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# PETROGRAPHY, GEOCHEMISTRY AND MINERAL CHEMISTRY OF ZIRCON OF THE ORTHOGNEISSES OF WADI SEDRI AREA, SOUTHWESTERN SINAI, EGYPT.

**By**
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## ABSTRACT.

Wadi Sedri is located to the north of Wadi Feiran southwestern Sinai, Egypt. The area is entirely covered by orthogneisses that extend to the western extremity of the Feiran-Solaf gneiss belt. The studied gneisses are well exposed in both of Wadi Um Maghar and Wadi Sedri and are represented by grayish, medium to coarse grained biotite- hornblende gneisses. Petrographically, they can be distinguished into two types namely tonalite-, and quartz-diorite gneisses. The mineral assemblage of the studied gneisses represented mostly by plagioclase, hornblende, biotite and sphene may suggest that the rock underwent medium grade metamorphism in the amphibolite facies. Based on their geochemical investigations, the studied gneisses were derived from an igneous protolith of tonalite to quartz-diorite composition. They were originated from a calc-alkaline magma of peraluminous nature and emplaced in a volcanic arc environment. The studied gneisses have LREE / HREE ratios [( La/Lu)cn =9.33)] and show negative Eu anomaly suggesting that the magma of these gneisses was produced by the partial melting of a garnet-bearing siliceous granulite. Some zircon crystals are studied with microprobe to determine their REEs contents and their probable alteration.

## INTRODUCTION

The studied area is located to the north of Wadi Feiran, southwestern Sinai, Egypt ( Fig.1). The area is entirely covered by orthogneisses which are part of the western end of the Feiran- Solaf gneiss belt. These gneisses are subdivided into an older group of sedimentary and volcano-sedimentary parentages and a younger group of gneissified plutonic rocks (Hassan and Hashad,1990). The Feiran – Solaf belt was interpreted to represent a thick (>5000 m) sedimentary succession containing minor basic magmatic intercalations and was metamorphosed into gneisses, migmatites and amphibolites (Akaad et al.1967 and El-Gaby and Ahmed,1980). The age of the Feiran gneisses is a matter of controversy. Some authors considered them as pre- Pan-African (Shurmann,1966 and El-Gaby et al.1990) while others obtained Pan- African ages namely a U/Pb age of 632±3 Ma (Stern and Manton,1987) and Rb/Sr age of 643±31 Ma ( Beilsky,1982). The protolith of the Feiran paragneisses were probably immature volcano sedimentary wakes or perhaps lithic arenites intercalated with felsic tuffs(Stern and Manton,1987). El-Aref et al. (1988) considered Wadi Baba gneisses, southwestern Sinai, as paragneisses derived from pelitic or semipelitic sediments metamorphosed up to the amphibolite facies. Wadi Sedri gneisses were described by Sherif (1998) as orthogneisses.

The aim of this paper is to discuss the petrographic and geochemical characteristics of the studied orthogneisses as well as the probable tectonic setting and the magma type of their protolith. Also, mineral chemistry of zircon can be discussed through their microprobe analyses.

## FIELD ASPECTS

The studied gneisses are well exposed in both Wadi Um Maghar and Wadi Sedri (Fig.1) and are represented by biotite- hornblende gneisses. They are grey, medium to coarse grained and occupy terrains of moderate to high relief. They are composed essentially of plagioclase, quartz, biotite, hornblende and minor amounts of potash feldspar. They show well-developed gneissose structure in which the melanocratic and the leucocratic bands alternate. The components of these bands are parallely arranged with their longest dimensions to produce well developed preferred orientation, which is probably developed as a result of deformation, recovery and recrystallization (Ihlers and Blatt,1982). These gneisses are intruded by younger granites with discordant sharp contacts and show signs of migmatization in the form of thin light streaks parallel to the main foliation. This migmatization phenomenon is well developed along their contacts with the granitoid rocks. The studied gneisses lack any sedimentary structures, which suggest their igneous precursors.

## PETROGRAPHIC INVESTIGATIONS

Petrographically, Wadi Sedri gneisses can be varied into two types namely tonalite-, and quartz-diorite gneisses. Because of the similarity in their mineral constituents, with slight differences in the mineral proportions, they can be collectively described as follows:

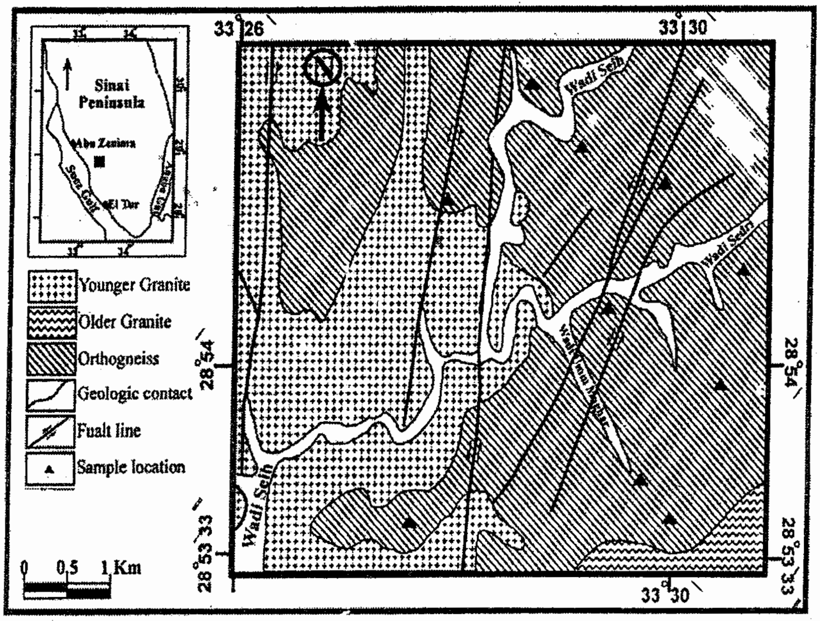

Fig. 1: Geologic map of Wadi Sedri orthogneisses, Southwestern Sinai, Egypt.

The rocks are mainly composed of plagioclase, quartz, hornblende, and biotite along with subordinate potash feldspars. The accessory minerals are iron oxides; apatite, zircon and sphene while the secondary minerals are chlorite, sericite and sphene.

**Plagioclase** ranges in composition from oligoclase to andesine. It is found as automorphic to hypautomorphic unzoned crystals exhibiting albite twinning(Fig.2). The unzoned plagioclase indicates the prevalence of equilibrium conditions during crystallization. The plagioclase shows bent and dislocated lamellae due to deformation. It is corroded by hornblende and biotite (Fig.2).

**Hornblende** occurs as xenoblastic to hypedoblastic crystals with deep green colour which is the typical amphibole of the amphibolite facies (Shelley ,1995). It is partly altered to chlorite and stretched together with biotite to form the main gneissose texture (Fig.3).

**Quartz** occurs mainly as xenomorphic crystals corroding the plagioclase, hornblende and biotite. Sometimes, quartz is strained with sutured outlines and shows undulose extinction. The strained quartz crystals are recrystallized into polygonal aggregates.

**Biotite** is found as elongate, sometimes, curved or bent crystals with brown colour. It is usually altered to chlorite. At least three generations of biotite can be recognized (Fig.4). The oldest one (S1) is elongated together with hornblende to form the gneissose structure while the second is mainly perpendicular to the first one. The last one, the youngest, is found to corrode the second one.

**Potash feldspar** is next in abundance to the other constituents and mostly occurs as xenomorphic perthite crystals. Sometimes, a myrmekitic texture was observed along their boundaries with the plagioclase. This type of myrmekite appears to have been grown inwards from grain boundaries, invading and replacing potash feldspar and the quartz rods branch in that direction.

**Sphene (titanite)** is represented by primary and secondary crystal varieties. Primary sphene occurs as independent crystals with well developed six-sided shape and generally associated with quartz, plagioclase and hornblende (Fig.5). The secondary sphene grows on the expense of biotite and hornblende.

**Epidote** and chlorite are the alteration products of plagioclase, biotite and hornblende respectively.

**Apatite** occurs as prismatic grains included in plagioclase and biotite. Zircon mainly occurs as idiomorphic crystals. The euhedral shaped crystals generally suggest the igneous origin of gneisses (Hassan and El-Gemmazy, 1985). The idiomorphism and length / breadth ratio of zircon crystals increase with the degree of ultrametamorphism.

**In conclusion**, the mineral assemblage of the studied gneisses that is plagioclase, hornblende, biotite and sphene may suggest that the rock underwent medium grade metamorphism in the amphibolite facies (Turner,1981).Also, this mineral assemblage together with the investigated textures such as myrmekitic texture, the corrosion relationships between the mineral constituents and the idiomorphic zircon may suggest the igneous origin of the studied gneisses and their derivation from tonalite and quartz diorite precursors.

## GEOCHEMICAL CHARACTERISTICS

The geochemistry of gneisses is a matter of controversy. While some authors considered the elemental constituents of the rock- forming minerals of gneisses have been affected by the metamorphic processes and consequently misleading interpretations will be obtained, others used the immobile elements to interpret their geochemical characteristics. However, most geochemical investigations are concerned with the protoliths of the metamorphic rocks. Accordingly, the geochemical investigations of the studied gneisses will be primarily concerned with their protoliths.

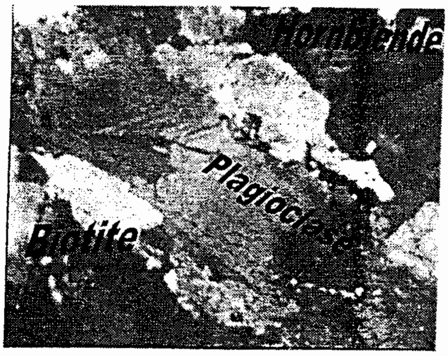

Fig. (2) : Photomicrograph showing unzoned plagioclase crystals that corroded by both biotite and hornblende CNx10.

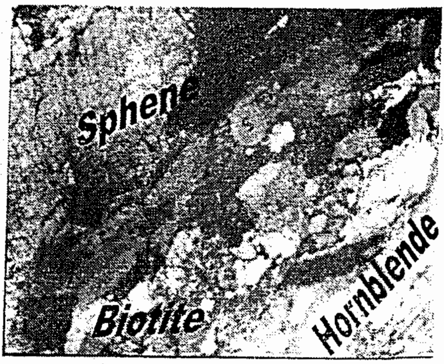

Fig.(3) Photomicrograph showing the stretched biotite, hornblende and synteconic sphene(S) together with the quartzo-feldspathic component to from the gneissose texture.

Fig. (4): Photomicrograph showing three generations of biotite (B1, B2 and B3 ), in addition to post tectonic sphene ( P.S). CNx10.

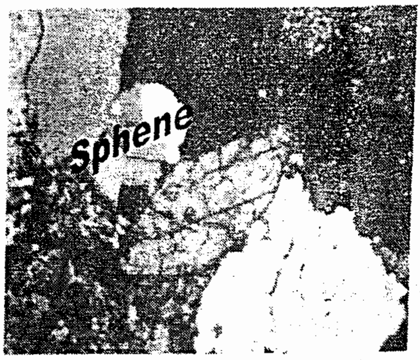

Fig. (5) : Photomicrograph showing well developed independent primary sphene crystal. CNx20.

## IDENTIFICATION OF THE PROTOLITH.

The analysis of the studied gneisses for major, trace and some rare-earth elements are given in table(1). The major constituents were determined by the wet chemical techniques of Shapiro and Brannock(1961). The trace elements were determined by X.R.F analysis carried out on a Phillips Sequential X-ray spectrometer system PW 1480. All the analysis were carried out in the Nuclear Materials Authority Laboratories(N.M.A). The analysed REE were done used the I.C.P. at the Central Laboratories of the Egyptian Geological Survey. The differentiation of the gneisses into ortho- or paragneisses was based on the $P_2O_5/TiO_2$ versus MgO/CaO described by Werner (1987 ) (Fig. 6). The data plot shows that all samples except one fall within the "magmatic" field. The paragneiss sample has higher $TiO_2$ content than the other samples. Also, Tarney (1977) proposed another diagram where $SiO_2$% is plotted versus $TiO_2$%. where all samples fall within the "meta-igneous" field except that sample which rich in $TiO_2$ (Fig.7). The data obtained from the two diagrams suggest an igneous origin for the studied gneisses. This result is consistent with the results of the petrographical investigations.

The igneous origin of the studied gneisses is also indicated by plotting some oxides versus each others. Tarney (1977) stated that many igneous rocks have well-defined positive correlation between $SiO_2$ and $K_2O$ and well-marked negative correlation between $SiO_2$ and CaO. Since the plotting of SiO2 vs. $K_2O$ of the studied gneisses (Fig.8) shows positive correlation except one sample which has low K-content due to the alteration of potash feldspar, and that of $SiO_2$ vs. CaO
shows an overall picture of negative correlation (Fig.9) with the exception of one sample which has high Ca-content due to the presence of some Ca-bearing minerals such as apatite, so the studied gneisses have an igneous origin.

## MAGMA TYPE OF THE PROTOLITH.

The magma type of the protolith of the studied gneisses's can be identified by plotting some geochemical parameters. Irvine and Baragar (1977) used the total alkalies vs. silica relationship (Fig.10) to distinguish between alkaline and subalkaline rock suites. The figure shows that all samples plot in the subalkaline field of Irvine and Baragar (op. cit). The subalkaline magma series is further subdivided by Irvine and Baragar (1977) into tholeiitic and calk-alkaline fields by plotting the three end-members, total alkalies, FeO* and MgO. The plotting of the data depict that they are plot within the calk-alkaline field (Fig.11).

**Table(1):Major oxides (%), trace, Rare-earth elements and eU and eTh (ppm) contents of the orthogneisses of Wadi Sedri area.**

| Oxides | HM1 | HM2 | HM3 | HM4 | HM5 | HM6 | HM7 | Average | Av1 |
|---|---|---|---|---|---|---|---|---|---|
| SiO2 | 69.00 | 68.70 | 67.70 | 66.36 | 67.76 | 66.57 | 66.91 | 67.57 | 66.46 |
| Al2O3 | 16.83 | 17.12 | 16.39 | 17.16 | 16.90 | 16.24 | 16.83 | 16.78 | 16.62 |
| TiO2 | 0.83 | 0.18 | 0.39 | 0.48 | 0.46 | 0.41 | 0.45 | 0.46 | 0.47 |
| Fe2O3 | 0.80 | 0.24 | 0.52 | 0.50 | 0.53 | 1.32 | 0.57 | 0.64 | 0.66 |
| FeO | 2.56 | 3.01 | 2.99 | 3.08 | 2.84 | 2.34 | 2.97 | 2.83 | 2.97 |
| MnO | 0.04 | 0.07 | 0.07 | 0.06 | 0.07 | 0.09 | 0.06 | 0.07 | 0.07 |
| MgO | 1.66 | 0.69 | 2.35 | 1.90 | 1.80 | 2.31 | 2.01 | 1.82 | 2.09 |
| K2O | 1.36 | 3.20 | 2.10 | 1.72 | 1.98 | 2.24 | 1.97 | 2.08 | 1.94 |
| Na2O | 3.70 | 3.62 | 3.67 | 4.09 | 4.01 | 4.09 | 3.82 | 3.86 | 3.97 |
| CaO | 4.80 | 3.71 | 3.55 | 3.70 | 3.58 | 2.89 | 3.78 | 3.69 | 3.51 |
| P2O5 | 0.02 | 0.04 | 0.11 | 0.17 | 0.13 | 0.13 | 0.14 | 0.11 | 0.15 |
| Total | 101.6 | 100.58 | 99.64 | 98.94 | 100.06 | 98.63 | 99.51 | 99.82 | 98.91 |
| V | 119 | 111 | 35 | 91 | 93 | 14 | 82 | 91.7 | 46.6 |
| Cr | 92 | 86 | 69 | 97 | 98 | 86 | 79 | 86.7 | 71.7 |
| Co | 52 | 50 | 21 | 44 | 46 | 44 | 42 | 42.7 | 44.3 |
| Ni | 32 | 32 | 20 | 37 | 39 | 28 | 35 | 31.9 | 39.9 |
| Cu | 38 | 40 | 36 | 49 | 50 | 42 | 44 | 42.7 | ----- |
| Zn | 81 | 73 | 42 | 75 | 67 | 75 | 72 | 69.3 | 68.3 |
| Ga | 15 | 15 | 20 | 15 | 15 | 18 | 16 | 16.3 | 19.86 |
| Rb | 37 | 52 | 66 | 47 | 44 | 52 | 51 | 49.9 | 61.71 |
| Sr | 629 | 609 | 318 | 776 | 675 | 621 | 599 | 603 | 349.6 |
| Ba | 2937 | 2725 | 1227 | 2665 | 2723 | 3608 | 2665 | 2650 | 2650 |
| Nb | <2 | 11 | 5 | <2 | 4 | 6 | 5 | 6.2 | 7.4 |
| Zr | 63 | 65 | 112 | 97 | 71 | 89 | 78 | 82 | 82.13 |
| Y | 5 | 5 | 8 | 7 | 5 | 6 | 7 | 6.1 | 11.9 |
| Pb | 43 | 42 | 53 | 34 | 43 | 52 | 44 | 44 | 6.85 |
| Ce | 30 | 25 | 37 | 26.5 | 25.7 | 54 | 36 | 33.46 | ----- |
| La | 16 | 13 | 21 | 17 | 17 | 24 | 18 | 18 | ----- |
| Pr | 8 | 7 | 8.5 | 7.4 | 7.2 | 12.8 | 9.7 | 8.66 | ----- |
| Nd | 15 | 15 | 17.5 | 14 | 14 | 29.4 | 28 | 18.99 | ----- |
| Eu | 1 | 1.1 | 0.8 | 0.9 | 0.9 | 1.5 | 1.3 | 1.07 | ----- |
| Gd | 3.6 | 3.5 | 4 | 3.6 | 3.5 | 6.5 | 5.5 | 4.3 | ----- |
| Yb | 1.5 | 1.6 | 2.2 | 2.2 | 2.3 | 4.1 | 2.5 | 2.3 | ----- |
| Lu | 0.5 | 0.5 | -- | --- | --- | 0.6 | 0.4 | 0.5 | ----- |
| eU | 7 | 7 | 6 | 5 | 7 | 5 | 5 | 6.0 | ----- |
| eTh | 6 | 7 | 7 | 6 | 9 | 9 | 8 | 7.4 | ----- |

* Av1= The average of the orthogneisses ( Hornblende-biotite gneisses) of Taba area , South- eastern Sinai, Egypt. ( Abu El- Nein,1995).

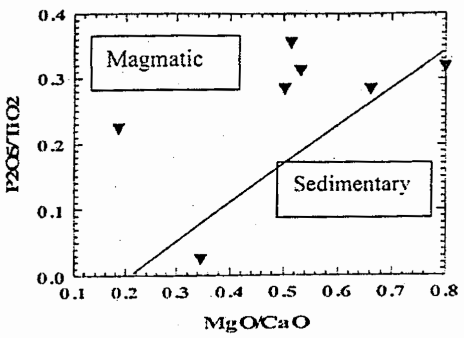

Fig.(6):MgO/CaO vs. $P_2O_5$/ $TiO_2$ binary diagram (after Werner, 1987)

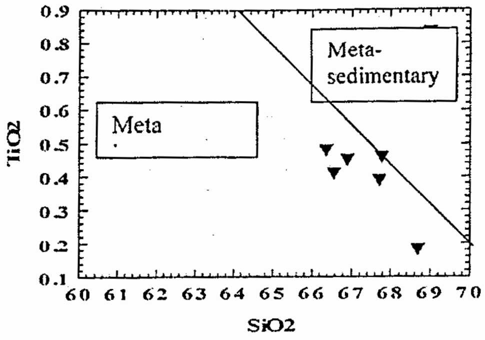

Fig.(7): $SiO_2$ vs. $TiO_2$ of the studied Gneisses, after Tarney(1977).

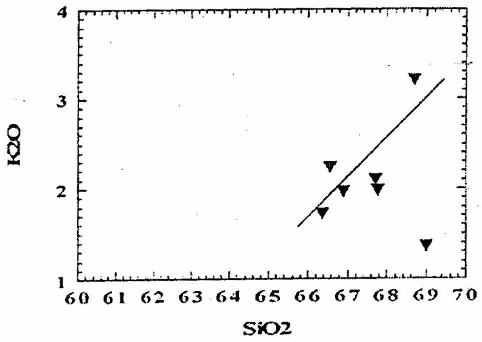

Fig.(8): Positive correlation between $SiO_2$ and $K_2O$ of the studied

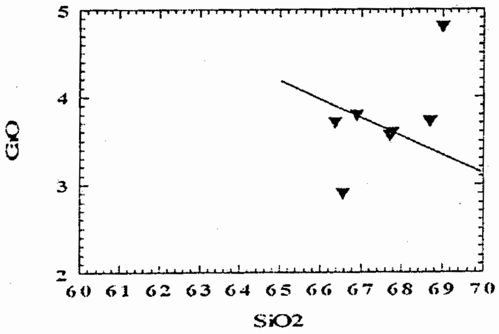

Fig.(9): Negative correlation between SiO2 and CaO of the studied gneisses.

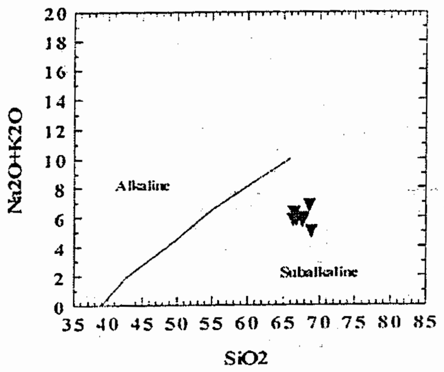

Fig.(10):Total alkalies vs.SiO2 for the studied gneisses. The alkali and subalkaline fields are after Irvine and Baragar (1971).

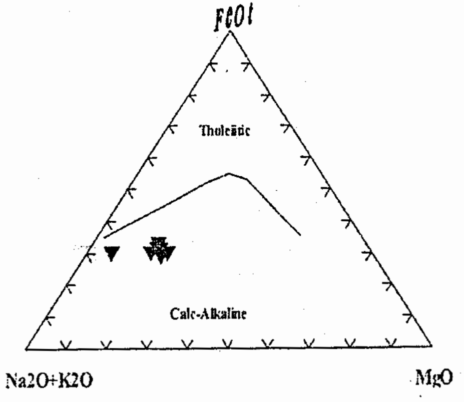

Fig.(11):AFM diagram of the studied gneisses after Irvine and Baragar (1971).

The chemical data are plotted on the $Al_2O_3$/ $CaO+Na_2O+K_2O$ versus $Al_2O_3$/( $Na_2O+K_2O$). (Maniar and Piccoli ,1989, Fig. 12 ) where all data points plot in the peraluminous field.

## TECTONIC SETTING OF THE PROTOLITH.

As mentioned and concluded above, the studied gneisses were most probably calc-alkaline igneous rocks of tonalite and granodiorite composition. Accordingly, the tectonic setting of the protolith will be discussed under the tectonic setting of the granitoid rocks.

Pearce et al.(1984) classified the granitoids into four categories: ocean ridge granite (ORG), volcanic arc granite (VAG), syn-collsion granite (syn-COLG) and within plate granite (WPG). The variation diagram of Rb vs. Nb+Y (Pearce et al.1984) shows that orthogneisses samples fall within the volcanic arc field (Fig.13).

The noticed enrichment in LIL elements and concomitant depletion in the HSF elements in the orthogneisses suggest their derivation from a subduction related magma (Pearce,1983; Brown et al., 1984; Saunders and Tarney, 1984 ).

## RARE-EARTH ELEMENTS (REE).

The REE are better used to define the protoliths of the Wadi Sedri gneisses. The REE are generally immobile during weathering and medium-grade metamorphism.

The determined REEs of these gneisses are shown in table (1), they are normalized to the composition of chonderites and plotted in Fig.14. The pattern obtained indicates the presence of negative Eu anomaly. Henderson (1984) stated that rocks with negative Eu anomalies may occur at continental -margin setting and of any geologic age. Eu is compatible in plagioclase and K-feldspars in felsic magmas. Thus removal of feldspars from a felsic melt by crystal fractionation, or retention of feldspar in the source of a rock undergoing partial melting will give rise to a negative Eu anomaly in the melt.

Henderson (1984) stated that granodiorites, tonalites, quartz-diorites and trondhjemites containing negative Eu anomalies and fairly large REE contents and LREE / HREE ratios [( La/Lu)cn =8.9-66)] which require sources with abundant plagioclase (to produce the negative Eu anomalies in the melt) and small amounts of garnet, amphiboles or pyroxenes( to reduce the HREE relative to LREE in the melt). Such sources are garnet- bearing siliceous granulite ( Condie, 1976; Condie and Hunter,1976; Fryer and Jenner,1978;Peccerillo et al., 1979) or eclogite (Barker et al., 1976).

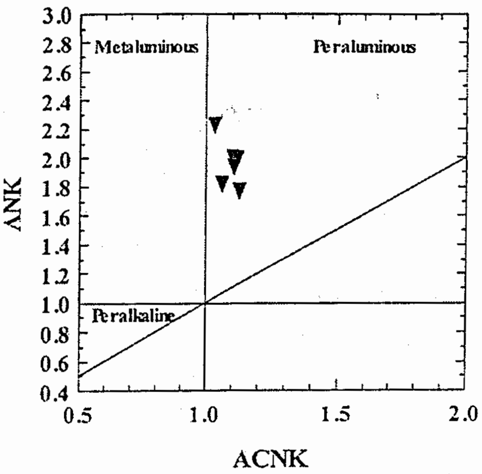

Fig.(12): $Al_2O_3$/ $CaO+Na_2O+K_2O$ vs. $Al_2O_3$/ $Na_2O+K_2O$ diagram of the studied gneisses after Maniar and Piccoli (1989).

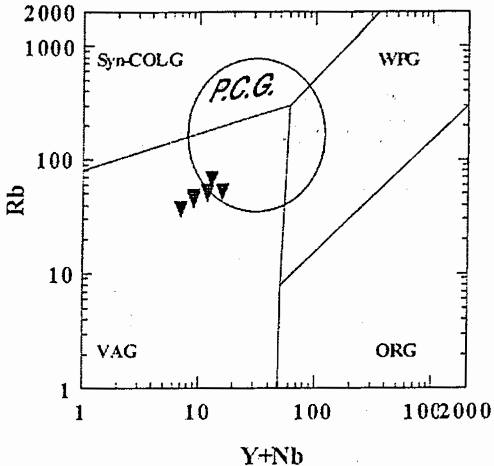

Fig.(13):Rb vs.Y+Nb diagram of the studied gneisses after Pearce et al., (1984). The field of P.C.G is modified by Pearce (1996).

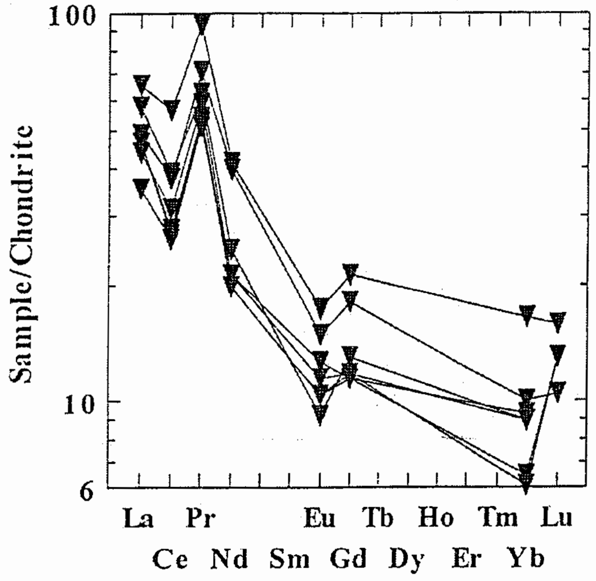

Fig.(14):Chonderites-normalized REE abundances in the studied gneisses

The studied gneisses have LREE / HREE ratios [( La/Lu)cn =9.33)] and show negative Eu anomaly suggesting that the magma of these gneisses was produced by the partial melting of a garnet-bearing siliceous granulite.

**In conclusion**, the protolith of the studied gneisses may be originated from a calk-alkaline magma of peraluminous nature and at an active-continental margin by partial melting of a garnet- bearing siliceous granulite or eclogite.

## ZIRCON OF THE WADI SEDRI GNEISSES

In the studied gneisses, a lot of zircon crystals are studied and investigated, where some of them are un-zoned while others are zoned. Some of these minerals occur as individual crystals while the majority are associated with other minerals such as feldspars, micas and amphiboles. Overgrowths of small zircons and other minerals upon the large zircon crystals are observed. The growth of zircon does not only take place under magmatic conditions, but it is also an important process during the deformation of igneous rocks. (Hassan, 2001). Fine zircon grains can be grown metasomatically as those recorded in the psammitic gneiss of Wadi Nugrus, south Eastern Desert, Egypt (Hassan and Gemmizi, 1985). These zircon crystals are much larger than the other varieties of zircons in the unmetasomatized rock varieties. Equant and euhedral zircon grains with simple zoning occur only in the mesosome of Kirtomy Migmatite Suite of Southerland Scotland (Watt et al.1996). Vavra et al. (1999) mentioned that fine zircon grains were probably formed during metamorphic processes of the metapelites and/or metagraywacke within the granulite facies of the Ivrea zone ,Southern Alps. Vavra et al. (op. cit.) mentioned that the zircon growths and overgrowths in restites, leucosomes and meta-igneous granulite, are supposed to have entirely formed in an anatictic environment. Driks and Hand (1991,cite in Bishady et al.,2005) concluded also that zircon in migmatitic feldspathic gneisses can grow and re-crystallizes under granulite facies conditions in the presence of a limited amount of felsic melt. They added that the overgrowths in zircon might be attributed to more than one generation of crystallization.

## MINERAL CHEMISTRY OF THE STUDIED ZIRCON

Several zircon grains of the studied gneisses were analyzed using electron-microprobe technique (Table2). The analyses were carried out in the institute of Wissenschaftspork Albert Einstein, Potsdam University, Germany using the microprobe instrument model CAMECA Sx100. The table shows that the analyses of the zircon grains, except the inclusion, displaying normal distributions of $SiO_2$, $ZrO_2$ and $HfO_2$. The LREE and HREE are rarely represented, with only Ce, Nd, Sm, Gd, Yb and Dy. The low REEs content may due be to the effect of weathering acting upon the studied orthogneisses. Many authors demonstrated that the REE can be transported and fractionated during weathering (e.g. Vlasov, 1966; Burkov and Podporina, 1967; Nesbitt, 1979; Duddy, 1980; Harris, 1985). Nesbitt (1979) suggested that fractionation of REEs during weathering is due to adsorption of LREE relative to HREE on the primary and secondary minerals. Uranium and thorium are also present with minor amounts, which suggest their leachability due to the weathering of the studied gneisses.

Table(2) also shows the microprobe analyses of an inclusion within a crystals of the studied zircons. The analyses displayed the presence of high percentages of both $P_2O_5$ and CaO(20.46% and 27.10% respectively) within the inclusion while these two oxides are not represented in the host zircon. Also, $SiO_2$, $ZrO_2$ and $HfO_2$ are remarkably decreased in the inclusion relative to the host.

The REEs $Ce_2O_3$, $Nd_2O_3$, $Sm_2O_3$ and $Gd_2O_3$ are only represented in the inclusion while $Sm_2O_3$ and $Yb_2O_3$ are decreased in the inclusion relative to the host.

The high percentages of both $P_2O_5$ and CaO in the inclusion rather than the host zircon may suggest that the inclusion is apatite. The presence of this inclusion at the core of the host zircon may suggest its growth on the expense of this host and this growth may contemporaneous with the decreasing of the main constituents of the host zircon, e.g. $SiO_2$, $ZrO_2$ and $HfO_2$. This interpretation is confirmed by the appearance of both $P_2O_5$ and CaO at the inclusion and the remarkable decreasing of $SiO_2$, $ZrO_2$ and $HfO_2$ in this inclusion.

Apatite group includes a lot of P-bearing minerals the commonest of which is fluorapatite $Ca_5(PO_4)_3F$. Several minerals of the group(e.g. belovite and britholite) contain REEs as a major constituent, but in general fluorapatites contain small but important amounts ( usually tens of a percent), rising to as much as 12 wt % in apatites from alkaline rocks. The REE occupy the Ca positions in the apatite structure, in two distinct sites having 7- and 9- fold co-ordination. According to Fleischer (1965) this should led to complex distributions with both the Ce and Y groups present. Fleischer and Altschuler(1969) have shown that apatites from mafic, ultramafic and alkaline igneous rocks have dominant Ce-group compositions; those from granitic rocks and granitic pegmatites have a wide range of compositions, from Ce-group dominant to those with a high content of the intermediate and heavy REE. Ce is dominant, but some analyses show maxima at Nd, Gd, Dy, or Yb. Lee et al.(1973) determined the REE composition of a number of apatites from hybrid granitoid rocks of the southern Snake Range , Nevada, finding that apatites from the more mafic rocks contained rare earth assemblages richer in the lighter REE.

**Table( 2 ): Microprobe analyses of Wadi Sedri gneisses zircon grains.**

|  | Zircon-1 |  | Zircon-2 | Zircon-3 | Zircon-4 | Zircon-5 |
|---|---|---|---|---|---|---|
| Oxides | Host | Inclusion |  |  |  |  |
| $P_2O_5$ | --- | 20.46 | --- | --- | --- | --- |
| $SiO_2$ | 32.73 | 17.29 | 32.49 | 32.85 | 32.88 | 32.24 |
| $ZrO_2$ | 65.20 | 32.64 | 64.71 | 66.23 | 65.56 | 64.86 |
| $HfO_2$ | 1.41 | 0.62 | 1.50 | 1.53 | 1.71 | 1.41 |
| $ThO_2$ | 0.01 | 0.01 | --- | --- | 0.04 | 0.02 |
| $UO_2$ | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 | 0.03 |
| $Al_2O_3$ | 0.01 | --- | --- | --- | 0.01 | 0.01 |
| $Sc_2O_3$ | 0.01 | --- | 0.01 | 0.02 | --- | --- |
| $Y_2O_3$ | --- | --- | --- | --- | --- | --- |
| $Ce_2O_3$ | --- | 0.36 | 0.01 | --- | --- | 0.02 |
| $Nd_2O_3$ | --- | 0.23 | 0.07 | --- | --- | --- |
| $Sm_2O_3$ | 0.03 | 0.01 | --- | --- | --- | --- |
| $Gd_2O_3$ | --- | 0.01 | --- | 0.01 | --- | --- |
| $Dy_2O_3$ | --- | 0.04 | 0.10 | 0.02 | --- | --- |
| $Yb_2O_3$ | 0.06 | 0.03 | 0.02 | 0.04 | --- | 0.02 |
| CaO | 0.02 | 27.10 | --- | --- | 0.01 | --- |
| FeO | 0.07 | 0.09 | 0.03 | 0.03 | 0.05 | 0.03 |
| PbO | --- | --- | --- | 0.01 | 0.04 | 0.02 |
| Total | 99.60 | 98.92 | 99.71 | 99.67 | 99.22 | 99.33 |

Brockite was defined by Fisher and Meyrowitz(1962) as a variety of apatite with a formula that is $(Ca,Th,Ce)PO_4.H_2O$. The mineral was described by them as massive reddish aggregates and as earthy yellow coatings in veins and altered granitic rocks in the Wet Mountains, Colorado.

The studied inclusion has a composition that can be correlated with the composition of the apatite variety brockite i.e Ca, Ce, Th and $P_2O_5$.

According to Rapp and Watson(1986), the atomic substitutions within monazite can take place through the following reactions:

The first is the substitution of silicon and phosphorous due to the equation;

1-$PO^{5+}$ == $SiO^{4+}$ or $REE^{3+}$== $Si^{4+}$.

2- $Th^{4+}$ +$U^{4+}$coupled with that of $Ca^{2+}$ in a proportion 1:1 for REE to preserve the electrostatic balance of the charges according to the equation;

$2REE^{3+}$== $Th^{4+}$+$Ca^{2+}$ or $2REE^{3+}$== $U^{4+}$+$Ca^{2+}$

3- The third is a substitution of $Th^{4+}$ or $U^{4+}$ to the trivalent $REE^{3+}$ coupled with $Si^{4+}$ substitutions to $P^{5+}$ in the tetravalent site according to the following equation;

$P^{5+}$+ $REE^{3+}$== $Th^{4+}$+ $Si^{4+}$ or $P^{5+}$+ $REE^{3+}$== $U^{4+}$+ $Si^{4+}$

In the same context, the studied apatite inclusion can be formed through the substitution of silicon and phosphorous due to the equation;

1-$PO^{5+}$ == $SiO^{4+}$ or $REE^{3+}$== $Si^{4+}$.

2- $Th^{4+}$ +$U^{4+}$coupled with that of $Ca^{2+}$ in a proportion 1:1 for REE to preserve the electrostatic balance of the charges according to the equation;

$2REE^{3+}$== $Th^{4+}$+$Ca^{2+}$ or $2REE^{3+}$== $U^{4+}$+$Ca^{2+}$

## CONCLUSION

Wadi Sedri orthogneisses are intruded by the older and younger granites with discordant sharp contacts. These gneisses show signs of migmatization in the form of thin light streaks parallel to the main foliation. This migmatization phenomenon is well developed along their contacts with the granitoid rocks. The studied gneisses lack any sedimentary structures, which suggest their igneous precursors. The protolith of the studied gneisses may be originated from a calc-alkaline magma of peraluminous nature and at an active-continental margin by partial melting of a garnet- bearing siliceous granulite or eclogite.

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# بتروجرافية وجيوكيميائية وكيمياء معادن الزيركون لصخور النايس بوادى سيدرى - جنوب غرب سيناء - مصر.

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## الخلاصة

يقع وادى سدرى الى الشمال من وادى فيران، جنوب غرب سيناء - مصر ويغطى كليا بصخور النايس التى تعتبر الامتداد الغربى لحزام نايس وادى فيران - سولاف. تمثل هذه الصخور بنوعين هما النايس التوناليتى ونايس الكوارتز دايورايت ذات اللون الرمادى. تتكون صخور النايس من صحبة معادن البلاجيوكليز - الهورنبليند - البيوتايت - الكوارتز والاسفين والتى تدل على أن هذه الصخور قد تعرضت لدرجة متوسطة من التحول فى سحنة الأمفيبوليت. بناءا على خواصها الجيوكيميائية فان هذه الصخور قد أشتقت من أسلاف نارية ذات التركيب التوناليتى والكوارتز دايوراتيتى كما أنها نشأت من صهاره ذات طبيعة كلسى - قلوية غنية بالألومينا وتموضعت فى بيئة الأقواس البركانية. كما أن صخور النايس قيد الدراسة تتميز باحتوائها على شذة الأوربيوم السالبة كما أن نسبة العناصر الأرضبة النادرة الخفيفة الى نسبة العناصر الأرضبة النادرة الثقيلة بها تساوى ٩,٣٣ مما يرجح نشوئها بالانصهار الجزئى من صخور الجرانيوليت السيليكاتية الحاملة للجارنيت. لقد أثبتت الدراسة بالمجس الالكترونى (الميكروبروب) أن معادن الزيركون فى صخور النايس تحتوى على نسب عادية من اكاسيد الزيركونيا والسيليكا والهافنيا وبعض العناصر الأرضية الندرة مثل السيريوم والنيوديميوم والسماريوم والجادولينيوم والأتيربيوم والدسبيروزيوم. كما أثبتت الدراسة أن معدن الزيركون يتحول الى معدن الأباتيت.