# *SUMMARY AND CONCLUSIONS*

The present area is located in the South Eastern Desert between latitudes 22° 41′ 00″ and 22° 57′ 00″ N, and longitudes 33° 15′ 00″ and 33° 33′ 00″ E. The mapping of the study area is carried out using the vertical aerial photographs (scale 1: 40,000) and photomosaics (Scale 1:50,000) as well as the thematic landsat (TM). Geologically, ultramafic rocks and their sheared derivatives, amphibolites, metasediments, metavolcanics and metatuffs cover the area. These rocks are intruded by foliated gabbro-diorites, syn-tectonic granitoids, late-tectonic granitoids and gabbros. Later on, dykes of varying composition dissected the area.

The ultramafic rocks and their sheared derivatives are the oldest rocks in the study area. They form disrupted allochthonous and discontinuous remnants and thrusted over the underlying amphibolites, metasediments, metavolcanics and metatuffs. Along their contact with these rocks, strong shearing or mylonites, talc-magnesite veinlets and sheaths of asbestos were developed. The ultramafic rocks are divided into elongated masses of different sizes of serpentinites which are still have rare relics of dunite and pyroxenite. These masses are predominantly surrounded by pervasive sheared ultramafic derivatives. The sheared ultramafic derivatives involve tremolite schist, talc schist, talc graphite schist and talc carbonates. Microscopically, the serpentinites are mainly composed of antigorite, lizardite, chrysotile, ankerite and opaques. These rocks display mesh and relics of bastite texture. On the other hand, the sheared ultramafic derivatives have the mineral composition of talc, tremolite, plagioclase, pyroxene relics, chlorite, quartz and carbonate minerals, as well as sphene, epidote, garnet and iron oxides forming the accessory minerals. These mineral constituents commonly exhibit the schistose texture.

Amphibolites are dominantly exposed in the central part of the mapped area. Whilst unmappable boundins of these rocks are incorporated, in some places, inside the metasediments. Microscopically, they are mainly composed of hornblende, plagioclase ($An_{40-52}$) and iron oxides as well as biotite, chlorite and epidote. These constituents show mainly the gneissose texture and locally exhibit alternated leuco- and melanocractic bands. Occasionally, the amphibolites contain sphene and relics of pyroxene contents advocating the gabbroic parentage as those observed by Takla et al. (1987).

The metasediments cover the greater part of the mapped area and crop out in the southwestern corner between Wadi Haimur and Wadi Ashira. They are classified into marble, biotite-almandine to biotite schists, metasiltstone, metamudstone and narrow zones of quartzitic bands. Well preserved graded bedding and other primary structures support their sedimentary origin. The metasediments are deformed and tectonically dissected into sheets alternated with the metavolcanics and metatuffs but separated from the ultramafic rocks and their derivatives by thrusts and unmappable zones of mylonites. Marble is distinguished microscopically into pure marble, tremolite marble, foresterite marble, quartz marble and graphite marble. Biotite schist consists in thin section mainly of biotite, quartz and plagioclase with calcite, graphite and iron oxides. Whereas, the metamudstone, metasiltstone, quartzofeldspathic schist and quartzites show the mineral assemblages of quartz, undifferentiated feldspars and biotite together with sericite, epidote, muscovite and iron oxides.

The metavolcanics and metatuffs are represented by two elongated belts. The first belt is located in the southwestern part of the study area alternating with the metasediments. The second one is located near the northeastern corner of the study area and intruded by metagabbro-diorites and granitoid rocks. The metavolcanics are highly sheared and represented mainly by the hornblende schist. In localities subjected to strong shearing and

deformations, zones within and along the margin of these hornblende schists are transformed into epidote chlorite schist. Microscopically, the metavolcanics are mainly composed of hornblende (of prismatic form and extinction angle between 8°-15°), plagioclase (An $_{30-44}$), quartz and iron oxides. Epidote, chlorite, actinolite and tremolite are the secondary minerals.

The metatuffs, on the other hand, are exposed dominantly in the northeastern corner of the area and range in size from ash to lapilli tuffs of intermediate to acidic composition. Microscopically, they are composed mainly of lithic fragments of plagioclase (An $_{8-12}$), quartz, orthoclase and biotite embedded in a cryptocrystalline groundmass of the same composition.

The metagabbro-diorites are mainly exposed in the northeastern part of the mapped area showing intrusive contact with the metavolcanics and metatuffs. Another small mass is outlined within the metasediments north of Wadi Quleib. Frequently, the metagabbro-diorites exhibit melano- and leucocractic bands, in particular, around the shear zones. Microscopically, these rocks mainly composed of plagioclase (An $_{40-50}$), hornblende with pyroxene relics and quartz. Sphene and iron oxides are the main accessories, but the secondary minerals are epidote and chlorite. The dioritic rocks are less common and consist mainly of plagioclase (An $_{30-38}$), hornblende, quartz and biotite associated with accessory and secondary minerals of sphene, iron oxides, apatite, epidote and chlorite. All the criteria of petrography, geochemistry and mode of occurrence indicate that these rocks are most probably developed in island arc environments.

The syn-tectonic granitoids are tonalite to granodiorite in composition and form low relief hillocks at the southeastern and southern parts of the mapped area. In the central part they form small cupolas within the inner part of the major anticlinal fold. They are intruded in the pre-existing rocks showing in locality xenoliths of mafic composition. These granitoids are composed of plagioclase (An $_{28-36}$), hornblende, quartz, biotite and few

amounts of orthoclase. Sphene, apatite and iron oxides are the accessories, whereas muscovite, chlorites and epidote are the secondary minerals. Geochemically, these rocks are poor in alkali contents, peraluminous in character and calc-alkaline to sub-alkaline in nature. They were developed under moderate to deep crustal thickness (20-30 Km) related to compressional tectonic setting .In general, the characteristics of the syn-tectonic granitoids are comparable with the $G_1$ granites of Hussein et al. (1982).

The late-tectonic granitoids form circular mass in Deneibet El Quleib and elongated body in Wadi Heisurbah. Moderately isolated masses of these granitoids are also encountered in the central part of the mapped area. To the north, they extend beyond the present area forming the main mass of Gabal Umm Araka granitoids. They show intrusive contact to the surrounding rocks and range in composition from biotite granites of white and pink colours to muscovite granites of yellowish and red colours. These rocks emphasize granitic to perthitic textures and mainly consist of quartz, orthoclase, plagioclase ($An_{8-28}$), microcline, perthite, biotite and / or muscovite . Allanite, apatite, zircon and iron oxides are the main accessory minerals. The secondary minerals are sericite, kaolinite and chlorite. The geochemical analysis of these rocks shows low CaO content and has the granite- adamelite composition. Genetically, the late- tectonic granitoids are I-type (i.e. mantle origin) and formed over subduction zone in compressional tectonic environment. Comparably, these granitoids belong in their characters to $G_2$-granites of Hussein et al. (1982) and group -2 granites of Noweir et al. (1990).

The gabbros are represented by small masses at the western flank of Wadi Haimur and characterized by intrusive contact with the metavolcanics. Under the microscope, they made up of plagioclase ($An_{50-60}$), augite, iron oxides, little amount of quartz and sphene; being typified by ophitic to subophitic textures

The dykes dissecting the study area are of varying composition including basic, acidic and alkaline types. The basic dykes are basaltic to doleritic in composition and oriented N 40° - 60° E. The acidic dykes consist of felsite dykes and quartz to pegmatitic veins. The quartz and pegmatitic veins mostly oriented N 50° - 70° W, but the felsite dykes run along NW-SE and locally attain E-W to ENE-WSW trends. The alkaline dykes are less common and represented by the bostonite types oriented N 35° E.

Detailed structural studies were carried out on the present area and revealed polyphase of deformations ($D_1$, $D_2$ and $D_3$) deciphered from macro– and mesoscopic structures. The first deformational phase $D_1$ included the formation of $S_1$ foliation parallel to bedding plane ($S_1$//So) and the development of $F_1$ minor folds of very tight, recumbent and interfolial styles. The axes of these folds are trending WNW-ESE and plunging gently and predominantly to ESE. $D_2$ is marked by regional thrusting, $S_2$ foliation and the second phase of folding ($F_2$) .$F_2$ folds are represented by the less tight and overturned types, trending NW-SE and plunging at moderate angles due SE and NW directions. The last phase $D_3$ is recorded by strike slip faults, $S_3$ foliations and the third phase of folding ($F_3$). The latter is developed in the style of open folds with axes trending ENE-WSW and steeply plunging toward ENE and WSW. The accurate field relationships indicated that $F_1$ folds are arranged and mostly well preserved as shear pods within the limbs of $F_2$ major folds. On the other hand, $F_3$ folds are superimposed on $F_1$ and $F_2$ folds.

The thrust faults are oriented WNW-ESE to NW-SE and subsequently dissected the area into local belts of high strained rocks characterized by mylonites and spectacular zones of sheared ultramafic rocks. The subsequent thrust planes exposed number of horses, which are compiled to form a duplex in the area. The strike slip faults run in a straight manner along ENE-WSW

and horizontally dislocate the rock units in a sense of sinistral slip movements.

Field and petrographic studies of the rock units in the study area revealed that most of these rocks were subjected to polymetamorphic events of at least three episodes. These are the progressive regional metamorphism ($M_1$), contact or thermal metamorphism ($M_2$) and retrograde metamorphism ($M_3$). These metamorphic episodes were developed essentially within the greenschist facies except for some rocks reached the almandine zone of the amphibolite facies.

The regional metamorphism ($M_1$) is widespread and its imprints are quite visible in most rock units such as ophiolitic assemblages, amphibolites metasediments and metavolcanics. It started with $D_1$ deformation, but the major effect was developed during $D_2$ deformation, and the prevailing condition during this episode of metamorphism was low pressure-high temperature.

The contact metamorphism ($M_2$) was developed after the regional metamorphism and represented by zonations or aureoles around the granitic intrusions. It is dominant in biotite schist, subordinate in the sheared ultramafic derivatives and marble but is not easily traced in the amphibolites.

Retrograde metamorphism ($M_3$) was developed mainly in amphibolites, some metasediments and metavolcanics. These rocks metamorphosed under low pressure - low temperature conditions, which was controlling the last phase of deformation ($D_3$).

Based on field and structural analysis of the fault measurements, the direction of thrusting and the WSW slickenside striations on the thrust planes, the direction of transport in the study area was concluded toward WSW resulted from a nearly compressive forces directed form the ENE. Lately, this force may by changed by another one directed form SE. This force is coaxial with the shortening direction perpendicular to $F_3$ folds (ENE and WSW) and

responsible form bending of thrust planes. Hence, a later NW- transport can be assumed.