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OPAQUE MINERALOGY OF THE PRECAMBRIAN ROCKS OF WADI GHADIR, EASTERN DESERT, EGYPT

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ABSTRACT

Most of the rock units of the Egyptian Precambrian belt are exposed in Wadi Ghadir area. The present work gives the opaque mineralogy of these rocks (gneisses and migmatites; ophiolitic mélange and intrusive granitoids). The study is based on ore-microscopic investigation as well as some XRD data for separated opaque fractions. The work revealed the great applicability of opaque mineralogy in the classification and petrogenesis of the concerned igneous and metamorphic rocks.

The opaque mineralogy of the gneisses, migmatites and porphyroblastic granitoids is similar to that of the granite mobilizate indicating that this association is cogenetic. These are characterized by predominance of homogeneous titanomagnetite and little ilmenite. The amphibolites, which occur as enclaves in the migmatites, are shown to be of ortho-origin and mainly contain ilmenite. The distribution of the opaques in the ophiolitic mélange (blocks and matrix) have been also given. Distinction between the ophiolitic metagabbro and the intrusive diorites is well exhibited. As to the intrusive granitoids, six types are distinguished: diorite, granodiorte, biotite granite, perthitic leucogranite, albite and graphic granites. The results of their opaque mineralogy support the geologic interpretation.

INTRODUCTION

It is unfortunate that most authors currently describe the opaque minerals, occurring in igneous and metamorphic rocks, as accessory minerals without any detailed investigation. During the late two decades, the significance of the accessory opaque minerals in the petrogenesis of igneous and metamorphic rocks of the Egyptian shield has been emphasized (Takla, 1966; 1971; Basta and Takla, 1968 a, b; Noweir and Takla, 1975; Takla and Noweir, 1977; Takla *et al.*, 1982; on the Egyptian gabbros; Takla *et al.*, 1975; Takla and Noweir, 1980; Basta, 1978; Ghoneim *et al.*, 1984; on ultramafic rocks; Shazly *et al.*, 1977; on the metavolcanics; Basta *et al.*, 1981; on amphibolites).

The previously mentioned studies were concentrated only on the ultramafic and mafic rocks. The opaque mineralogy of gneisses and granitoids has been ignored, not only on local scale but also on international scale. Ishihara (1977) was the pioneer in using the opaque minerals to classify the granitic rocks into magnetite-series and ilmenite-series. In this article, the detailed study of the opaque mineralogy of the different rock units, exposed at Wadi Ghadir area is given. An attempt is made to characterize these rocks, which represent the main rock units in the Precambrian belt of Egypt, according to the type of opaque minerals, their frequency and the prevailing textures and intergrowths. It is believed that such study will help to a great deal in classifying the Egyptian Precambrian rocks and reaching a better understanding for their nature and petrogenesis.

In the present article the following terminology is used : for homogeneous single-phase solid solution, the minerals will be named according to the minor metal as for example ferriilmenite (for ilmenite containing up to 20% Fe_2O_3 in solid solution) and titanomagnetite (for magnetite containing $Fe\ TiO_3$ or $Fe_2\ TiO_4$ or both in solid solution). The microscopic exsolution intergrowths of two or more minerals are described for example as ilmenite - magnetite, rutile-hematite - ilmenite intergrowths..... etc., with the name of the host at the end. For detailed terminology reference is made to Takla (1966) and Basta (1970).

Takla, *et al.* (1987), mapped the area (Fig. 1) and classified the Precambrian rocks into three major groups. The oldest group is represented by metamorphic rocks, above which the ophiolitic mélange was thrusted. Both rock groups are intruded by a variety of granitoids. This model is different from previous tectonic

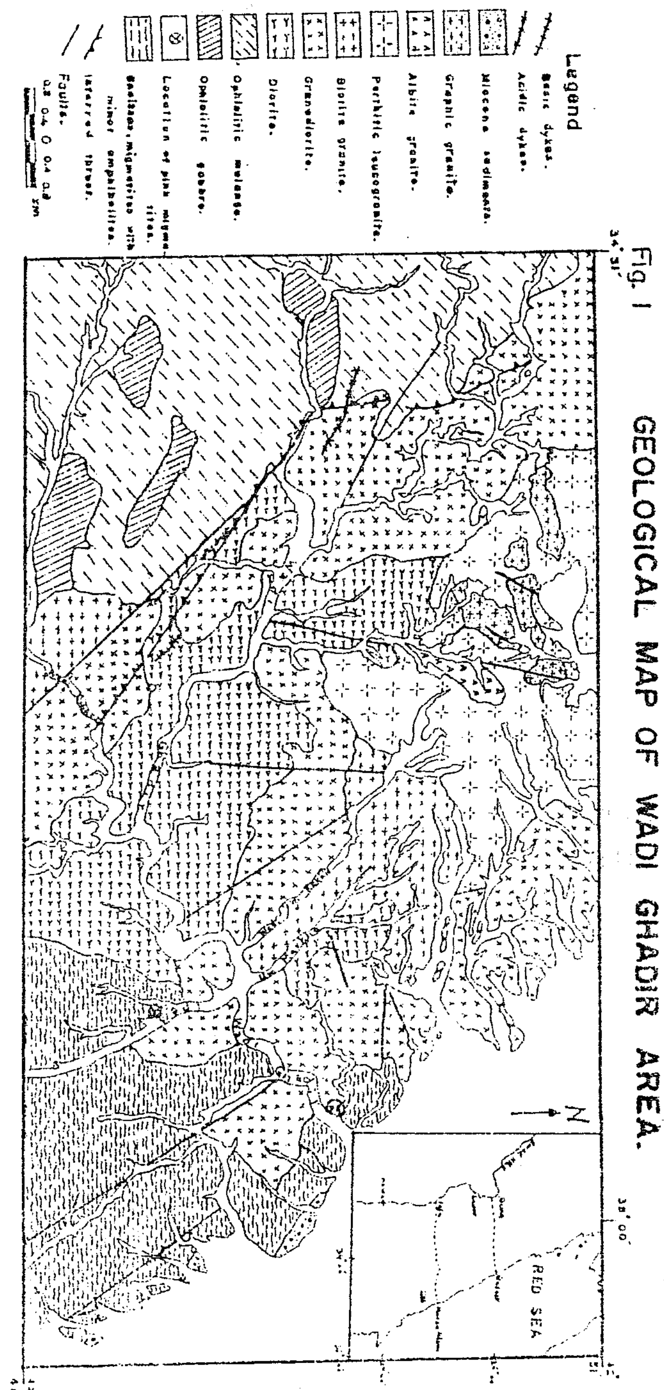


Fig. (1) : CEOLOGICAL MAP OF WADI GHADIR AREA.

models of the area (El-Bayoumi, 1980, and Basta, 1983) particularly as regard the presence of rocks older than the mélange. The same authors (op. cit) suggested that the old metamorphic rocks could represent a window of an old continental crust. The following scheme gives the major aspects of their classification.

A) Old metamorphic rocks

1) Amphibolites.
2) Gneisses, migmatites and porphyroblastic migmatoid granite.
3) Granite mobilizates.

B) Ophiolitic mélange rocks.

1) Ophiolitic fragments (ultramafics, gabbros, sheeted diabases and pillowed basalts).
2) Mélange matrix.

C) Intrusive granitoid rocks.

1) Diorites.
2) Granodiorites.
3) Granites.

OPAQUE MINERALOGY

The work presented here is based essentially on ore-microscopic examinations, as well as X-ray diffraction for some separated fractions. The mineral chemistry of the opaque phases will be the subject of a future work.

A) Old Metamorphic Group.

1) Amphibolites.

These rocks have the hgihest content of opaque minerals among all rocks in the studied area (7% to 10%). Petrographically, the amphibolites are differentiated into coarse-grained and fine-grained varieties.

The coarse-grained amphibolites contain essentially homogeneous ferriilmenite together with a very subordinate sulphides (Pyrrhatits, pentlamdite, chalcopyrite and pyrite). The rock is rich in sphene, which is mostly pseudomorphs after ferriilmenite (Fig. 2) or as idiomorphic crystals of sphenoidal habit and in few cases, grow at the expense of amphiboles, along cleavage planes. The mechanism of transformation of ilmenite to sphene was given by Takla (1971), where calcium and silica released during saussuritization of calcic plagioclase attack ilmenite to form CaTi SiO_5. Some of the ilmenite crystals are also altered to rutile-hematite aggregates, indicating high temperature alteration (Basta, 1960).

The fine-grained amphibolites are different in opaque mineralogy from the coarse-grained amphibolites. They consist essentially of ilmenite and subordinate amount of magnetite. Ilmenite occurs as idiomorphic to subidiomorphic homogenous discrete grains and as exsolved hematite-ilmenite intergrowth. Composite grains and sandwich intergrowths of ilmenite and magnetite are not uncommon. The hematite-ilmenite intergrowth is made of minute exsolved rods of hematite parallel to the (0001) planes of the ilmenite host. In few cases especially the big grains, the hematite rods exhibit a remarkable zonal arrangement (Fig. 3), where the big rods of hematite predominate at the core of the ilmenite host, followed by an intermediate zone, containing smaller-sized hematite rods and finally an outer rim free of exsolutions. Basta and Takla (1968) attributed such zonation to recrystallization, which cause the diffusion and migration of hemaite outside the ilmenite host with simultaneous reduction of hematite to magnetite. Ilmenite-hematite intergrowth is rarely observed in the fine-grained amphibolites (Fig. 4). Basta *et al.* (1981) indicated that this intergrowth is characteristic for ortho-amphibolites. Ilmenite, in most cases, is partly altered to a subgraphic intergrowth of rutile and hematite. Such alteration was attributed to high temperature oxidation of ilmenite, as a result of regional metamorphism (Basta, 1960; and Ramdohr, 1969).

2) *Biotite granodiorite gneiss.*

In this rock, the opaques amount about 6%, that are cocentrated in the mafic-rich laminae. The opaque minerals are represented mainly by magnetite together with much less amount of exsolved ilmenite. Sulphides are very subordinate. Magnetite occurs as idiomorphic crystals of dodecahedral and octahedral habits and is represented by Ti-bearing and Ti-free varieties, as revealed by variation in colour, reflectivity and alteration products. The titanomagnetite is characterized by sphene rim replacement, less martitized and somwhat darker colour (pinkish tint) as compared with Ti-free magnetite. The latter is usually transformed to geothite and "limonite". Ilmenite, ranks second in abundance, occurs as prisms, which are extensively replaced by sphene with the survival of ilmenite relics in the sphene pseudomorphs. These ilmenite relics commonly contain hematite exsolution lamellae, which vary in size from one grain to another. Rarely, the fresh relics are composed of hemo-ilmenite and ilmeno-hematite complex grains.

3) *Migmatitic granite genisses and porphyroblastic migmatoid granites.*

The opaque content in these rocks is up to 4% by volume being commonly confined to the mafic-rich schlierens. The opaques are represented by magnetite and homogeneous ferriilmenite, which exhibits very extensive replacement to sphene and anatase. Magnetite occurs mostly as idiomorphic octahedra and dodecahedra, which is extremely fresh due recrystallization. Magnetite is mainly homogeneous and rarely contain ilmenite exsolution lamellae, forming ilmenite-magnetite trellis intergrowth. The magnetite host is completely martitized.

4) Granite mobilizate.

This rock, which is confined to the mobilized parts of the migmatites, contains the least amount of opaques (1%) among the gneisses and migmatites. The opaque minerals are the same as the biotite granodiorite gneiss and migmatites, indicating that this type of granite is formed at their expense.

B) Ophiolitic mélange.

The ophiolitic mélange forms an extensive stretch in wadi Ghadir area (El-Bayoumi, 1980; Basta, 1983) and consists of ophiolitic and non-ophiolitic fragments of variable dimensions enclosed by metasedimentary matrix of mudstones and greywackés. In the following, the opaque mineralogy of the ophiolitic fragments as well as the metasedimentary matrix is given, with aim of characterizing the ophiolitic rocks and their associating metasediments, according to their opaque mineralogy.

1) Ophiolitic fragments

The ophiolitic fragments are represented by ultramafics, gabbros, sheeted diabases and pillowed basalts.

i) Ultramafics.

These are represented by an association of serpentinites, chlorite-tremolite and talc-actinolite rocks together with minor chromitites. Chromite and magnetite are constant accessory minerals in the ultramafics, with / or without martite and sulphides. Beside the disseminated chromite, the ultramafic masses of the ophiolite suite enclose lensoidal bodies of cumulus chromitite.

Chromite is a primary accessory mineral occurring as large rounded and rarely idiomorphic grains, which are extensively cracked and either encrusted by magnetite

(Fig. 5) or altered to ferrichromite and chromian magnetite during serpentinization (Fig. 6). The alteration of chromite commonly exhibits zonation, which was attributed to metamorphism of the original ultramafic rocks (Ramdohr, 1969). X-ray diffraction data for separated chromite from Gebel Ghadir (Basta, 1978) indicates that the fresh chromite is a Mg-Al-rich variety (chrome-spinel), which is similar to that described from the Alpine-type ultramafites (Stanton, 1972).

Magnetite occurs in an appreciable amount, in the form of fine disseminations and thin veinlets. Sometimes, dense aggregates of minute magnetite disseminations marking the original outlines of the pre-existing olivine and pyroxene crystals. In most cases, magnetite exhibits various degrees of martitization.

Sulphides, occasionally occur as few small crystals of chalcopyrite, pyrite and pyrrhotite, either enclosed by the serpentine minerls or along cracks of chromite. It should be noted that the graphite-bearing varieties contain higher amounts of sulphides than all other ultramafics.

ii) Ophiolitic gabbros.

These rocks occur as massive and mylonitized blocks of variable dimensions in the mélange matrix. Mylonitization is common along thrust faults. In the ophiolitic gabbros, ilmenite is the only opaque constituent, occurring as homogeneous single phase (ferriilmenite) free from any exsolution lamellae. In the mylonitized (flaser) gabbros, the ilmenite crystals are strongly stretched, boundinaged and cracked (Fig. 7), exhibiting undulose extinction, transaltion and glide twinning. These effects are commonly observed in the gabbros exposed near the contact between the mélange and the granitoids. Ilmenite of the ophiolitic gabbros, exhibits various degree of replacement by sphene. The opaque mineralogical characteristics of the ophiolitic gabbros are identical to that of the

Fig. (2)

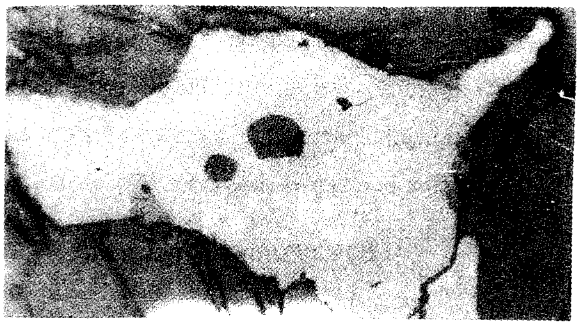
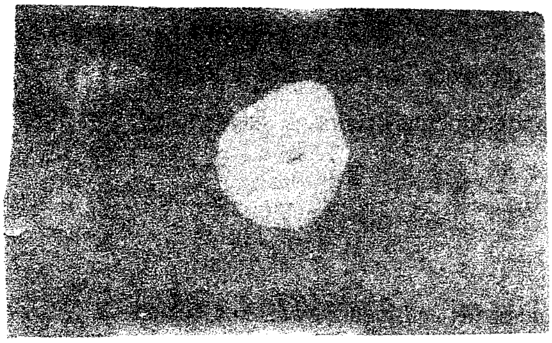


Fig. (3)



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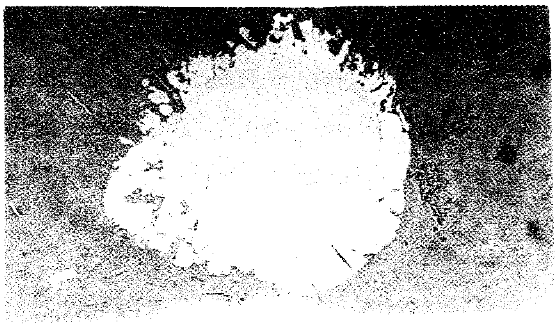

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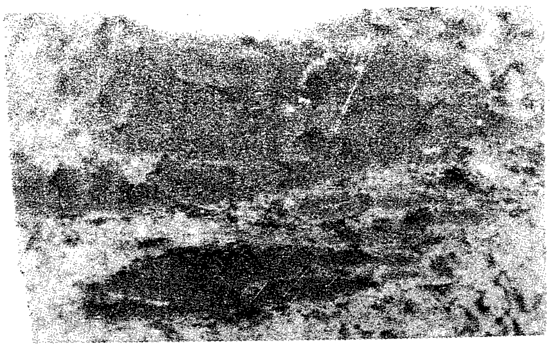

Fig. (6)

Fig. (7)

older metagbbros of Egypt (Takla, 1971).

iii) Sheeted diabases.

The opaque mineralogy of sheeted diabases is much similar to that of the ophiolitic gabbros, being represented by the homogeneous single-phase ferriilmenite, which is partly transformed to sphene. The sheeted diabases are very poor in opaques (less than 1%).

iv) Pillowed basalts.

The pillowed basalts are richer in opaques than the sheeted diabases. The opaque minerals are mainly homogenous ferriilmenite together with occasional minor amounts of titanomagnetite. Ilmenite occurs as rather fresh prisms and skeletal crystals that exhibit slight alteration and replacement into rutile, hematite, anatase and sphene. The bomogeneous titanomagnetite occurs as skeletal and leaf-like crystals (Fig. 8).

2) Metasedimentary matrix

The matrix consists of pebbly metamudstones and metagreywackes, which contain quartzite, chert and metavolcanic pebbles. Generally, the matrix and the sedimentary pebbles are very poor in opaques (less than 1%).

The metamudstones and metagreywackes contain ilmenite as the chief opaque constituent together with minor pyrrhotite. Ilmenite occurs as homogeneous discrete grains, which are intensely to competely altered to sphene, anatase and goethite.

The mylonitized matrix represented by tremolite-biotite banded schists (blastomylonites). In the tremolite schist, hematite is the only opaque constituent, in the form of extremely fine crystals, elongated parallel to the rock foliation, forming chain-like aggregates (Fig. 9). The biotite schist contains "limonite" as elongated crystals oriented parallel to the rock foliation. Large goethite-"ilmonite" grains, formed after pyrite are also observed.

Quartz and chert pebbles, contain small amounts of pyrite, chalcopyrite as well as graphite disseminations.

3) Mélange dykes.

The mélange dykes cut both the ophiolitic suite as well as the matrix. They are usually disrupted and chaiotically incorporated by the ophiolitic mélange and are represented by diabase. The opaque percentage of these dykes is much higher than the sheeted diabases, being formed of titanomagnetite together with much less amount of homogeneous ilmenite and sulphides (pyrrhotite and chalcopyrite). Titanomagnetite shows slight to extensive replacement by sphene, whereas ilmenite is frequently altered to sphene, anatase and rutile.

C) Intrusive Granitoids

1) Diorites

The amount of opaques in these rocks is up to 8% by volume and are mainly of magnetite together with lesser amount of ilmenite. Minute inclusions of pyrrhotite are rarely observed in magnetite.

Titanomagnetite is the most common opaque mineral, occurring as discrete grains or forming composite grains in juxtaposition with ilmenite. Minor ilmenite-magnetite exsolution intergrowths also occur. The titanomagnetite forms idiomorphic to subidiomorphic extremely fresh crystals.

Ilmenite occurs in two forms, a homogeneous and exsolved types. The latter is represented by hematite-ilmenite exsolution intergrowth (Fig. 10). Commonly, ilmenite is partially altered to ilmenite-hematite intergrowths and replaced by sphene.

2) Granodiorites

The opaque content of these rocks ranges from 1% to 2%, consisting of magnetite together with lesser amount of ilmenite. Magnetite occurs as idiomorphic to subidiomorphc crystals either discrete or in juxtaposition with ilmenite. Rarely, magnetite contains exsolved lamellae of ilmenite forming trellis intergrowth (Fig. 11). Magnetite is extremely fresh and commonly rimmed by sphene (Fig. 12)

3) Granites

According to the field, petrographic and geochemical characteristics, the granites were classified into four types (Takla *et al.*, 1987), namely, biotite granite, perthitic leucogranite, albite granite and graphic granite.

i) Biotite granite.

The amount of opaques in the biotite granite is generaly about 1% but may reach 1.5% in some samples. The opaque minerals are represented only by magnetite, or sometimes contain very subordinate amount of ilmenite and few crystals of pyrite.

Magnetite is a Ti-free variety, slightly or extensively martitized as a result of low temperature alteration. Ilmenite, when present, occurs as minute subidiomorphic prisms, that are completely altered to rutile and hemtite or slightly replaced by sphene.

ii) Perthitic leucogranite.

This rock is poor in opaques (0.5 - 0.6%), represented only by ilmenite, which is extensivey altered to a patchy mixture of "limonite" and anatase (Fig. 13).

Fig. (8)

Fig. (9)

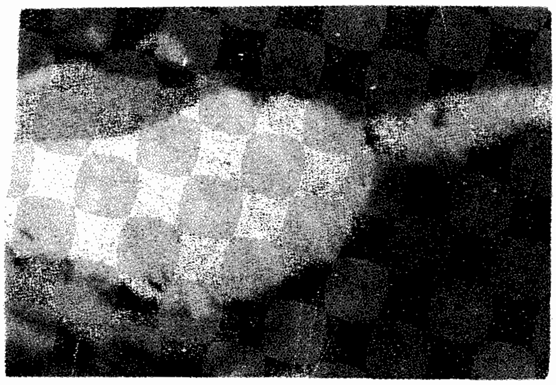

Fig. (10)

Fig. (11)

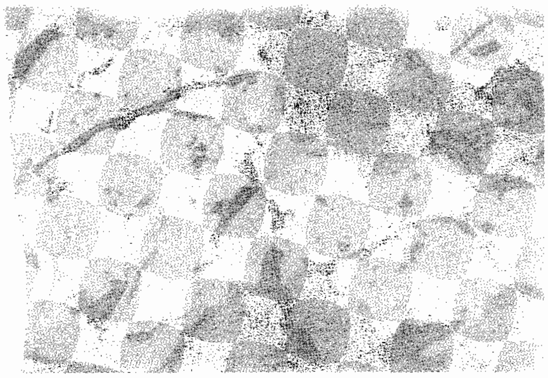

Fig. (12)

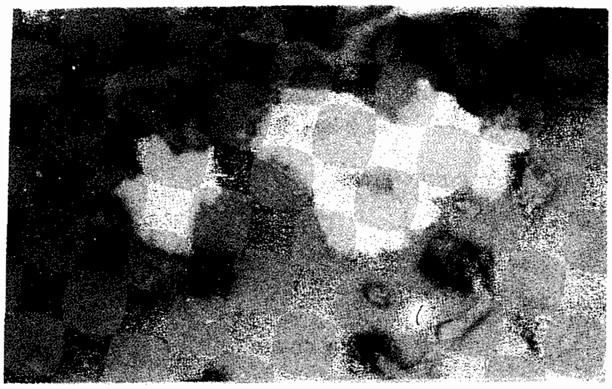

Fig. (13)

Occasional cubes of pyrite may exist.

iii) Albite granite.

This rock is extremely poor in opaques (0.2%), composed only of fresh homogeneous Ti-free magnetite. One or two crystals of ilmenite as well as few minute pyrite crystals are observed.

iv) Graphic granite

The amount of opaque content in this granite is about 0.5%, composed of homogeneous Ti-free magnetite, and ilmenite-magnetite trellis and sandwich intergrowths.

4) Post-granitic dykes

These dykes are represented by andesite and trachyandesites, which contain magnetite and ilmenite in equal amounts. Magnetite occurs as homogeneous discrete grains or intergrown with ilmenite, forming coarse-trellis, banded and composite grains. The magnetite grains exhibit various degrees of martitization along (111) and (100) planes. Ilmenite occurs either as homogeneous grains free of any exsolutions or containing hematite exsolution lamellae, oriented along the (0001) planes of the ilmenite host. The ilmenite grains are frequently altered to sphene and rutile.

Pyrite, chalcopyrite and pyrrhotite occur as small inclusions in magnetite and ilmenite.

CONCLUSIONS

The summary of the opaque minerals and their intergrowths present in gneisses, migmatites and related rocks, ophiolitic mélange, and the intrusive granitoids are given in Table 1. From this table and the foregoing description, the following points are relevant :

1. The coarse - and fine - grained amphibolites were not originated from the same rock type although both are of orth-origin. They are probably the result of regional metamorphism of a very old gabbro and old mafic volcanics of pre-Pan-African age, respectively. This is reflected in the strong difference in their grain size, the granularity of the opaques as well as their opaque mineralogy. In the coarse-grained amphibolites, ilmenite occurs alone, as homogeneous ferriilmenite. The fine grained amphibolites contain both ilmenite and magnetite, the former is represented mainly by ferriilmenite and subordinate hematite-ilmenite intergrowth, while the latter is solely of a homogeneous Ti-free variety.

2. The biotite-granodiorite gneiss as well as the migmatites, the porphyroblastic granite and the granite mobilizate contain both ilmenite and magnetite; and are characterized by similar magnetite / magnetite + ilmenite ratio (0.7 - 0.8). However, there is an important differentce between the biotite granodiorite gneiss on one hand; and the migmatites, prophyroblastic granite and the granite mobilizate, on the other. This is exhibited by the presence of hematite-ilmenite exsolution intergrowth in the granodiorite gneiss. This could be explained by the homogenization of the hematite-ilmenite intergrowth during migmatization and mobilization. The magnetite also supports this conclusion, where in the biotite granodiorite gneiss 20% of magnetite occurs as ilmenite magnetite trellis, sandwich and composite grains, while this amount decreased to 5% in the migmatites. In the porphyroblastic granites and the granite mobilizate, all magnetite (100%) is represented by a homogeneous Ti-free variety.

3. *Chromite and its alteration products (ferrichromite and chromian* magnetite) are characteristic for the serpentinites and their chromitite cumulates only. The degree of alteration of chromite increases with the increase of

Table (1) : Distribution of opaque minerals and their intergrowths in the Precambrian rocks of wadi Ghadir.

Rock Group	Rock Unit	Total opaque%	Mt. / Mt.+Il.	Ilmenite: Ferriilm.	Ilmenite: With hem. exsolutions	Ilmenite: Alteration textures	Sandwich and composite grains	Magnetite: Ti-free	Magnetite: Ti-bearing	Magnetite: With Ilm. exsolutions	Magnetite: Alteration textures	Hematite	Chromite	Sulphides
A	Coarse - grained amphibolites	9	0.0	++++	-	++++	-	-	-	-	-	-	-	+
	Fine-grained amphibolites	7	0.1	++++	++	+++	+	+	-	-	-	+ (2)	-	-
	Biotite granodiorite gneiss	6	0.8	+	++	++	-	+++	+++	-	+++	+ (2)	-	+
	Migmatitic granite gneiss	4	0.7	++	+	++	-	-	++++	+	++	-	-	-
	Porphyroblastic granite	1-3	0.6	++	-	++	-	-	++++	+	++	-	-	-
	Granite mobilizate	1	0.7	++	-	++	-	-	++++	+	++	-	-	-
B	Ultramafics	7		-	-	-	-	++	-	-	-	-	+++	+
	Chromitites	95		-	-	-	-	+	-	-	-	-	++++	-
	Ophiolitic gabbro	2-5	0.0	++++	-	++	-	-	-	-	-	-	-	-
	Sheeted diabase	<1	0.0	++	-	+	-	-	-	-	-	-	-	-
	Pillowed basalts	1.5	0.1	+++	-	++	-	-	-	-	-	-	-	-
	Mudstones, greywackes and	<1	0.0	++	-	+	-	-	-	-	-	-	-	+
	biotite schist			-	-	-	-	-	-	-	-	++	-	-
	Tremolite schist	<1	-	-	-	-	-	-	-	-	-	-	-	++
	Quartzite and chert (1)	<1	-	++	-	+	-	-	+++	-	+	-	-	-
	Melange dykes	4	0.7											+
C	Diorites	7	0.5	-	++++	+++	-	+	+++	-	+++	-	-	+
	Granodiorites	1-2	0.7	-	+++	++	+	-	+++	-	++	-	-	-
	Biotite granite	1	1.0	-	-	-	-	+++	-	-	-	-	-	-
	Perthitic leucogranite	0.5	0.0	++	-	-	-	-	-	-	-	-	-	-
	Albite granite	0.2	1.0	-	-	-	-	++	-	-	-	-	-	+
	Graphic granite	0.5	1.0	-	-	-	-	++	-	+	+	-	-	-
Postgranite Dykes	Andesites and trachyandesites	2	0.5	++	++	++	+	++	-	++	++	-	-	+

(1) With graphite disseninations

(2) Hematite with ilmenite exsolutions

++++ Predomninant +++ Common ++ Fairy common + Rare - Not recorded

A = Old Metamorphic Rocks B = Ophiolitic Mélange Rocks C = Intrusive Granitoids serpentinization. Chromite grains of the cumulates are fresh or slightly altered. This is probably due to the low content of silicates of the chromite cumulates, which are considered as the source of iron responsible or alteration.

4. The ophiolitic gabbros have great variation in their opaque contents (2 - 10%), being formed of homogenous ferriilmenite, exhibiting various degrees of replacement by sphene. This points out that the ophiolitic gabbros are identical to the older gabbros of Egypt (Takla, 1971; Basta and Takla, 1974; Takla and Noweir, 1978 and Basta, 1978). The younger intrusive gabbros of Egypt show a completely different opaque mineralogy (Takla *et al.*, 1982). These results enable the descrimination of the ophiolitic gabbros from the post-Hammamat intrusive gabbros.

5. The opaque mineralogy of the sheeted diabase is much similar to that of the ophiolitic gabbros, this may point out to a comagmatic source.

6. The pillowed basalts contain homogenous ferriilmenite as the chief opaque mineral together with minor amounts of titanomognetite. The opaques occur as small prisms and skeletal crystals due to rapid cooling (quenching) as a result of submarine eruption.

7. The mudstones and grywackes are generally very poor in opaques (< 1%), reprsented by ilmenite together with minor amount of pyrrhotite. Quartzites and chert bands and fragments are characterized by sulphides (pyrite, chalcopyrite) and graphite disseminations. The mylonitized metasediments (tremolite and biotite schist bands) show remarkable differences in opaque mineralogy. The former contains hematite while the latter contains ilmenite.

8. The mélange dykes (diabases) are characterized by homogenous titanomagnetite together with much less amounts of ilmenite and sulphides, which are strikingly different from the sheeted diabses.

9. The intrusive diorites are distinctly different from the ophiolitic gabbros. They are characterized by magnetite, and ilmenite. The latter, is usually containing exsolved hematite, whereas, the former is represented by titanomagnetites and Ti-free varieties in equal amounts, together with minor amounts (5%) of magnetite, containing exsolved ilmenite.

10. The granodiorites have much similar opaques as the diorites (magnetite and ilmenite) but the amount of opaques are much less (2%). This supports that the diorites and granodiorites belong to one granitic phase (G1 granites of Hussein *et al.*, 1982) and not affiliated to the metagabbros. In many previous works, most of the diorites are grouped with the metagabbros as the metagabbro-diorite complex, however, the results of this work affiliate the diorite with the G1 granitoids which are of intrusive nature, having no relation to the ophiolitic gabbros.

11. The biotite granite contains much less opaques than the granodiorites, which are represented by a Ti-free magnetite. Ilmenite, when present, has a homogenous nature containing no exsolutions. These characteristics are strongly contrasting which these of the granodiorites.

12. The perthitic leucogranite has a very specific nature containing only ilmenite. This character, as well as field and petrographic data support its separation into specific granite phase which is younger than the biotite granite.

13. The albite and graphic granites show distinct differences in their opaque characteristics, although both are containing only magnetite. Magnetite in the ablite granite is a homogenous Ti-free variety, while in the graphic granites, both Ti-free magnetite and ilmenite-magnetite trellis intergrowth occur in an almost equal amount. Ishihara (1977) classified granites, according to the presence or absence of magnetite as magnetite-series and ilmenite-series, respectively. Takahashi *et al.* (1980) disignated the magnetite-series and ilmenite-series granites as I-type and

S-type granitoids, respectively. According to this view, most of the granitic rocks (granite mobilizates, granodiorites, biotite granites; and albite and graphic granites) of the Wadi Ghadir area, are I-type granites. The only exception is the perthitic leucogranite which is S-type. Hussein *et al.* (1982) considered G1 granites as I-type while G2 granites as S-type. The present detailed study revealed that the simple application of Ishihara (1977) and Takahashi *et al.* (1980) criteria would lead to unrealsitic conclusions, e.g., the granite mobilizate which formed at the expense of the granodiorite gneiss is I-type granite of essentially mantle origin ! . Also, the biotite granite and perthitic leucogranite, which are considered here as belonging to G2 granites, one of them (the biotite granite) is I-type, whereas, the other (perthitic leucogranite) is S-type !. It is surprising that the application of the criteria of Chappel and White (1974) by Hussein *et al.* (1982) on the Egyptian granitoids revealed that the G1 granites is of I-type, while the G2 granite is of S-type. Hussein *et al.* (op. cit.) did not use the opaque mineralogy in their interpretation. Adding the data of opaque mineralogy of the present work and direct application of Takahishi *et al.* (1980) view, led to a different conclusion. It is suggested here to use field, petrographic, opaque mineralogical and geochemical data together, in order to reach a better understanding of the nature and setting of granitoids.

14. Post granitic dykes (andesite and trachyandesite) are characterized by the presence of magnetite (homogeneous or intergrown with ilmenite) and ilmenite (hematite-ilmenite exsolution intergrowth) in equal amounts. Sulphides occur as inclusions in the oxide minerals.

Finally, it is concluded that the opaque minerals and their intergrowths could be used to characterize and to differentiate between the different rock units of the Egyptian Precambrian belt.

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CAPTIONS TO FIGURES

Fig. 1. Geological map of W. Ghadir area (after Takla *et al.,* 1987).

Fig. 2. Feriilmenite relics in sphene, coarse-grained amphibolite. R.L., X. 220.

Fig. 3. Zoned hemo-ilmenite in juxtaposition with martitized magnetite; Fine-grained amphibolite. R.L., X. 440.

Fig. 4. Small discrete grain of ilmeno-hematite in fine - grained amphibolite. R.L., X. 1100.

Fig. 5. Chromite grain in partly serpentinized wherlite, encrusted by magnetite. R.L., X. 440.

Fig. 6. Chromite grain in serpentinite extensively embayed by the surrounding silicates. The fresh chromite relics (grey) surrounded by outer rim of ferrichromite (light grey). R.L., X. 285.

Fig. 7. Cataclased ferriilmenite prism, replaced by sphene along peripheries and cracks; ophiolitic gabbro. R.L., X. 110.

Fig. 8. Pillowed basalt, showing leaf-like titanomagnetite, completely altered to "leucoxene". R.L., Oil immersion X 385.

Fig. 9. Chain - like aggregates of hematite, oriented parallel to the rock foliation of the tremolite schist. R.L., Oil immersion, X. 285.

Fig. 10. Hemo-ilmenite exsolution intergrowth in diorite. R.L., X. 440.

Fig. 11. Ilmenite-magnetite trellis intergrowth in granodiorite. R.L., X. 220.

Fig. 12. Homogeneous titanomagnetite partly replaced by sphene along grain peripheries, Granodiorite. R.L., X. 440.

Fig. 13. Anhedral ilmenite grains, completely altered to subgraphic intergrowths of "limonite" and anatase; Perthitic leucogranite. R.L., X. 440.

المعادن المعتمه فى صخور البريكامبرى بمنطقة وادى غدير بالصحراء الشرقية المصرية

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يتضمن البحث دراسة المعادن المعتمه وانسجتها وتوزيعها فى مجموعة من صخور البريكاميرى بمنطقة وادى غدير والتى سبق أن قسمها المؤلفين إلى :

(أ) صخور متحولة قديمة (نايس ، مجماتيت ، امفيبوليت)

(ب) صخور الميلانج (الصخور فوق المافية ، الجابرو الاوفيوليتى ، البازلت الوسادى والرسوبيات المتحولة الحاوية لها)

(جـ) الصخور النارية المتداخلة (ديوريت ، جرانوديوريت ، جرانيت بيوتيتى ، جرانيت برثيتى ، جرانيت البيثى ، جرانيت مخطط) .

ولقد أوضحت الدراسة اهمية استخدام المعادن المعتمة فى دراسة الصخور النارية والمتحولة وبالذات عندما تتشابه نوعياتها حيث تبين مايلى :

١ – بالرغم من أن صخور الامفيبوليت من أصل نارى الا أن هناك نوعين يختلفان فى محتوى المعادن المعتمة أحدهما من أصل جابرو والاخر من أصل بركانى قاعدى .

٢ – تتميز صخور النايس والمجماتيت بانواعه المختلفة بتواجد الالمنيت والماجنتيت وتتشابه فى نسبة الماجنتيت / الماجنتيت الالمنيت (٧ر٠ – ٨ر٠) غير أنها تختلف فى الانسجة وبالتالى يمكن تمييزها عن بعضها .

٣ – تحتوى الصخور فوق المافية على الكروميت والذى يظهر تحولا إلى كروميت حديدى وماجنيتيت كرومى اضافة إلى نسبة من الماجنتيت .

٤ – تتماثل صخور الجابرو الاوفيوليتى والدياباز فى المعادن المعتمه نوعا وكما

وانسجة مما يوحى انهامشتقة من صهير واحد حيث يتميزا بوجود الالمنيت الحديدى المتجانس .

٥ – يحتوى البازلت الوسادى على الالمنيت الحديدى والماجنتيت التيتانى .

٦ – تتميزز والبيروهوتيت (الجرايواك ، الحجر الطينى) أو البيريت والكالكوبيريت وبعض الجرافيت (الكوارتزيت ، التشرت) .

٧ – تحتوى صخور الديوريت على الماجنتيت وقليل من الالمنيت وبذل يمكن تمييزها بسهولة من صخور الجابرو الاوفيوليتى اما الجرانوديوريت فهو مماثل للديوريت .

٨ – بالنسبة للجرانيتات الحديثة فمنها مايحتوى على الالمنيت فقط (الجرانيت البرثيتى) أو الماجنتيت (الجرانيت البيوتيتى والجرانيت الالبيتى) أو الماجنتيت المتجانس مع أنسجة الماجنتيت والالمنيت (الجرانيت المخطط) .