CHAPTER (VI)

SUMMARY AND CONCLUSIONS

The evolution of the Arabian — Nubian Shield in the light of the plate tectonic concept involved multicyclic island arcs (fore — arc), with continuos deformation and ophiolitic obduction occurring primarily during phases of arc collision, however the ultimate result of these processes was the progressive cratonization of a large volume of new crust (Greenwood et. al.1976; Gass, 1977, 1981). Another mode suggests the Precambrian continental crust of Egypt and western Saudi Arabia is evolved in the same way to the Indian type orogeny in its broad sense (Nawab, 1978).

The Precambrian rocks of Egypt (100, 000 Km^2) outcrop over an extensive area in the Eastern Desert, southwestern part of the Western Desert and south Sainai. The Precambrian belt represents the NE part of the Arabian — Nubian Shield which is exposed in both sides of the Red Sea, and belonging to the Pan — African orogenic belt.

The Egyptian Precambrian belt of the Eastern Desert is composed of an upper — Proterozoic volcano — sedimentary complex containing scattered ultramafic mafic bodies and intruded by syn- to late- tectonic plutonites (mainly tonalite to granodiorite) with extrusive series of calc- alkaline volcanic rocks. This sequence is unconformably overlain by molasse sediments of the Hammamat group. The sequences are cut by alkaline to sub alkaline late- to post- tectonic granites.

The age of crystallisation of oceanic crust ranges from 550 to 788 Ma. The major episodes of igneous activity have been occurred scince 500 Ma

with the eplacement of numerous Pan — African granitic plutons (Fullagar and Greenberg, 1978)

In the Central and Southern Eastern Desert, the deformed and largely mylonitized rocks of the infrastructure crop, out in gneiss domes disposed along the axes of genetic lines trending NNW — SSE which also functioned as magmatic arcs (El Gaby, 1983). Remobilize infrastructure rocks are well displayed at Wadi Feiran, SW Sinai (El Gaby and Ahmed, 1980), along the Qena — Safaga road (Sabet et. al.1972; Akaad et. al.1973) and around Aswan (Gindy, 954).

Gabal Ribdab — Gabal Shashoba area is located in the southern most part the Eastern Desert of Egypt, about 100 km east of Aswan — Allaqi asphalt road. The area is named after the conspicuous mountain ranges of Gabal Ribdab (700 m) and Gabal Shashoba (500 m) occupying the northwestern and southeastern parts of the study area respectivily. The investigated area lies in Elba topographic sheet (No. 12), scale 1: 500,000 and covers an area of about 800 km^2 of crystalline Precambrian rocks.

It is convenient to review briefly the sequence of the studied rock units and their inferred tectonic setting which represents a grossly simplified version of lithologic sequence of rock units (Table 12).

The following is a brief outline of the tectonic setting and field occurrences of the main lithologic units in the study area:

Table (12) The sequence and tectonic setting of rock units in the study area.

Tectonic setting	Rock units
Dykes and Veins	Mafic and felsic dykes
	Quartz veins
Post- tectonic granitods	Alkali-feldspar granite
Late- tectonic granitoids	Granodiorite and monzogranite
ACM volcanic rocks	Dokhan volcanics
Syn- tectonic plutonic rocks	Mainly tonalite
	Gabbros
Arc volcanic assemblages	Mafic to intermediate metavolcanics
	Intermediate to felsic metavolcanics
	Metatuffs
Dismembered ophiolites	Highly sheared ultramafics
	Ultramafic rocks
	Metagabbro
	Deformed pillow lavas
Gneisses	Tonalite gneisses and amphibolites
	Garnet biotite gneisses
	Biotite gneisses

Gneisses occupy the northwestern part of the study area and cover an area of about 50 km^2. They are classified into biotite gneisses, garnet biotite gneisses, tonalite gneisses and amphibolites. They represent the oldest rock unit in the study area and locally migmatized. Structurally, they occupy the core of F2 major duble plunging anticline and are seperated from the dismembbered ophiolites and arc volcanic assemblages by thrust contacts and slices of highly sheared ultramafic rocks detached on top of the gneisses in shape of klippen structures. Chemical studies revealed that the biotite gneisses are derived from sedimentary origin, while the amphibolites are derived from igneous origin (Miyashiro, 1973; Winkler, 1976, Khaffagy and Mahouyz, 1984; Jarrar, 1985). The gneisses are para-gneisses of continental island arc and active continental margin sediments defned by Bahatia, (1983). Their grade of metamorphism is mostly within the upper greenschist and lower amphibolte facies.

The dismembered ophiolites are made up of serpentinite and highly sheared ultramafic rocks, metagabbros and deformed pillow lavas. This sequence is tectonically interleaved with metavolcanics and both are thrusted over gneisses.

The serpentinite and the highly sheared ultramafic rocks represent the main rock units of Gabal Urn Krush and follow antiform shape. The serpentinites occur in the southern part of Gabal Um Krush, whereas the highly sheared rocks (chlorite talc schist, tremolite talc schist and talc-carbonates) occur in the central and northern parts of Gabal Um Krush. Petrographic study showed that these rocks comprise massive serpentinite, talc carbonate rocks, talc schist and tremolite talc schist. Ore microscopic studies showed that the ultramafic rocks contain high content of opaques (up to 20%) dominated by chromite and magnetite

The ophiolitic metagabbros are encountered in the northwestern part of Gabal Urn Krush as large lenticular bodies and sheets associated with pillow lavas, schistose basic metavolcanics and ultramafic slices. Petrographically, they are composed of altered plagioclase, actinolitic hornblende, pyroxene, few amounts of quartz (< 5%) and iron oxides. The opaque contents varies between 12 — 8% and is dominated by ferri-ilmenite and titanomagnetite in addition to small contents of chalcopyrite and pyrite. The ilmenite is densely altered to sphene and graphic hematite — rutile. They are comparable with the older metagabbros of Takla et al. (1981)

The deformed pillow lavas occur tectonically in the matrix of ultramafics and highly sheared basic metavolcanics at Gabal Urn Krush. Petrographically, they are composed of altered amphiboles, plagioclase, chlorite and minor quartz together with epidote, carbonates, sphene and iron oxides. Geochemical studies of pillow lavas show that they are classified as basalt and basaltic — andesite (Winchester and Floyd, 1977; Jenes, 1976 and Le Maitre, 1989). The tectonic setting diagrams illustrate that they are tholeiitic, High- Fe tholeiite and ocean floor basalts (Irvene and Baragar, 1971; Miyashiro, 1974; Pearce, 1975; Beccaluva, et. al.1979; Pearce and Morry, 1979; Shervais, 1982 and Meschede, 1986)

Arc volcanic assemblages form large exposures in the eastern, central and southwestern parts of the map area; extending from Gabal Shashoba in the east to Wadi Urn Ghalga in the west. These assemblages comprise basic to intermediate metavolcanics, intermediate to acidic metavolcanics and metatuffs.

Basic to intermediate metavolcanics are cropping out in Gabal Shashoba and around Gabal Abu Brush. They range in composition from basaltic —

andesite to andesite but transform commonly into chlorite schist. Chemically they classified into basaltic andesite and andesite (Jensen, 1976; Winchester and Floyd, 1977 and Le Maitre, 1989). They are calc — alkaline basalt basaltic andesites and andesites. They seem to have evolved in an island arc tectonic setting and may possibly represent the first stage of island arc volcanism. North and northwest Gabal Shashoba these rocks are occasionally sheared and rich in iron, sulphides and mineralized quartz veins, which are well exemplified in old gold mines.

Intermediate to acidic metavolcanics are exposed at the southwestern parts of the study area and represented by the mass of Gabal Dheis and area localized in the west of it. Petrographically, they are described as andesite, metadacite — rhyodacite rocks calc — alkaline associated with metatuffs. Geochemical studies revealed that they are classified into andesite, dacite and rhyolite (Jensen, 1976; Winchester and Floyd, 1977 and Le Maitre, 1989). They are clac - alkaline and arc volcanic type (Irvene and Baragar, 1971; Shervais, 1982 and Meschede, 1986).

The metatuffs are mainly associated with the intermediate to acidic metavolcanics, especially in the southern part of Gabal Um Krush. They include mainly meta — andesitic tuffs and meta — acidic tuffs.

The syn - tectonic metagabbros are represented by small exposures east of Gabal Abu Brush, along Wadi Abu Had and south Gabal Ribdab, along Wadi Um Ghalga. They intrude the metavolcanics and are intruded by tonalite, monzogranite of Gabal Ribdab and alkali granite of Gabal Abu Brush. Petrographycally, they consist of hornblende, plagioclase and few amounts of quartz (5 —10%) together with iron oxides, apatite and sphene as accessory minerals. Ore microscopic studies show lower content of opaques

(5 — 8%) than the ophiolitic metagabbros. They are dominated by ilmenite, magnetite, ilmenite — magnetite exsolusion intergrowth, minor chalcopyrite and pyrite. They are also comparable with Egyptian older metagabbros of Takla et. al. (1981).

The syn- tectonic granitoids in the study area are mainly represented mainly by tonalite which crop out at the northern, central and southern parts of Wadi Abu Had and in Southern part of Gabal Um Krush. They intrude the older rocks especially metavolcanics and are intruded by younger granitoids (granodiorites, monzogranites and alkali feldspar granite). Petrographically, the tonalites consists of plagioclase, quartz, biotite and hornblende. Epidote, chlorite and sericite are the secondary minerals, whereas zircon, apatite and iron oxides are the main accessory minerals. Geochemical classification of syn- tectonic granitoids (older granitres) reveal that they are mainly of tonalitic composition (Barker, 1979; Lefort, 1983; Middlemost, 1985, Batchalor and Bowden, 1985 and Le Maitre, 1989). They are volcanic arc, calc alkaline, I- type granite of orogenic granite type and formed in compressional environment, (Irvene and Baragar, 1971; Pearce et. al. 1984 and Maniar and Poccoli, 1989). It is comparable with G1 group of the Egyptian granites (Hussein et. al. 1982).

Less metamorphosed subvolcanics are resemble to these of Dokhan type and exposed in the southwestern part of the study area, as approximately crescent - like shaped body intruded by the granitic pluton (Alkali-feldspar granite) of Gabal Abu Brush. They are unconformably overlain the surrounding metavolcanics. Microscopically, they consist mainly of plagioclose and potash-feldspares as phenocrysts embedded in fine grained groundmass of micro crystalline plagioclase, hornblende, quartz, epidote and iron oxides. Geochemically, they are classified into basaltic - andesite and

andesite (Winchester and Floyd, 1977; Gill, 1981; Middlemost, 1985 and Le Maitre, 1989). They are calc alkaline, immature island arc and active continental margin volcanics (Irven and Baragar, 1971; Jensen, 1976; Pearce and Cann, 1973; Miyashiro, 1974 and Ramsay et. al. 1981).

The late — teconic granitoids (mainly monzogranite with little granodiorite) are represented by large plutonic masses of Gabal Ribdab, Gabal Nasb El Hosan and Gabal Siga. They intrude the older rock units particulary the gneisses, metavolcanics and tonalite. As shown on the discrimination digrams (after Irvene and Baragar, 1971; White and Chapple, 1983; Pearce et. al. 1984), they are calc alkaline in character and pertain to the S- type, volcanic arc granites and post orogenic granites. They are equivalent to S- type (White and Chappell, 1983) and G2 granite (Hussein et. al. 1982).

The post- tectonic granitoids (mainly alkali feldspar granites) are represented by the oval- shaped mass of Gabal Abu Brush. They are intruded metagabbro — diorites, tonaite and less metamorphosed subvolcanics. Microscopically, they consist of potash feldspar, quartz and biotite together with variable contents of K- feldspars. Apatite, sphene and iron oxides are the accessory minerals, whereas kaoline is the main alteration product of the potash feldspars. Chemically they are classified as alkali feldspar granite according (Middlemost, 1985). They are calc alkaline to alkaline and follow the extinesional trend defined by Petro et. al. (1979) and post orogenic granites (Mainiar and Poccoli, 1989). They are A- type granites (white and Chappell, 1983), within plate granite (Pearce et al. 1984) and equivalent to G3 group of the Egyptian granites (Hussein et. al. 1982).

The last magmatic activity in the study area includes dykes and veins. The acidic dykes are the main dykes and cut the monzogranite of Gabal

Ribdab and southern of Gabal Urn Krush along NE — SW and E — W trends. The basic dykes cut mainly the metavolcanics and alkali granite of Gabal Abu Brush, with general trend E — W. The quartz veins in the study area are mainly represented by the gold bearing quartz veins and cut the altered metavolcanics occupying the old gold mines (Shashoba, Siga 1 and Siga 2 gold mines) and in old working for gold north Gabal Dheis and southwest Gabal Urn Krush with a general trend E — W.

Due to the subduction — related processes in the Eastern Desert, the arc volcanics in the area are tectonically interleaved and, in part, intermingling with the ophioitic sequence and consequently the both are transported and thrust over the gneisses. This tectonic regime brought the oceanic- arc volcanic rocks of low metamorphic grade over the gneisses and induced polyphase of deformations (D1, D_2 and D_3) and two metamorphic episodes (M_1 and M_2) as well as progressive localization of strain partitioning in the outer margin of gneisses and along the contacts of the oceanic and arc volcanic asseblages. The first phase of deformation (D_1) is well developed in the gneisses and rare in the oceanic — arc volcanic rocks. It is represented by F_1 minor, very tight folds trending NW — SE and commonly plunging SE. Occasionally they are developed as transposed folds at the base of the oceanic- arc volcanic rocks nearby the gneisses contact. D_2 is more intensive than D_3 and is mainly represented by F_2 major double plunging anticline. F_2 folds are asymmetric, major to minor, overturned and tight. These folds are trending NNW — SSE and plunging NNW and SSE. D_3 of deformation is less common and developed by F_3 minor, open, symmetric and asymmetric folds. These folds are trending NE — SW to NNE — SSW and plunging NNE to NE and sometimes SSW to SW.

The different structural features revealed a tectonic transport in the area from SSE towards NNW, continuity of this transport was accompanied by strong fluid movement which formed economic mineralized — quartz veins and pyritifereous chlorite schist in highly alterated volcanic zones .