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PETROCHEMICAL DISCRIMINATION OF THE GABBROS IN WADI UM NAR AREA, EASTERN DESERT, EGYPT.

BY

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ABSTRACT

Gabbros in Um Nar area are composed of two masses of different nature and age. The older is a mass of metagabbro which forms a central part of the metamorphic belt covering the terrain of Um Nar area, while the younger mass is olivine gabbro intruding the older metagabbro and occupies a peripheral or marginal part.

Both the older and younger gabbros have a calc-alkaline affinity. With application of the chemical parameters on the investigated gabbroid rocks, it is demonstrated that the metamorphosed gabbros are generated in ocean floor setting, while the young olivine gabbros are post-tectonic and emplaced in island arc medium.

INTRODUCTION

The gabbroic rocks of wadi Um Nar area are located north-west of wadi Um Nar after which the pluton was named. It is crossed by lat. 25^0 16\` N and long. $24^0$ 13\` E.

A few members of the Geological Survey of Egypt visited wadi Um Nar area for field investigation. Akaad and El-Ramly

(1963) gave a generalized geological picture for wadi Um Nar area.

El-Shazly (1964) in a classification of the Basement Complex in the Eastern Desert considered the metagabbro-diorite complex disregarding the fresh gabbros as synorogenic plutonites. On the other hand, Sabet (1961) and El-Ramly (1972) named the fresh gabbros in the Eastern Desert collectively "Younger Gabbros" considering them younger than the Hammamat series and younger than the syntectonic grey granitoids.

Basta and Takla (1974) classified the gabbros of Egypt into synorogenic older gabbroic rocks (which are regionally metamorphosed) and postorogenic younger gabbros (non metamorphosed). Regarding the petrochemical aspects of the gabbroic rocks in Egypt, Takla et al (1981) concluded that both the older and younger gabbros are generally of calc-alkaline composition.

Fasfous and Salem (1987) dealing with the petrography of wadi Um Nar rocks reported that the older gabbros consist of plagioclase (An_{36-40}) and amphibole together with minor amounts of pyroxene, chlorite, actinolite and apatite. Opaque minerals comprise ilmenite, magnetite and traces of sulphides. The younger gabbros, on the other hand, are composed of plagioclase (An_{45-60}), clinopyroxene and variable proportions of amphibole and olivine. Sulphide minerals with traces of magnetite and ilmenite are the main accessory minerals.

No petrochemical work has been done, as yet, on the Um Nar gabbroic rocks. The purpose of the present work is to investigate the geochemical and petrochemical affinities of these rocks, in order to throw light on their genetic relationships and elucidate their tectonic setting.

FIELD INVESTIGATION

The Um Nar area is mainly covered by basement rocks which comprise : metasediments, serpentinites, metagabbros and gabbroic rocks. These assemblages posses different field occurrences, field relations, as well as, rock associations.

The distribution of the different gabbro types in particular is shown on the simplified geological map of Um Nar area (Fig. 1). The Um Nar gabbroic occurrence generally comprises a group of scattered hilly masses and bodies of metagabbros previously called epidiorites. The term metagabbro is used here to designate a gabbroic rock in which both pyroxene and calcic plagioclase are partly to highly altered, the former into amphibole and the latter into more acidic plagioclase.

The contact between the olivine gabbros and the metagabbros is sharp but highly irregular and a hybrid zone of intermediate alteration of variable width is rarely observed. Actually, the gabbroic mass of Um Nar is formed of two main distinct rock types, presumably different in age and geologic history. These are the older metamorphosed gabbros and the younger olivine gabbros marginally emplaced in the former.

The metagabbroid rocks are generally hard, coarse crystalline, massive and lack any apparent foliation. Variation in crystal size as well as in relative abundance of the mafic to the felsic constituents are appreciable, even within short distances. They are usually weathered into big rounded low lying blocks with dark brown coloured surface.

The younger fresh olivine gabbros are rather marginal masses in the metagabbro intrusions and occur in the area as rounded stock. These unmetamorphosed gabbroic rocks do not, as a rule, show pronounced primary or secondary structures, except for being crossed by minor faults or dislocations which hardly developed pronounced shearing foliation.

Evidently, thorough field inspection of the gabbros in Um Nar area does not show features of ophiolitic affinity. Generally, ophiolitic assemblages in the Eastern Desert of Egypt are dismembered and are hardly to identify in some localities.

PETROGRAPHY AND ORE MICROSCOPY

Several thin-sections representing both younger and

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older gabbroids rocks were prepared and examined under the polarizing and reflected light microscope. This is briefly summarized below.

Younger Gabbros

The younger gabbroid rocks from wadi Um Nar area are found to consist mainly of the following minerals:-

* Fresh plagioclase feldspars (An_{52}) with coarse euhedral to subhedral prismatic crystals and showing albite-carlsbad twins. The plagioclase are about 57% of the bulk rock composition. Plagioclase are primary cumulate recorded as crystals dissecting with the mafic crystals (Fig. 2).
* Pyroxenes are dominantly represented by fresh augite with minor diopside (about 11% of the bulk mineral constituents). The augite is of the diallage type usually surrounded by reaction rim of brownish amphibole. Ophitic and subophitic texture is sometimes observed (Figs. 2&3).
* Olivine is represented by colourless rounded to subrounded coarse crystals which constitute about 27% of the total constituents. The crystals exhibit slight alteration to secondary magnetite along the irregular fractures and sometimes enveloped by kelyphitic rims.
* Primary brown hornblende crystals (reaching ~ 2% of the bulk constituent) are recorded as anhedral shape filling the

interstitial spaces of the mineral constituents that is probably generated at the final stages when water becomes high enough for its crystallization (Fig. 4).

* Opaque minerals are represented by pyrrhotite and minor chalcopyrite and pyrite (about 3% of the bulk mineral constituents) Minute crystals of chromite (Fig. 5), homogeneous magnetite (Fig. 6) and homogeneous ilmenite are recorded. Under high magnification X300, chalcopyrite-pyrrhotite exsolution intergrowth is observed.

<u>Metamorphosed Gabbros</u>

The metamorphosed gabbros of Um Nar area show the following characteristics:-

* Plagioclase feldspar (An_{44}) is oftenly clouded and altered to epidote, sericite and kaolinite to the degree that it sometimes loses its identity. The alteration is so extensive that rare crystal remained uneffected and the twin lamellae were in part obliterated. Plagioclase show cataclastic features such as bending, wedging lamellae, wavy extinction and dislocation. Plagioclase constitutes about 47% of the bulk mineral composition.
* Amphiboles are represented by hornblende and actinolite and constitute about 42% of the bulk mineral constituents. The hornblende crystals enclose occasionally small plagioclase crystals forming blasto-ophitic texture. Fibrolamena of

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chlorite are in intimate association with hornblende (Fig. 7). The actinolite crystals are colourless but sometimes with pale green colour. They are highly associated with pyroxene crystals indicating that they are pseudomorphous after augite.

* The augite crystals are highly deformed and occupy the interstices between the plagioclase or are mostly enclosed within hornblende, with amount reaching 3% of the bulk mineral constituents. It is generally colourless and partially or completely altered to hornblende or actinolite.
* Quartz, apatite and calcite are recorded as accessory minerals constituting about 3% of the bulk mineral composition.
* Homogeneous ilmenite is the essential opaque mineral. Magnetite, martite, goethite, pyrrhotite, chalcopyrite (Fig. 8), pyrite, rutile and sphene (Fig. 9) are recorded as minor opaques. Total opaque is about 5% of the total mineral constituents.

From the microscopic investigation it can be concluding that the metamorphosed gabbros and fresh olivine gabbros of Um [illegible] area, can be considered as ilmemite and sulphide-bearing rocks respectively. These results agree with the conclusion obtained by Takla et al (1981) and Basta and Takla (1974).

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PETROCHEMICAL INVESTIGATION

The petrochemical characteristics of Um Nar gabbroids were investigated through the complete analyses of twelve samples, six samples from each of the older and younger gabbros. Major and trace elements were determined by XRF at the Mining Institute, Leningrad, Russia. The value for FeO was obtained by titration (wet methods). The results are shown in table (1) together with C. I. P. W. norms. Chemical parameters have been used for investigating the magma type and consequently their tectonic setting.

1) Major Elements

The major element contents of the older gabbros are characterized by high average values of SiO_2 and TiO_2 and low MgO when compared with those of the younger gabbros. Accordingly, the younger gabbros seem to be more mafic than older gabbros. Therefore, it is difficult to assume that the younger gabbros were differentiated from the metamorphosed gabbros or the young gabbros were generated from the same magma as the metagabbros, as assumed by Abdel Maksoud et al (1988).

Assuming that these chemical parameters are original, values of the mafic (M. I.) and felsic (F. I.) indices for the studied rocks have been calculated (table 1) and their relationships are graphically illustrated in Fig. 10 (Drever and Johnstone, 1966). Both types of gabbro have a basic character. In the present work, the felsic-mafic ratio of the older gabbro ranges from 1.47 to 2.14, while that of the younger gabbro ranges from 1.45 to 2.07 which pertain to gabbroic rocks according to Segerstrom and Young (1976).

Another evidence that might support difference in magmatic source of the metagabbro and fresh gabbroic rocks in wadi Um Nar area is the calculated average of differentiation index. The investigated gabbros have values 23.44 and 21.37 for older and younger gabbro respectively, denoting that younger gabbros are less differentiated than older gabbros. Moreover, the calculated CIPW normative values indicate that normative leucite is absent in both gabbros pointing to the non-alkaline character of them. Notice also the low value of normative orthoclase.

Furthermore, normative compositions given in Table 1 for the fresh olivine gabbros and the metagabbros show that the fresh olivine gabbros have lower contents of the Ap, IL and Qz normative minerals than the metamorphosed gabbros. In addition, the anorthite contents of plagioclase (Table 1) were calculated according to Caracas and Lexington (1974). The average An content in normative plagioclase is 65.75 for the older gabbro and 66.85 for the young gabbro, indicating that the metamorphosed gabbros are more salic than younger gabbros.

The normative Or, Ab and An proportions of the studied gabbroic rocks (Table 1) have been plotted (Fig. 11) on the ternary diagram after Hietanen (1963). This figure shows that both the older and younger gabbros are plotted in the mafic gabbros with the exception of one sample (No. 7) from the metagabbro which is plotted in gabbroic field.

The studied gabbroic rocks exhibit a clear variation in the oxidation ratio (Table 1). The oxidation ratio of the older gabbro ranges from 9.08 to 24.36 with an average value 16.73 whereas for the young gabbro it ranges from 21.02 to 32.86 with an average 27.20. A significant difference which is attributed to the higher Fe_2O_3 content of the younger gabbros, most probable due to the nature of the rock constituents especially the opaques.

It has been reported that availability of sufficient water content has an important effect in the crystallization sequence of basaltic magmas (Mathison, 1975). On the other hand, the presence of highly basic plagioclase indicates that the melts contained $\geq$ 2-3 wt.% H_2O (Smith et al 1983).

Thus it might be concluded that, the high oxidation ratio of the younger gabbro, might be attributed to a high water content at the inception of crystallization of magma (presence of primary hornblende) where the water would serve

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as a reservoir for oxygen, depress the temperature of crystallization and lastly, make the magma less viscous and thus increase the rate of crystal growth of the fresh olivine gabbro as deduced from the petrographic study.

The alteration processes recorded in Um Nar gabbros are not related to hydrated granitic magma. This remark is deduced from the scarcity of hybrid rocks and the absence of any of granitic materials within or nearby the gabbros. Similar results were described by Bishady et al (1983) working on Gebel Atud gabbros.

ii) Trace Elements

Analyses of 12 representative samples were quantitatively analysed for trace element distribution. The results of 14 detected elements (Table 1) are compared with other available data of minor element of Vinogradov (1962).

The trace element distribution in Um Nar gabbro is elucidated as follow:-

a) Both the older and younger gabbros are impoverished in the elements Zn, Ga, Y, Cu, Nb and Mo.
b) The younger gabbro is relatively rich in Co, Ni and Cr whereas, the older gabbro is rich in Ti, V, Ba, Pb and Zr elements.

The increase of Ni, Cr and Co in the more mafic younger gabbro, could be partly due to the frequency and type of opaque minerals in it. However, the difference in the ratio of Ni/Co in both the older and younger gabbros is large being 2.2 - 6.6 in the former and 6.2 - 11.3 in the latter. This difference could be due to the difference in their ferro-magnesium minerals on one hand, and on the other hand due to the effect of metamorphism that affected the older gabbro and consequently the possible migration and redistribution of the trace elements.

It is known that, the distribution of Zr in igneous rocks clearly increases with fractionation. When we compared the average contents of Zr in both metagabbro (80.48 ppm) and young gabbro (57.03 ppm) we can notice that the metamorphosed gabbro is more fractionated relative to the younger olivine gabbro.

Langmir et al (1977) and Bender et al (1978) assumed that primitive magma which is in equilibrium with mantle peridotite is enriched in Cr> 600 ppm and Ni > 200 ppm. Concerning the gabbroid rocks of Um Nar and their Cr & Ni contents, we could visualize that at later phase of igneous activity, a pipe-like structure of olivine gabbro derived from a mafic magma, was introduced into the metagabbros.

The contents of TiO_2 in the studied gabbros are plotted versus Cr, Ni, V and Co contents in a diagrams (Fig. 12) after

Takla et al (1981). From the diagrams it is evident that the older gabbros plot in the same field of Takla et al (op.cit.), whereas the young gabbros mostly plot at higher points more rich in Co and Ni with TiO_2 less than 1%. These relationships according to Takla et al (1981) are significant features for young gabbroid rocks in Eastern Desert of Egypt.

STATISTICAL CORRELATION COEFFICIENTS

The correlation coefficients between the major and minor elements for both older and younger gabbros of wadi Um Nar area were calculated by the IBM compatible apparatus and using the Statistix Ver. 3.1 programe at the Central Data processing Department, National Research Centre, Cairo.

A statistical test was carried out for K_2O and P_2O_5 in the young gabbros. This ascertained the highly positive relationship between both variants (r= 1.00). As mentioned before, fresh gabbros are less differentiated, relatively they are less depleted in K_2O and P_2O_5 and thus posses the stronger coherent relationship between both elements, otherwise will be removed as feldspars or mica and apatite.

Provisionally, the metamorphosed gabbros demonstrated ordinary high positive correlation coefficients* between FeO and TiO_2 (r=0.97), Mg (r=0.79), Mn (r=0.99) and Ni (r=0.86), whereas in the young gabbros SiO_2 showed ordinary positive correlation with TiO_2 (r=0.74), FeO (r=0.87), K_2O (r=0.71) and Ga (r=0.69). Furthermore, for the metamorphosed gabbros the following relations are recorded :-

* SiO_2 shows strong positive correlation with LOI, indicating the dominant minerals rich in OH group e.g. hornblende.
* TiO_2 shows strong positive correlation with FeO, MnO, MgO and K_2O (r=0.97, 0.95, 0.76, 0.70) indicating the presence of ilmenite and micas. The correlation between TiO_2 and Ni (r=0.91) denotes that Ni possibly camouflaged in the accessory minerals e.g. ilmenite and sphene.
* Al_2O_3 shows strong positive correlation with CaO and Na_2O (r=0.87 and 0.89) which reflecting the presence of plagioclase feldspars.
* Fe_2O_3 shows strong positive correlation with Zn (r=0.92) which explains the fact that early magmatic oxide ores are actually weakly zinciferous. Worth of remark, Zn abundance in minerals is a function of two parameters :- a) The Zn concentration of the magma (premetamorphic rock) and b) The ability of crystal structure to incorporate Zn at a given T and P.
* FeO shows strong positive correlation with Mn, MgO, Ni (r=0.99, 0.79, 0.86) which are related to the occurrence of minerals.

* Tables of statistical correlation coefficients are available

from the first author on request. As hornblende and mica.

* The strong positive correlation between CaO and Na_2O (r=0.72) is related to the type of plagioclase feldspars which deviates toward the andesine composition.
* Ti shows strong positive correlation with V, Ga, Y and Zr (r=0.82, 0.94, 0.89, 0.80) indicating that ilmenite is a chief opaque mineral.
* The positive correlations between V and Ga, Ba and Pb on one hand (r=0.72, 0.83, 0.82) and Cu-Y on the other hand (r=0.72) possibly reflect the effect of metamorphism responsible for the redistribution of these elements.

However, in case of the young gabbros, important observations can be summarized in the followings :-

* It worthy to notice that according to Abramovich and Groza 1972, during the sequence of magmatic differentiation, elements power of correlation are as follows :- rK_2O-Na_2O > rK_2O-CaO> rK_2O-MgO. This system of correlation can be noticed in the young gabbros rather than the metamorphosed varieties which are, most probably, affected by the metamorphic processes.
* SiO_2 shows positive correlation with TiO_2, FeO, K_2O, Na_2O, CaO and P_2O_5 (R=0.74, 0.87, 0.71, 0.56, 0.47 and 0.71 respectively) reflecting the silicate mineral constituents.
* TiO_2 shows strong positive correlation with FeO and MnO

(r=0.90 and 0.85) denoting ilmenite occurrence.

* Al_2O_3 shows positive correlation with Y, Na_2O and Ba (r=0.97, 0.33 and 0.54 respectively) referring to the feldspars.
* The positive correlation between FeO and CaO (r=0.79) denotes the nature of pyroxene.
* The positive correlation between MgO, Co and Ni (r=0.78 and 0.44) indicates the presence of olivines. However, the moderate correlation coefficient between MgO and Ni (r=0.44) reflecting, most probably, that the young gabbros generated at a later phase of magmatic crystallization.
* Zn shows positive correlation with Pb (r=0.76), possibly due to weak sulphide mineralization.

MAGMA TYPE

Plotting of the present analyses on the SiO_2 versus Na_2O + K_2O diagram (Fig. 13) of Irvine and Baragar (1971) shows that the rock under consideration plot firmly within the field of sub-alkaline composition (b).

In (Fig. 14), the data presented on a standard AFM diagram where analyses of the gabbroid rocks of Um Nar have a tendency to plot slightly below the boundary defined by Irvine and Baragar (1971) separating tholeiitic composition (above) from calc-alkaline composition (below). The older and younger gabbros appear to have rather similar magma type. The majority

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of the older and younger gabbro samples are localized outside the field of the mafic-ultramafic cumulate ophiolitic rocks after Coleman, (1977).

The ternary diagram Al_2O_3 - CaO - MgO is also used to throw light on the genetic relation and geochemical affinity of the investigated metamorphosed and unmetamorphosed gabbros. The fields (Fig. 15) are separated according to Colemann (1977). The majority of the studied samples plot close to the field of mafic cumulate.

TECTONIC ENVIRONMENT

Several hypotheses have been proposed for interpreting the tectonic evolution of the gabbroic rocks in the Eastern Desert of Egypt. Takla et al (1981) in a comprehensive study on some gabbroic plutons distributed in the Eastern Desert, arrived to the conclusion that the young gabbros are post-tectonic intrusions with low-potassium tholeiites affinity, whereas the metamorphosed gabbros showing no contact effects on the country rocks were generated within plate according to the diagram of Pearce and Cann (1973).

Soliman et al (1985) assumed that the gabbro-tonalite association of wadi El-Rahaba area was generated in a volcanic arc environment with addition of mantle to the crustal materials.

Abu El-Ela (1985) classified the older gabbros of the Eastern Desert into:- a) Ophiolitic metagabbros and b) Metagabbros with calc-alkaline characters related to island arc environment.

Lebda (1988) subdivided the metagabbroic rocks of Eraddia, El-Sid, Wizr, Ghadir and El-Gemal areas Eastern Desert into three categories :- MG1= Gabbros with calc-alkaline affinity, henerated in island arc environment. MG2= Gabbros of ocean floor affinity. MG3= Gabbros merging from island arc to ocean floor.

Generally, accumulation of certain major and trace element and their mutual relationships in magmatic rocks have been widely utilized as a geological guide for elucidating the condition of generation and emplacement of these rocks. But the use of these relationships may sometimes be inconclusive or misleading (Smith and Smith, 1976 and Morrison, 1978) due to the probability of mobilization and redistribution of the elements accompanying weathering, metasomatism and hydrothermal alterations. However, identification of tectonic setting on basis of a group of element such as Ti, Zr, Y and Cr with a less extent Fe, Mg and Ni, gained lately much support for petrogenetic investigation of rocks, because they are relatively immobile (Cann, 1970; Pearce and Cann, 1973; Pearce, 1075).

Miyashiro and Shido (1975) discussed the relation between Ni content and the FeO^* / MgO ratio in the tholeiitic and calc-alkaline rocks of various tectonic setting. From the Figure 16, it is observed that the older and younger gabbros of Um Nar area are partly abyssal tholeiites and partly island arc tholeiites.

For comparison between the gabbros of Um Nar area and others previously studied plutons, the authors plotted the present analyses on the AFM diagram Fig. 17, which clearly demonstrates that the older and young gabbros of Um Nar area have similar trend to that of alpine intrusive complexes of Thayer, (1967).

Plotting the analyses of the metamorphosed gabbros on the K_2O - TiO_2 - P_2O_5 ternary diagram of Pearce et al., (1975,) one can observe the the metagabbros deviate toward the oceanic field (B) (Fig. 18).

By applying the immobile trace elements Ti, Zr and Cr in Figs. 19 & 20, after Pearce (1975) and Pearce and Gale (1977), a better picture of the tectonic setting of the gabbros of Um Nar area has been achieved. These figures show that the metamorphosed gabbros were emplaced at ocean floor setting while the olivine gabbros show intermediate conditions between rocks emplaced at both the island arcs and the ocean floor setting but mostly island arc.

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SUMMARY AND CONCLUDING REMARKS

In the light of field and petrochemical investigations of gabbros of Um Nar area, it can be concluded that the gabbroic rocks are composed of fresh olivine gabbros and metagabbros. The metagabbroic rocks which form an outer zone around the olivine gabbro mass might be looked at, historically and not lithologically as a part of the old metamorphic belt.

Meanwhile, the fresh olivine gabbroic rocks, dominantly, localized as a central mass in the metagabbroic, is considered as a younger stock body emplaced along faults or fracture zones.

According to the geochemical characteristic both the older and young gabbros are of calc-alkaline affinity and plot in the fields of mafic gabbro and gabbroic nature. Furthermore, the metagabbros of Um Nar lie outside the field of cumulate ophiolitic rocks of Colemann (1977).

The presence of primary amphibole and relatively high basic plagioclase feldspars in the olivine gabbros and their degree of oxidation ratio suggest a medium magmatic chamber enriched in water vapour.

The field work, petrography, opaque mineralogy, petrochemical and geochemical investigations add more light on the characteristic features and petrogenesis of the gabbros of wadi Um Nar area. This is summarized in the following:-

* The metamorphosed gabbros show composition different from the composition of Komatiite and Skaergaard liquid trend and is generated at ocean floor environment.
* Petrographic examination of the metagabbros revealed that they are essentially composed of amphiboles (hornblende and actinolite) while pyroxene is scarce and olivine is absent. This is confined to the greenschist facies and to the epidote-amphibolite facies as elaborated by winckler (1967).
* Opaque mineralogy of both young and metamorphosed gabbros of Um Nar area are different. The young gabbro is sulphide-rich while the metamorphosed gabbros are ilmenite-rich.
* The young gabbro of Um Nar area is pertaining to post-orogenic younger gabbros as elaborated by Sabet (1961), El-Ramly (1972) and Takla et al (1981).
* The olivine gabbros can not be correlated with the cumulate mafic rocks of ophiolitic nature but the petrochemical affinity bears similarities with the island arc environment.
* The calculated mafic and felsic indices and the differentiation index favour the idea that both older and young gabbros are generated from two different magmatic sources.
* Advancement of differentiation and magmatic fractionation, most probable, caused crystal aggregation and settling of

either olivine or plagioclase crystals. This condition promotes the generation of olivine-rich rocks in wadi Um Nar area.

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FIGURE CAPTIONS

Fig. 1: Simplified geologic map of the gabbroic rocks of Um Nar area (after Akaad and El-Ramly, 1963), showing location of samples and their numbers.

Fig. 10: Relationship between felsic index (F. I.) and mafic index (M. I.). Dashed line represents the basic-ultrabasic felsic index of Drever and Johnston, 1966. Closed circle=Older gabbro. Open corcle=Younger gabbro.

Fig. 11: Ternary diagram of normative An, Ab, and Or (after Hietanen, 1963), (A) alkali granite; (B) granite; (C) granite trondhjemite; (I) granodiorite; (J) quartz diorite; (K) calci-monzonite; (L) granogabbro; (M) gabbro and (N) mafic gabbro.

Fig. 12: TiO_2 versus Cr, Ni, V and Co discriminant diagrams to distinguish older gabbros (solid line) from younger gabbros (dashed lines). The field boundaries are after Takla et al., 1981.

Fig. 13: Alkali-silica variation diagram for the examined gabbroic rocks. The field boundary is after Irvine and Baragar, 1971.

Fig. 14: AFM diagram showing the variation of the relative proportions of A($Na_2O + K_2O$), F($FeO + 0.9Fe_2O_3$) and M(MgO) for the older and younger gabbros. Ophiolitic

rocks (solid line) is after Coleman, 1977. The field boundary separating tholeiitic above from calc -alkaline composition (dashed and dot line) is after Irvine and Baragar, 1971.

Fig. 15: Ternary diagram of Al_2O_3-CaO-MgO for the investigated fresh olivine gabbros and metamorphosed gabbroic rocks, (after Coleman, 1977).

Fig. 16: Variation of Ni with FeO^* / MgO for the examined rocks (after Miyashiro and Shido, 1975). Composition field of abyssal tholeiites (solid line) and island arc tholeiites (dashed line)

Fig. 17: AFM ternary diagram for the investigated gabbros.

1- Skaergaard trend (Wager and Brown, 1967).
2- Stillwater (Wager and Brown, 1967).
3- Gabal Al-Tirf (Coleman and Irwin, 1974).
4- Alpine intrusive complexes (Thayer, 1967).
5- Egyptian younger gabbros (Takla et al., 1981).
6- Egyptian older gabbros (Takla et al., 1981).

Fig. 18: TiO_2-K_2O-P_2O_5 ternary diagram for the metamorphosed gabbros, after Pearce et al., 1975.

Fig. 19: Binary diagram of Ti/100 Vs Cr for the studied metamorphosed gabbros, after Pearce 1975.

Fig. 20: Binary Ti-Zr diagram for the investigated gabbroic rocks. Field boundaries after Pearce and Gale, 1977.

Table 1: Major element analyses (wt%), elemental ratio, C.I.P.W. norms and trace element analyses (ppm) of the gabbroic rocks of the [illegible] area.

	Older Gabbro							Younger Gabbro							
Sample no.	1	16	17	18	19	21	Average	4	5	6	7	8	20	Average	W.a.g.
SiO_2	46.06	46.70	46.37	47.30	47.06	46.87	47.01	46.92	45.72	46.36	47.41	45.52	46.12	45.70	50.14
TiO_2	0.86	0.06	0.55	0.42	0.20	1.31	0.67	0.77	0.58	0.12	0.09	0.47	0.06	0.46	1.17
Al_2O_3	16.41	19.35	19.80	22.44	22.02	16.44	19.35	16.61	16.76	19.77	18.70	17.40	19.88	19.50	15.48
Fe_2O_3	0.58	1.80	0.91	0.80	1.04	1.10	1.76	2.27	2.00	1.90	1.61	1.74	2.06	1.95	3.01
FeO	5.61	3.99	3.88	4.01	3.28	8.38	5.80	5.07	5.74	4.05	6.08	4.79	4.28	5.50	7.62
MnO	0.11	0.11	0.11	0.09	0.07	0.14	0.10	0.11	0.11	0.09	0.11	0.11	0.10	0.10	0.12
MgO	7.03	10.30	10.74	6.06	6.16	11.60	8.70	5.53	11.44	12.30	8.05	10.76	11.84	10.00	7.59
CaO	9.36	10.52	10.72	11.28	10.65	10.07	10.30	9.85	10.47	9.77	10.71	9.77	9.65	10.04	9.58
Na_2O	2.06	2.09	3.10	3.28	3.27	2.06	2.80	3.00	2.01	1.06	2.15	2.15	2.56	2.50	2.39
K_2O	0.17	0.02	0.02	0.09	0.11	0.27	0.10	0.44	0.03	0.02	0.02	0.02	0.02	0.10	0.93
P_2O_5	0.10	0.05	0.01	0.01	0.01	0.06	0.05	0.51	0.01	0.01	0.01	0.01	0.01	0.10	0.24
L. O. I.	3.06	1.90	3.98	2.76	4.27	3.15	3.56	2.26	1.96	3.46	2.08	6.20	5.72	3.66	0.86
Total	99.69	99.81	98.53	100.26	98.27	100.17	99.60	99.63	99.41	99.82	99.81	100.22	98.07	99.42	99.13
Elemental ratios:															
FeO*/MgO	0.90	0.73	0.80	0.90	0.88	0.81	0.77	1.43	0.66	0.53	0.94	0.46	0.53	0.74	1.28
F. I.	19.30	16.00	16.50	22.40	26.30	16.00	20.70	26.00	16.30	17.30	16.50	18.00	19.00	19.55	26.74
M. I.	47.30	42.10	37.50	47.40	40.50	44.05	43.27	55.80	30.90	36.70	48.80	31.70	34.40	41.05	56.34
F/M	2.14	1.61	1.66	2.06	2.11	1.47	1.85	2.07	1.55	1.57	1.74	1.46	1.54	1.65	1.84
Fe_2O_3.100 / FeO+Fe_2O_3	9.06	28.50	18.91	16.79	24.06	12.34	16.78	27.30	26.00	28.15	21.02	26.65	32.56	27.20	28.32
C.I.P.W. norms															
Ap	0.26	0.18	0.06	0.05	--	0.26		1.07	--	0.37	--	--	--		0.56
Il	1.64	1.00	0.86	0.60	0.40	1.80		1.30	0.80	0.30	1.00	0.60	0.20		2.13
Mt	0.66	1.06	0.90	0.90	1.18	1.26		2.40	2.25	1.06	1.00	1.00	2.25		4.36
Or	1.00	0.1	0.10	0.10	0.65	1.50		2.50	0.10	0.10	0.10	0.10	0.10		5.49
Ab	20.50	26.00	19.00	27.65	27.30	19.00		26.10	21.00	16.00	20.00	18.30	19.65		20.26
An	36.25	42.30	44.85	50.45	48.00	32.75		26.75	40.06	46.50	42.30	30.30	46.20		28.80
Ne	--	--	--	0.90	2.50	--		--	--	--	--	0.72	1.48		--
Di	9.40	7.52	5.76	5.16	5.20	13.06		5.02	6.04	1.90	9.04	8.04	8.44		13.70
Hy	24.00	5.26	7.56	--	--	0.10		18.92	2.06	0.12	17.06	--	--		--
Ol	--	10.21	10.77	15.02	14.11	21.21		0.24	24.00	22.14	5.10	30.36	27.74		22.13
Qz	2.83	--	--	--	--	--		--	--	--	--	--	--		0.71
D. I.	24.93	26.00	19.10	27.96	28.15	20.50		30.60	21.10	16.10	20.10	18.40	19.65		26.48
C. I.	36.42	37.07	35.52	20.70	24.92	46.50		29.21	37.26	34.64	37.82	40.66	33.53		42.66
An	65.10	67.30	70.00	64.40	64.00	63.40		56.60	66.00	71.00	67.60	66.20	60.50		56.53
Trace Elements:															
Ti	10761	7070	10064	6696	3201	3000	7070	5900	8237	7500	5510	1630	3000	5505	
V	197.3	190.4	237.3	153.6	64.80	156	161.55	126.7	166.3	135.1	138.8	59.70	120	124.50	
Cr	333.1	445.9	550.0	812.7	806.4	350	417.50	157.4	253.1	1030	1062.5	605	170.6	719.30	
Co	47.70	64.90	65.10	57.00	41.80	51.70	55.20	42.00	68.00	96.00	63.50	77.40	62.50	70.06	
Ni	293.7	362.1	274	146	210	542	296.15	470.2	356.8	804.4	307.2	665.6	274	544.40	
Cu	80.00	80.00	80.00	80.00	80.00	63.00	77.17	80.00	80.00	80.00	80.00	60.00	60.00	70.17	
Zn	72	141.5	72	72	72	65	85.75	85.2	72	72	72	72	80	77.2	
Ga	14.2	12	12.8	10.6	10.1	9.5	11.53	15.0	8.1	10.2	9.8	8.6	10.5	10.56	
Y	17.3	13.0	24.5	9.6	9.4	0.5	12.52	20.2	10.6	19.0	13	2.5	10	14.03	
Zr	136.5	44.5	147.8	57.6	60.8	26	80.46	47.3	61.8	80.8	52.5	60	40	57.03	
Nb	4.3	5.2	5.3	2.8	4.6	3.1	3.87	6	2.5	3.1	2.7	4.6	4.5	3.8	
[illegible]	--	--	--	--	1.3	--	0.22	--	--	--	--	--	--	--	
Ba	207.2	40	500.4	40	40	40	145.1	264.3	40	256.7	40	40	40	113.5	
Pb	10.7	10	28	4	4	12	12.95	4	4	4	4	4	14	5.67	

W.a.g. = World average gabbro (Le Maitre, 1976)

ID: Older Gabbro

Table 2: Correlation coefficient between major and trace elements of the older gabbros of Um Nar area.

	SIO2	TIO2	AL2O3	FE2O3	FEO	MNO	MGO	CAO	NA2O	K2O	P2O5	LOI
SIO2	1.0000											
TIO2	-0.4257	1.0000										
AL2O3	-0.0143	-0.8582	1.0000									
FE2O3	-0.5395	0.1752	0.0213	1.0000								
FEO	-0.3760	0.9796	-0.8625	0.1943	1.0000							
MNO	-0.3397	0.9553	-0.8756	0.1524	0.9920	1.0000						
MGO	-0.6875	0.7646	-0.6108	0.5020	0.7907	0.8088	1.0000					
CAO	-0.4601	-0.5272	0.8767	0.2563	-0.5275	-0.5521	-0.2120	1.0000				
NA2O	0.0813	-0.7305	0.8909	-0.0585	-0.7957	-0.8549	-0.7650	0.7227	1.0000			
K2O	-0.0067	0.7025	-0.7121	-0.2529	0.5799	0.5256	0.1894	-0.6663	-0.3534	1.0000		
P2O5	0.3388	0.6577	-0.8888	0.0068	0.6722	0.6654	0.2885	-0.9193	-0.6810	0.6659	1.0000	
LOI	0.8260	-0.0532	-0.3072	-0.6623	-0.0983	-0.1007	-0.5537	-0.6772	-0.0216	0.5368	0.5419	1.0000
TI	0.4724	-0.1877	-0.1499	-0.2587	-0.0212	0.0965	0.0534	-0.2835	-0.4685	-0.4535	0.1294	0.0865
V	0.0495	0.3251	-0.5042	-0.2180	0.4564	0.5643	0.5184	-0.3999	-0.7999	-0.1089	0.2621	-0.0895
CR	-0.3718	-0.3154	0.2837	0.2106	-0.3392	-0.2869	0.2687	0.3136	-0.0239	-0.4206	-0.5366	-0.4861
CO	-0.3097	-0.0375	0.2501	-0.0116	0.1008	0.1580	0.2306	0.4921	-0.0688	-0.5913	-0.4401	-0.6061
NI	-0.6090	0.9185	-0.7375	0.4522	0.8622	0.8215	0.8378	-0.3880	-0.6281	0.6271	0.5277	-0.2348
CU	0.5468	-0.8914	0.6172	-0.1047	-0.7967	-0.7311	-0.5590	0.2892	0.3739	-0.8004	-0.4247	0.0435
ZN	-0.2567	0.1986	-0.1634	0.9286	0.2641	0.2462	0.4789	-0.0155	-0.2557	-0.2435	0.2668	-0.4582
GA	0.6550	-0.1710	-0.2803	-0.3026	-0.0362	0.0715	-0.0338	-0.5171	-0.5015	-0.2576	0.3351	0.3459
Y	0.3284	-0.4323	0.1211	-0.2277	-0.3069	-0.1861	-0.0031	-0.0362	-0.2663	-0.6127	-0.2110	-0.0694
ZR	0.4909	-0.3063	-0.0617	-0.6401	-0.2333	-0.1186	-0.1384	-0.2876	-0.3074	-0.2289	-0.0522	0.3074
NB	0.1599	-0.3077	0.0275	-0.4369	-0.3232	-0.2347	-0.0052	-0.1434	-0.1989	-0.1378	-0.2423	0.1240
MO	0.0327	-0.5293	0.5038	-0.0524	-0.6837	-0.7311	-0.4878	0.2795	0.6428	0.0396	-0.4247	0.1691
BA	0.0104	-0.0510	-0.1229	-0.4063	0.0273	0.1431	0.2799	-0.1072	-0.4725	-0.2730	-0.1852	-0.1301
PB	-0.3564	0.2778	-0.3354	0.2478	0.3770	0.4680	0.7596	-0.1191	-0.7164	-0.2892	0.0179	-0.5188

TI	V	CR	CO	NI	CU	ZN	GA	Y	ZR	NB	MO	BA	PB
0000													
9212	1.0000												
1429	0.1640	1.0000											
4412	0.5182	0.0583	1.0000										
.3687	0.1305	-0.0515	-0.1952	1.0000									
5769	0.0517	0.3286	0.1629	-0.8618	1.0000								
0185	-0.0207	0.0784	-0.0454	0.4005	0.0132	1.0000							
9434	0.7216	0.0870	0.1223	-0.3304	0.5570	0.0241	1.0000						
8973	0.6871	0.5311	0.3919	-0.4848	0.7238	-0.0593	0.8271	1.0000					
8062	0.6825	0.3552	0.1997	-0.4608	0.5200	-0.4631	0.8106	0.0715	1.0000				
4511	0.4282	0.7374	-0.0571	-0.2625	0.3828	-0.4128	0.4908	0.7204	0.8329	1.0000			
.5372	-0.7187	0.4182	-0.6238	-0.2704	0.2000	-0.2423	-0.3926	-0.1877	-0.1059	0.3162	1.0000		
7286	0.8343	0.5440	0.4779	-0.1577	0.2741	-0.3321	0.6149	0.8317	0.8679	0.7994	-0.2741	1.0000	
5999	0.8219	0.5822	0.4653	0.3099	0.0502	0.3169	0.4707	0.6443	0.4452	0.4657	-0.4732	0.7582	1.00

ID: Younger Gabbro

Table 3: Correlation coefficient between major and trace elements of the younger gabbros of Um Nar area.

	SIO2	TIO2	AL203	FE203	FEO	MNO	MGO	CAO	NA20	K20	P205	LOI	TI
SIO2	1.0000												
TIO2	0.7477	1.0000											
AL203	0.2190	-0.3899	1.0000										
FE203	0.2170	0.0277	0.5918	1.0000									
FEO	0.8772	0.9020	-0.1414	-0.0261	1.0000								
MNO	0.3418	0.8595	-0.6058	-0.0391	0.6009	1.0000							
MGO	-0.8970	-0.6375	-0.3982	-0.4289	-0.6812	-0.3615	1.0000						
CAO	0.4772	0.6402	-0.2710	-0.3809	0.7993	0.5108	-0.2633	1.0000					
NA20	0.5675	0.4903	0.3371	0.7719	0.3355	0.4154	-0.8089	-0.1430	1.0000				
K20	0.7136	0.5148	0.3086	0.6485	0.4127	0.2928	-0.8424	-0.1810	0.9217	1.0000			
P205	0.7136	0.5148	0.3086	0.6485	0.4127	0.2928	-0.8424	-0.1810	0.9217	1.0000	1.0000		
LOI	-0.8453	-0.6123	-0.2769	-0.2381	-0.8635	-0.2027	0.6472	-0.6717	-0.3092	-0.3816	-0.3816	1.0000	
TI	0.7717	0.4303	0.3944	0.4196	0.6804	-0.0315	-0.5609	0.3707	0.3352	0.4715	0.4715	-0.9244	1.0000
V	0.4459	0.1616	0.5387	0.3124	0.4884	-0.1091	-0.3507	0.5675	0.0955	0.0150	0.0150	-0.8124	0.7359
CR	0.0724	-0.2937	0.0845	-0.5970	0.0359	-0.5950	0.2313	0.1724	-0.6863	-0.4033	-0.4033	-0.1694	0.2119
CO	-0.7329	-0.9059	0.0921	-0.4008	-0.7801	-0.8098	0.7829	-0.4521	-0.7803	-0.7026	-0.7026	0.5935	-0.4483
NI	-0.1935	-0.2686	-0.3149	-0.3490	-0.2748	-0.4003	0.4441	-0.4143	-0.4456	-0.1244	-0.1244	0.2979	-0.0536
CU	0.5619	-0.6205	-0.4531	-0.2674	0.6804	0.2928	0.1748	0.4385	-0.0770	0.2000	0.2000	-0.5427	0.5645
ZN	-0.0346	-0.2178	0.6090	0.6660	-0.3386	-0.0700	-0.3971	-0.5121	0.6749	0.4781	0.4781	0.2357	-0.1960
GA	0.6923	0.3488	0.5326	0.6803	0.3209	0.1037	-0.8683	-0.2316	0.8982	0.9644	0.9644	-0.3788	0.4721
Y	0.4059	-0.2478	0.9718	0.5412	0.0123	-0.5485	-0.5442	-0.2119	0.3987	0.4416	-0.4416	-0.3832	0.4945
ZR	-0.0607	-0.2385	-0.1097	-0.2888	-0.0212	-0.5107	0.4469	0.0016	-0.6103	-0.3385	0.3385	-0.1681	0.3659
NB	0.1238	0.0970	0.1322	0.5217	-0.1911	0.1753	-0.4124	-0.6532	0.7467	0.7543	0.7543	0.3168	-0.1798
MO	M	M	M	M	M	M	M	M	M	M	M	M	M
BA	0.5712	0.0482	0.5436	0.4977	0.1658	-0.3598	-0.5336	-0.3698	0.4758	0.7285	0.7285	-0.3758	0.6294
PB	-0.5619	-0.6205	0.4531	0.2674	-0.6804	-0.2928	0.1748	-0.4385	0.0770	-0.2000	-0.2000	0.5427	-0.5645

An "M" is displayed when a coefficient cannot be computed.

V	CR	CO	NI	CU	ZN	GA	Y	ZR	NB	MO	BA	PB
1.0000												
0.1464	1.0000											
-0.2605	0.5758	1.0000										
-0.5278	0.5622	0.5225	1.0000									
0.0627	0.3881	-0.3152	0.4934	1.0000								
-0.0464	-0.6131	-0.1793	-0.5241	-0.7649	1.0000							
0.1155	-0.3172	-0.5864	-0.1982	0.0339	0.6036	1.0000						
0.5157	0.1669	-0.0039	-0.2377	-0.2840	0.5449	0.6507	1.0000					
0.1053	0.7548	0.4973	0.7646	0.5923	-0.7535	-0.3684	-0.0731	1.0000				
-0.5407	-0.5749	-0.3196	0.0333	-0.2155	0.6891	0.7222	0.1845	-0.5066	1.0000			
M	M	M	M	M	M	M	M	M	M	1.0000		
0.1131	0.2117	-0.1401	0.3512	0.3135	0.1979	0.7750	0.6771	0.2791	0.4541	M	1.0000	
-0.0627	-0.3881	0.3152	-0.4934	-1.0000	0.7649	-0.0339	0.2840	-0.5923	0.2155	M	-0.3135	1.0000

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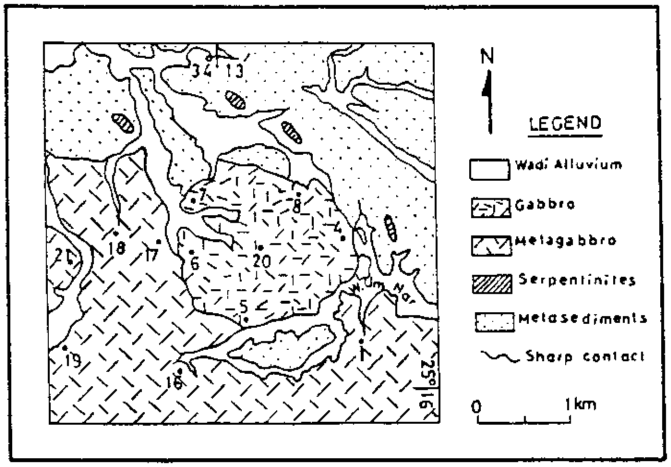

Fig.1

ig.1: Simplified geologic map of the gabbroic rocks of Um Nar area (after Akaad and El-Ramly, 1963), showing location of samples and their numbers.

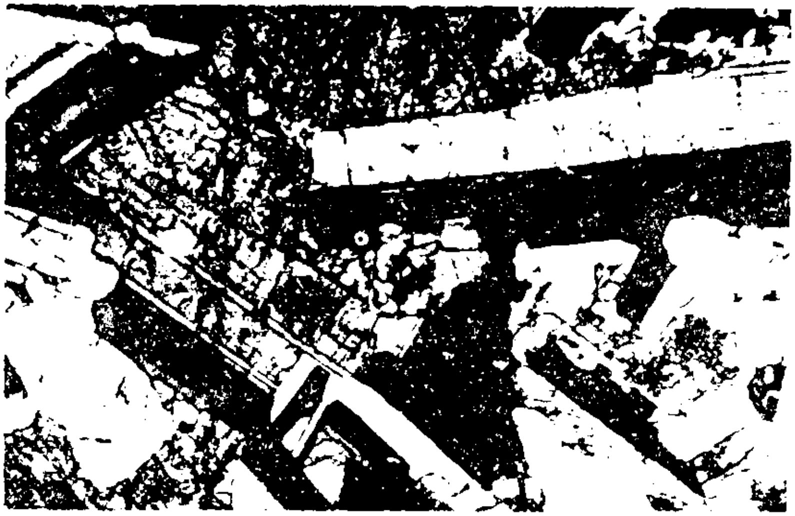

Fig.2: Photomicrograph showing the primary cumulate plagioclase crystals. Minute fractures traversing both the plagioclase and pyroxene. C.N. X6.

Fig.3: Photomicrograph showing diallage with schiller structure Ophitic and subophitic are clearly demonstrated. C.N. X

Fig.4: Photomicrograph showing primary amphibole. Crystals of olivine and plagioclase are included in amphibole. P.L. X 75.

Fig.5: Photomicrograph showing cracked chromite crystal partially altered to magnetite at the border in addition to the fine magnetite lamellae oriented parallel to the (111) planes of chromite. R.L. X230

Fig.6: Photomicrograph showing cracked magnetite intersecting olivine crystal. R.L. X75.

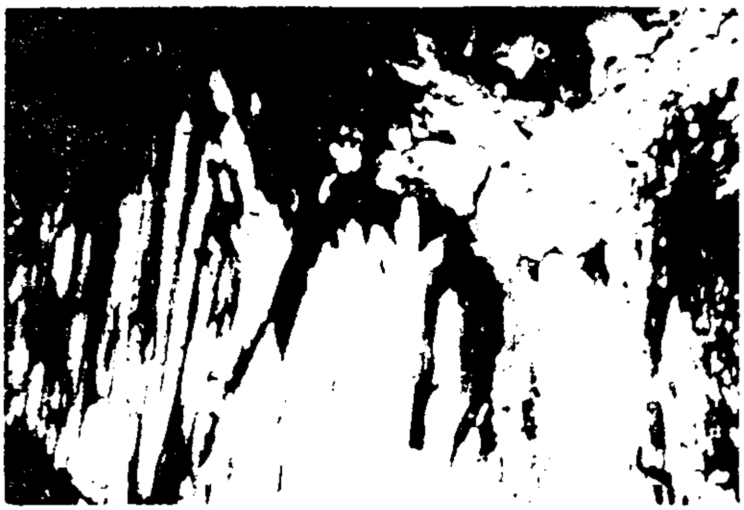

Fig.7: Photomicrograph showing fibrolamenae of chlorite after amphibole. C.N. X40.

Fig.8: Photomicrograph showing minute rods of chalcopyrite parallel to the cleavage planes of silicates. R.L. X230.

Fig.9: Photomicrograph showing ilmenite partially altered to sphene and hematite at the borders and along cracks. R.L. X230.

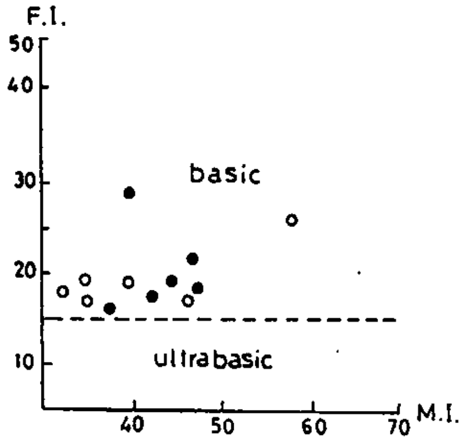

Fig.10: Relationship between felsic index (F.I.) and mafic index (M.I.). Dashed line represents the basic-ultrabasic felsic index of Drever and Johnston, 1966.
Closed circle=Older gabbro.
Open circle=Younger gabbro.

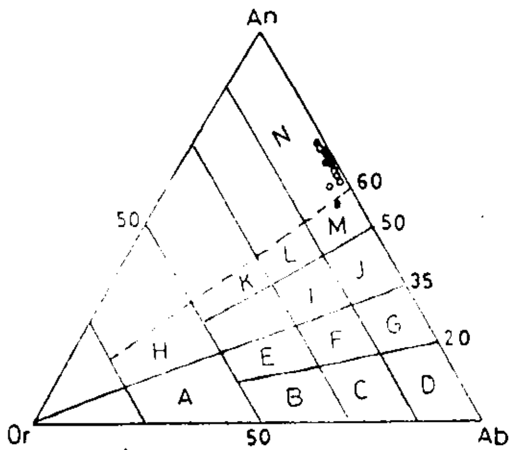

Fig.11: Ternary diagram of normative An, Ab, and Or (after Hietanen, 1963), (A) alkali granite; (B) granite; (C) granite trondhjemite; (I) granodiorite; (J) quartz diorite; (K) calci-monzonite; (L) granogabbro; (M) gabbro and (N) mafic gabbro.

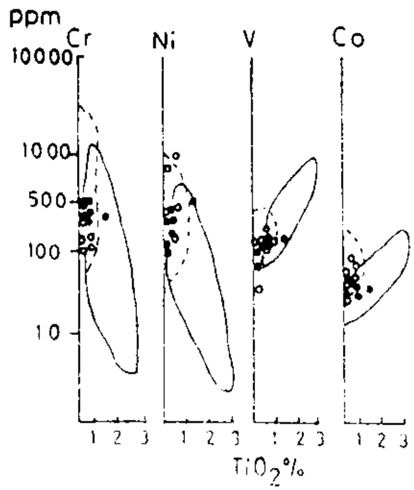

Fig.12: TiO_2 versus Cr, Ni, V and Co discriminant diagrams to distinguish older gabbros (solid line) from younger gabbros (dashed lines). The field boundaries are after Takla et al., 1981.

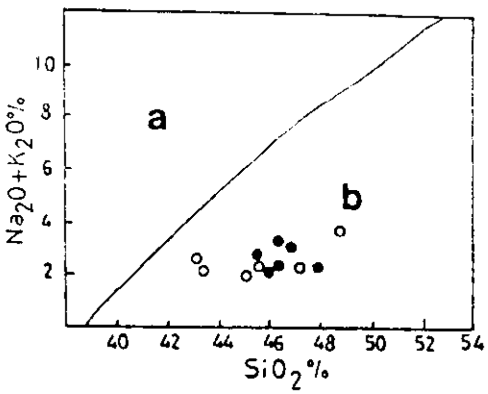

Fig.13: Alkali-silica variation diagram for the examined gabbroic rocks. The field boundary is after Irvine and Baragar, 1971.

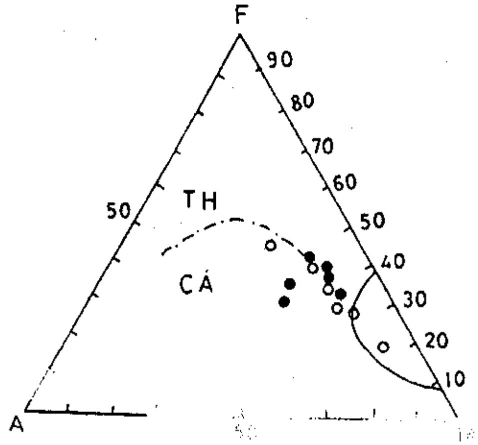

Fig.14: AFM diagram s[illegible] the variation of the relative pro- portions of A(Na_2O+K_2O), F ($FeO+0.9\ Fe_2O_3$) and M (MgO) for the older and younger gabbros. Ophiolitic rocks (solid line) is after Coleman, 1977. The field boundary separating tholeiitic above from calc-alkaline composi- tion (dashed and dot line) is after Irvine and Baragar, 1971.

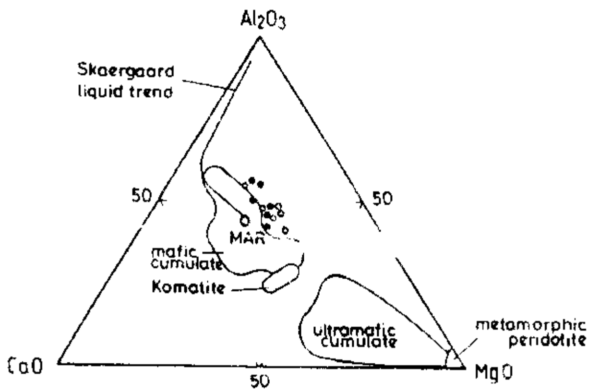

Fig.15: Ternary diagram of Al_2O_3-CaO-MgO for the investigated fresh olivine gabbros and metamorphosed gabbroic rocks, (after Coleman, 1977).

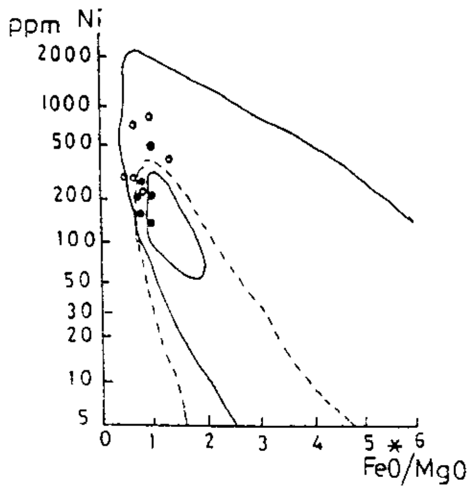

Fig.16; Variation of Ni with FeO* /MgO for the examined rocks (after Miyashiro and Shido, 1975). Composition field of abyssal tholeiites (solid line) and island arc tholeiites (dashed line).

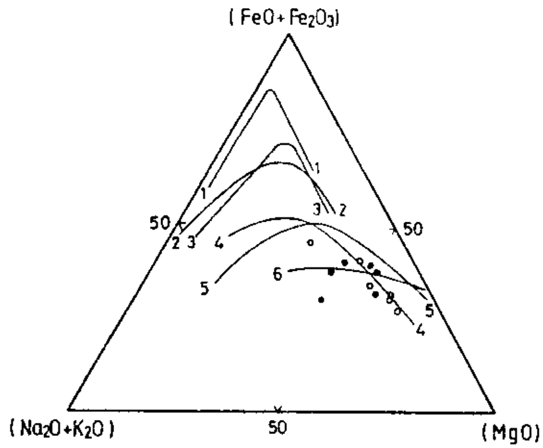

Fig.17: AFM ternary diagram for the investigated gabbros.
1-Skaergaard trend (Wager and Brown, 1967).
2-Stillwater (Wager and Brown, 1967).
3-Gabal Al-Tirf (Coleman and Irwin, 1974).
4-Alpine intrusive complexes (Thayer, 1967).
5-Egyptian younger gabbros (Takla et al., 1981).
6-Egyptian older gabbros (Takla et al., 1981).

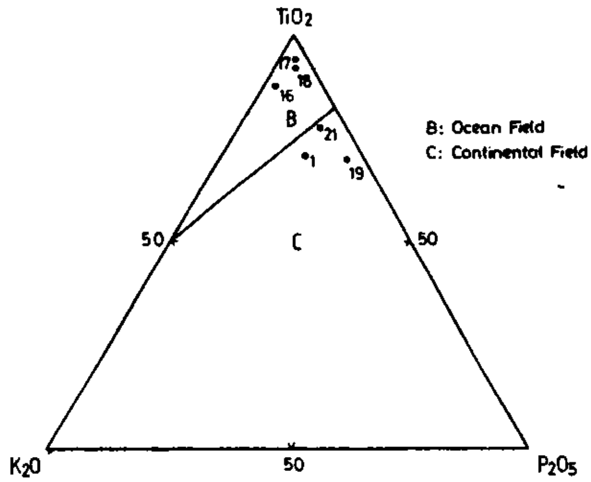

Fig.18: TiO_2-K_2O-P_2O_5 ternary diagram for the metamorphosed gabbros, after Pearce et al., 1975.

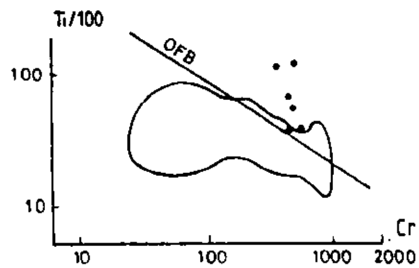

Fig.19: Binary diagram of Ti/100 Vs Cr for the studied metamorphosed gabbros, after Pearce 1975.

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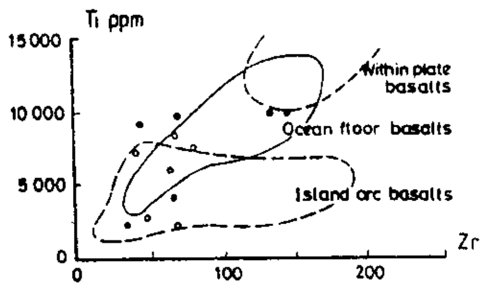

Fig.20: Binary Ti-Zr diagram for the investigated gabbroic rocks. Field boundaries after Pearce and Gale, 1977.

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التميز البتروكيماكى للجابرو بمنطقة وادى أم النار الصحراء الشرقية : مصر

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** المركز الدولى للبحوث - الدقى - القاهرة

يتناول هذا البحث دراسات حقليه وبتروجرافيه وكيميائيه وجيوكيميائيه لصخور الجابرو القديم والجابرو الحديث بمنطقة وادى أم النار ؛ الصحراء الشرقية بمصر فى محاوله لدراسة نشأة هذه الصخور وتحديد الوضع التكتونى لها ، ولقد أثبتت الدراسة الكيميائيه أن طبيعة أه جما التى نشأت منها هذه الصخور ذات تركيب كلس قلوى ، ولقد تم تحديد البيئه التكتونيه لها حيث وجد أن الجابر القديم قد تكون فى قاع المحيط بينما الجابرو الحديث تكون فى الجزر القوسيه ،