almandine to biotite schist, metasiltstones, metamudstones and quartzitic . bands. They are still preserving graded bedding and other primary structure support the sedimentary origin. These rocks are highly deformed and tectonically dissected into sheets alternated with metavolcanics and metatuffs but separate from the ultramafic rocks and their sheared derivatives by thrust faults. Along these thrust faults, they are characterized by strong shearing (Plate 4). Geologic and field observations of the metasediments and associated marble and quartzite bands are in the following:

(II-3-1) Marbles

Marbles are mainly exposed in the central part of the mapped area delineating the major anticline and drained by Wadi Umm Araka and Wadi Heisurbah. Other bands of these rocks are also located within the metasediments in southern part of the mapped area (Fig. 2). Unmappable exposures are also recorded at Gabal Umm Araka, Wadi Quleib and Wadi Haimur (Plate 4).

Marbles show tectonic contacts with the country rocks and concordant with the regional structure of the area (Plate 5,6). They form high ridges of 80 ms to 7.0 km or even more in length and average width of 200 ms. They are mostly white to dark grey in colour and, in places, exhibit bands parallel to the bedding plane (So). In localities, the marble bands enclose some boudins of ultramafics and amphibolites (Plate 4). Whereas in others, they are intruded by the late-tectonic granitoids (Plate7).

Structurally, marbles preserve the successive phases of ductile deformation because of their wide plastic properties and sometimes show big xenomorphic crystals as shown in plate (8). Generally, there are different types of marble are discussed in details in chapter (III).

(II – 3- 2) Biotite-almandine and biotite schists

These rocks form low lands but in few cases, they are characterized by high terraines and well developed foliation and schistosity planes. They cover extensive area and crop out mainly around Wadi Quleib alternating with the ultramafic rocks, metasiltstones, metamudstones and metavolcanics (Fig. 2). Along their contacts with the ultramafic rocks, there are well-developed narrow zones of mylonites marking the thrusts and shear zones. Commonly, they are fine to medium-grained, well-folded and easily weathered especially nearby shear zones and intrusive granitoids (Plate 9).

In places, they are intermingled with lensoidal masses of serpentinites, talc carbonates and amphibolites (Plate 10). They are intruded by the syn- and late-tectonic granitoids indicating an effect of contact aureole that will be dealt in more details later in chapter (VI).

Plate (4) Highly foliated marble (grey colour) interbedded tectonically within the sheared ultramafic derivatives, the southern part of Wadi Haimur. Photo looking SE.

Plate (5) White marble band boudinaged within biotite schist, east of Wadi Umm Araka. Photo looking NW.

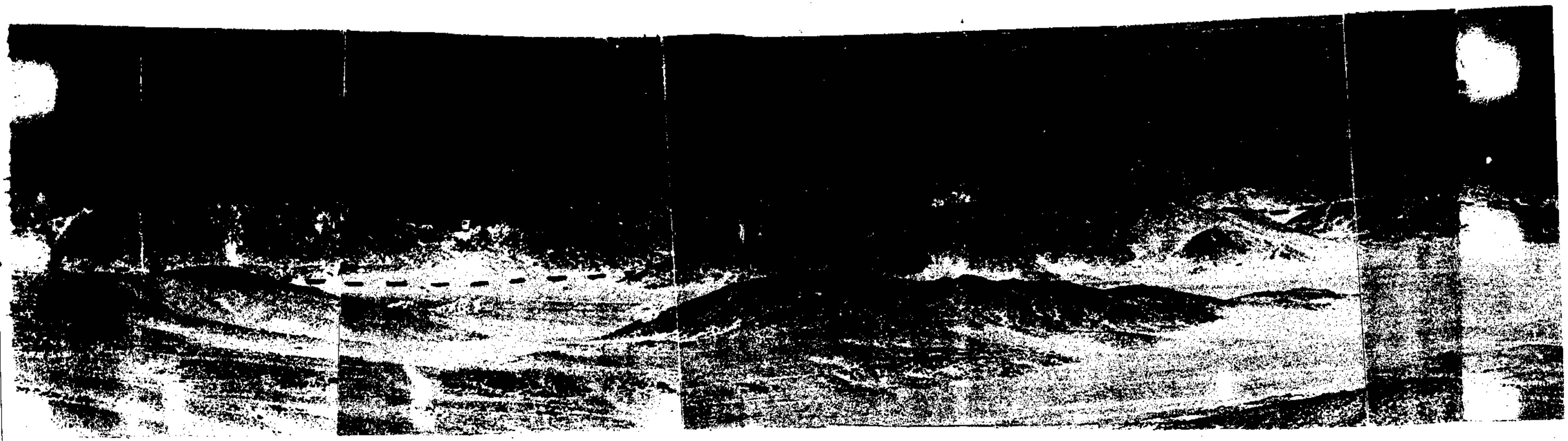

Plate (6) Panorma showing straight tectonic contact between marble (high) and Amphibolites (low), east of Wadi Umm Araka. Photo looking W.

Plate (7) Marble (grey colour) roof pendants of the late-tectonic granitoids (dark colour), east of Wadi Umm Araka. Photo looking NE.

Plate (8) Large xenomorphic crystal of quartz (white colour) in quartz marble, west of Wadi Heisurbah .

Plate (9) Well developed schistosity in the biotite schist, Wadi Umm Araka. Photo looking NE.

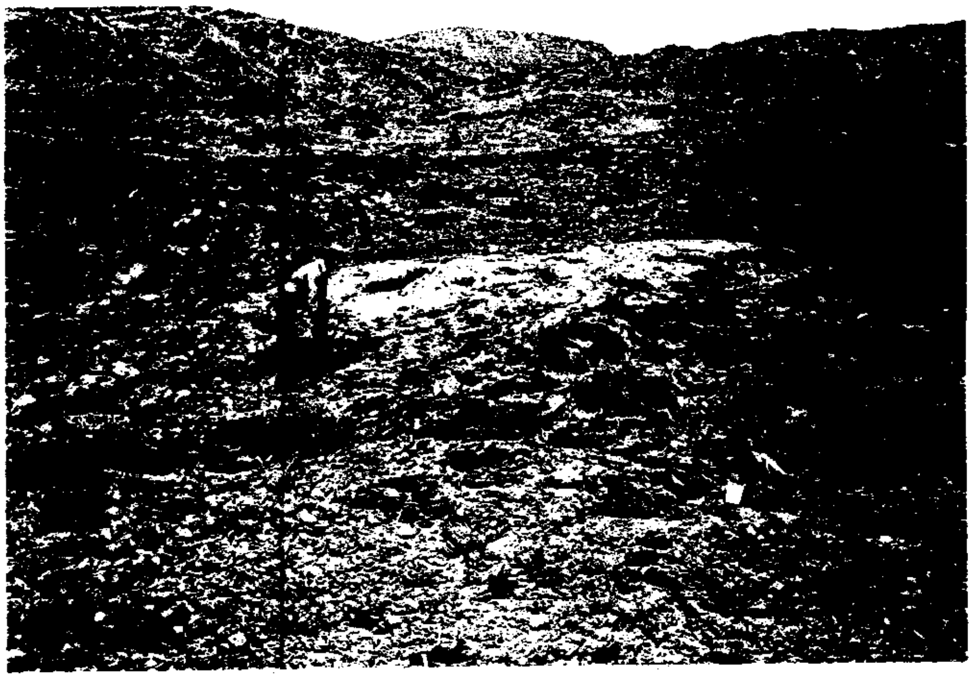

Plate (10) Lensoidal boudine of talc carbonate (yellow colour) emplaced tectonically within biotite schist; near Deneibet El Quleib. Photo looking NE.

(II- 3 – 3) Metamudstones-metasiltstones and Quartzitic Bands

The metasiltstones – metamudstones are less common and the important exposures form a minor syncline. This structure extends across the upper sector of Wadi Mereikha and covers an area of (5 x 1.5) km^2 (Fig. 2). In this locality, the metamudstones form most of the core, whereas the metasiltstones increase outward forming the limbs. Other locations of these rocks are recorded at Wadi Heisurbah and Wadi Umm Araka where they form disconnected sheets of well preserved bedding planes (Plate 11).

Quartzitic bands are rare and form unmappable bodies of limited extensions (200 ms. long and few meters wide) embedded in the biotite schist. They are presented in the area at Wadi Quleib and around Deneibet El Quleib

(II-4) Metavolcanics and Metatuffs

They are relatively common and represented by two separated belts covering an area of about 110 km^2 (Fig. 2). The first belt is located in the southwestern part of the study area alternating with the metasediments.
It forms low-lying outcrops (e.g. buttes) of less than 30 ms height and extends in a harmony with the regional structure of the area. The second belt has limited extension and situated near the northeastern corner of the mapped area where it is intruded by the metagabbro–diorites and granitoids. It is characterized by low discontinuous outcrops (e.g. cuestas and buttes) and, in places, shows signs of extensive weathering and shearing processes.

Metavolcanics are highly deformed and represented mainly by the hornblende schist (Plate 12). In localities where there are strong shearing and deformation acting, the hornblende schist is transformed into the epidote chlorite schist. The later is very weak and splits easily into thin

Plate (11) The S_0-bedding planes in the metamudstones, the eastern flank of Wadi Umm Araka. Photo looking NW.
(Hammer gives scale)

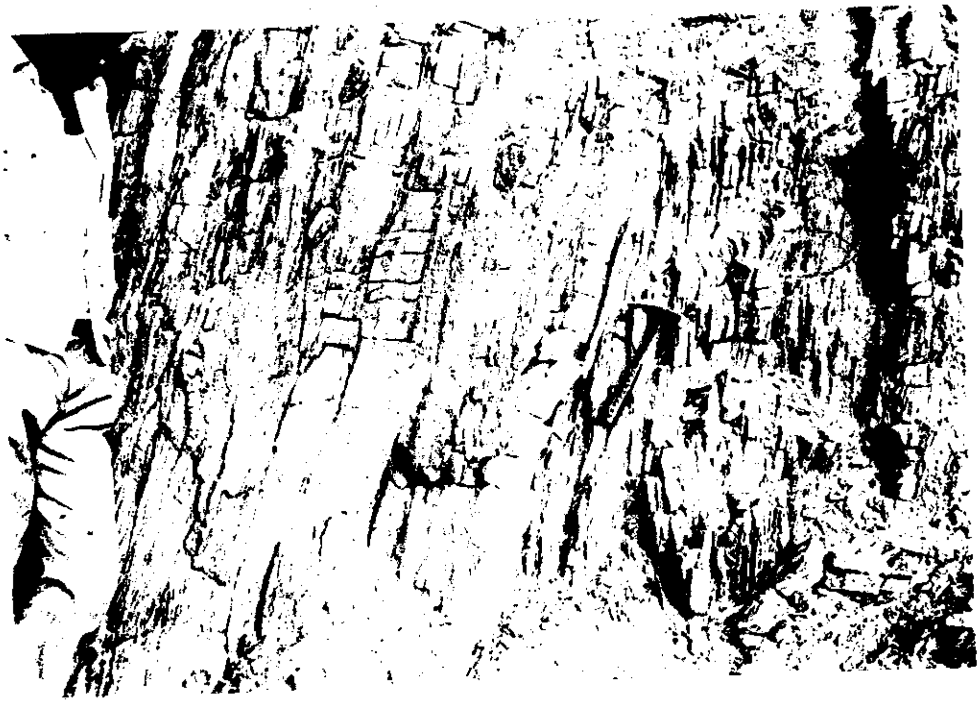

Plate (12) Hornblende schist showing well developed schistosity planes and injected by small pegmatitic vein (white colour), the eastern flank of Wadi Umm Araka. Photo looking NE.
(Hammer gives scale)

laminae. The metatuffs are very rare and exposed mainly at the northeastern corner of the studied area. They are intermediate to acidic in composition and range in size from fine ash to lapilli tuffs. They are massive, hard and highly deformed.

(II –5) Metagabbro-diorites

The presentation of the metagabbro- diorites is a new contribution to the geology of the study area. These rocks are wedge in shape and limited by marked shear zone at the northeastern part of the mapped area. They are characterized by obvious intrusive contacts with metavolcanics and metatuffs. Small masses of these rocks are also outlined within the metasediments north of Wadi Quleib and their intrusion resulted in local attenuation of the main foliation (Fig. 2). The main northeastern exposure covers an area of 50 km^2, whereas the other masses occupy only 4 km^2 area. These rocks are massive but along the shear zones, they frequently exhibit melano- and leucocractic bands. At juxtaposition with Gabal Umm Araka, they are intruded by the late-tectonic granitoids and this is characterized by xenolith structures and extrusion of composite acidic dykes (Plate 13) and (Fig. 2).

(II-6) Granitoids

These rocks occupy about an area 235 km^2 and are represented by two types; the syn- and late-tectonic granitoids.

(II-6-1) Syn-tectonic granitoids

These rocks are tonalitic to granodioritic in composition and form low hillocks in the southern and southeastern parts of the mapped area. Small cupolas of these rocks are also recorded intruding the core of the major anticline at the central part of the study area (Fig. 2). They are intruded in the pre-existing rocks taking xenoliths especially near the contact with the metagabbro-diorites (Plate 14).

The syn-tectonic granitoids are cataclased, sheared, fractured and occasionally show large spherical exfoliated blocks (Plate 15). These weak zones with the close-spaced joints facilitate the weathering processes acting on these granitoids to result in wide-open sandy Plains with granitic noles (Plate 16). In general, these granitoids change in composition from granodiorite at the middle to tonalite toward the peripheries reflecting the good magmatic differentiation during intrusion and cooling. Various types of dykes and veins traverse them, and currently their characteristics are comparable with the G_1- granitoids of Hussein et al. (1982).

(II-6-2) Late-tectonic granitoids

They are common and widely distributed allover the study area attaining different forms and attitudes. They form circular mass in Deneibet El Quleib but at the eastern flank of Wadi Heisurbah have a spindle-shape intrusion. Other small isolated outcrops of these rocks are also encountered at the central part of the mapped area tapering along the main foliation. To the north, they extend beyond the present area to form the main mass of Gabal Umm Araka granitoids. They show irregular intrusive contact with the pre-existing rocks and range in composition from biotite granites of white and pink colours to muscovite granites of yellow and red colours. Topographically, the late-tectonic granitoids form low features except few high ridges and conical bosses east of Wadi Ashira (Plate 17). In localities, the red muscovite granites show large glittering clusters of muscovite flakes and mostly exhibit high subconnected ridges (i.e. affected by faults) as exposed near Wadi Umm Araka (Plate 18).

Plate (13) Metagabbro - dioritic rocks (on the left) intruded by syn-tectonic granitoids (on the right), north of Wadi Umm Araka. Photo looking N.

Plate (14) Xenolith of metagabbro-diorite (black colour) enclosed by the syn-tectonic granitoids, near Wadi Ashira. Photo looking NE. (Hammer gives scale)

Plate (15) Exfoliation structure in the syn-tectonic granitoids, the western flank of Wadi Ashira. Photo looking NE.

Plate (16) Extensive weathering of the syn-tectonic granitoids resulted in open sandy plains with granitic noles, south of Deneibet El Quleib. Photo looking SE.

Fig. (17) High conical plug of the late-tectonic granitoids (G) intruded in The metasediments (Ms), near Wadi Ashira. Photo looking NW.

Plate (18) Ridge of red muscovite granitoids affected by strike slip fault with sinstral separation, northwest of Wadi Umm Araka. Photo looking NE.

At Gabal Umm Araka, the late-tectonic granitoids show high rugged mountainous topographic features with well-developed systems of joints. They are mainly made up of pink muscovite granites and extruded by quartz veins and acidic dykes.

At Deneibet El Quleib, these granitoids were studied in details by Noweir and El Amawy (1996) who stated that " These rocks form hillocks of moderate to relative high peaked features either scattered or coalesced together in sandy plains. Their contact with the enveloping pre-existing country rocks is rather sharp and the assimilation reactions are still notable. In the center, the pluton is coarse-grained but outwards change into medium-grained and chilled fine-grained margin characterized by pegmatitic phases and veins. The field observation envisaged a style of considerable metamorphic aureole in the pre-existing metamorphic rocks surrounding this pluton similar to those dealt with by Rostal (1910), Tilley (1924), Noweir (1965), El Sharkawy and El Bassyouni (1972) and Noweir and El Sharkawy (1979)".

At Wadi Heisurbah, the late-tectonic granitoids had been intruded along the foliation of the metasediments forming elongated mass of 14.5 km^2 area. They are high relief, jointed, fractured and moderately exfoliated.

Comparably, the late-tectonic granitoids belong in their characters to the G_2-granitoids of Hussein et al. (1982) and group – 2 granitoids of Noweir et al. (1990).

(II-7) Gabbros

They have limited occurrences and represented by small masses occupying an area 9 km^2 at the western bank of Wadi Haimur. In this locality, they show intrusive contacts with the sheared ultramafic derivatives and metavolcanics and, in parts, reveal thermal effect in the enveloping country rocks.

Topographically, they form curved disconnected ridges of moderate height and pointed straight summits.

(II-8) Dykes

The study area is dissected by limited number of basic, acidic to alkaline dykes and veins. Comparably, the acidic dykes follow the trend of S_2-foliation and thrust faults (i.e. WNW-ESE to NW-SE).On the other hand, the basic and alkaline dykes run parallel to the third phase S_3-foliation and strike slip faults. Therefore, as a sequence of extrusion effect, the dykes started with the acidic types and followed by alkaline and basic ones. Generally, these types will be discussed in more details in followings:

(II-8-1) Basic dykes

These dykes are basaltic to doleritic in composition and trending N40-60E. They are of limited extension and represented in the area at Wadi Umm Araka cutting across the metasediments. They have tan green colour, but mostly covered by greyish green weathering surface.

(II-8-2) Acidic dykes

They embrace felsite dykes and quartz to pegmatitic veins. They represent the most common features among the different types of dykes. Felsite dykes run along NW-SE direction, but locally attain the E-W to ENE-WSW trends. They are much longer than the other types of dykes as indicated in the northwest of Deneibet El Quleib where some of these felsite dykes reach up to 7 km in length or even more. At the contact between the metagabbro-diorite rocks and the southern border of Gabal Umm Araka granitoids, the acidic dykes form enormous high ridges (Fig.2). Quartz and pegmatitic veins, on the other hand, cut the granitoids