POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 26, 2005; Volume 26, 2005

GEOCHEMISTRY AND PETROGENESIS OF NEOPROTEROZOIC GRANITOIDS IN KILKBOB AREA, SOUTHEASTERN DESERT, EGYPT

Fawzy BAKHIT[1], Said EL-NISR[2], Gehad SALEH[1], Adel El-AFANDY[1]

Abstract: The granitoids (granodiorite, monzogranite-syenogranite and alkali-feldspar granite) in the Gabal Kilkbob area southeastern Desert of Egypt are calc-alkaline, to weakly alkaline and display most of the chemical characteristics of syn- to late-tectonic I-type granitoids to post-tectonic A-type granitoids. The granodiorite was generated by partial melting from a dioritc source, while the monzogranite-syenogranite and the alkali-feldspar granite were derived by fractional crystallization from the granodiorite and the monzogranite-syenogranite, respectively.

Keywords: Gabal Kilkbob, syn- to late-tectonic, I-type granitoids, post-tectonic, A-type granitoids

INTRODUCTION

The Precambrian rocks of Egypt represent the western part of the Arabian-Nubian Shield, which was formed during the Pan-African orogenic cycle (950-450 Ma, Kroner 1984) by the accretion of juvenile arc terrains, followed by crustal thickening accompanied by intrusion of batholiths of predominantly granitic composition. Generally, the Egyptian granitoids are broadly subdivided into three main groups: older, younger and alkali granitoids based on field relations, tectonic and geochronological determinations (Hussein *et al.* 1982, El-Gaby *et al.* 1988). The Egyptian Younger Granitoids attracted a great deal of interest because they mark a transitional stage from subduction-related magmatism to within-plate magmatism in the crustal evolution of the Nubian Shield (Beyth *et al.* 1994) which make their origin and classification somewhat controversial.

The aim of this work is to through more light on the petrological and geochemical characteristics of Gabal Kilkbob younger granitoids, the main evolutionary processes which have been responsible for their generation as well as their tectonic environment.

GEOLOGIC SETTING

The Gabal Kilkbob area is located in the southeastern Desert of Egypt about 250 km from Aswan city. The rocks exposed in the Gabal Kilkbob area comprise metagabbros, metavolcanics and metasediments intruded by granitoid rocks. The granitoid rocks in the Gabal Kilkbob area comprise younger granitoids represented by granodiorite, monzogranite, syenogranite and alkali - feldspar granites (AFG). The granodiorite is characterized by the granodiorite. abundant rounded to sub-rounded dioritic xenoliths of centimeter-size and sharp contacts with The contact of granodiorite with the other granitoids is transitional. The monzogranite occurs mainly as pendants enclosed in the syenogranite and is characterized by redish brown color. Moreover, the contact between

[1]*Nuclear Materials Authority, Cairo, Egypt.*
[2]*Faculty of Science, Alexandria University, Alexandria, Egypt, e-mail: saidelnisr_eg@yahoo.com*

the two varieties is difficult to be detected. The syenogranite is the predominant rock variety in the Gabal Kilkbob granitoids and characterized by porphyritic texture. The contact between the syenogranite and the AFG is sharp. Many uranium-bearing pegmatites are encountered in the syenogranite variety. The alkali feldspar granite represents the main body of Gabal Kilkbob (570 meters above sea level). Their contact with the syenogranite is sharp and locally chilled. Pegmatites in the AFG occur mainly along the contact zones as small dykes and clots. The Gabal Kilkbob area was affected of three sets of strick-slip faults having NW-SE, E-W and NE-SW directions.

PETROGRAPHY

Kilkbob granitoids are mostly characterized by porphyritic, perthitic and less common myrmekitic textures. Microscopically, the granodiorite and the monzogranite varieties consist of zoned and twinned plagioclase, quartz, K-feldspar, biotite and hornblende. Sphene, apatite, allanite and opaques are the main accessory minerals observed whereas sericite, epidote, calcite and chlorite are alteration products. The syenogranite and the alkali feldspar granite varieties consist of potash feldspar, quartz, plagioclase feldspar, riebeckite, aegirine and biotite. Sphene, apatite, fluorite, zircon, hematite and magnetite are the main accessory phases and opaques also observed.

GEOCHEMISTRY

Major and trace elements were determined by XRF techniques at the Nuclear Materials Authority (NMA) -Cairo. Precision of the analytical data was monitored by international rock standards and is better than 3% for major elements and 5-10% for trace elements. The Gabal Kilkbob granitoid rocks are classified using the R_1- R_2 diagram of Batchelor and Bowden (1985) and the nomenclature was confirmed by using molar norm compositions in a Q`-ANOR diagram after Streckeisen and Le Maitre (1979). The granodiorites are metaluminous to mildly peraluminous while the monzogranites-syenogranites and the AFG are metaluminous to weakly peralkaline. Using a Harker variation diagram (Fig. 1), TiO_2, CaO, total alkalis and Sr tend to decrease from the granodiorite to the AFG with increasing silica, while Y gives no good relation.

MAGMA TYPE AND TECTONIC SIGNIFICANCE

The magma type of the Kilkbob granitoids is illustrated by the relation SiO_2 vs. (Na_2O+K_2O; Fig. 1), where most samples fall in the non-alkaline field (calc-alkaline+ tholeiitic) and few samples in the trans-alkaline field (after Middlemost 1997). The Kilkbob granodiorite exhibits the mineralogical and geochemical features of calc-alkaline I-type granitoids: 1- presence of hornblende, biotite, magnetite and titanite, 2- relatively high $Na_2O > 3.2$ %, 3- metaluminous to slightly peraluminous, 4- Agpaitic index (Na+K/Al) < 0.87. On the other hand, the AFG exhibits the alkaline character of A-type granitoids: 1- low CaO and MgO, 2- high SiO_2, Na_2O+K_2O, Nb, Y and 4- Agpaitic index > 0.87. Also, according to Rogers, Greenberg (1990) the granodiorite belongs to late-orogenic granite (LO) while the other granitoids related to post-orogenic granitoids (PO; Fig. 1).

The Y/Nb ratios of the Kilkbob granodiorites, monzogranites- syenogranites and the AFG are 1.38, 1.54 and 2.54, respectively, on average. This indicates that the Kilkbob granitoids are orogenically-related, A_2-subtype granite. On the Rb-(Nb+Y) discrimination diagram of Pearce *et al.* (1984) the granodiorite samples plot in the volcanic-arc granite field while the rest of the granitoid samples plot in the within-plate granite field.

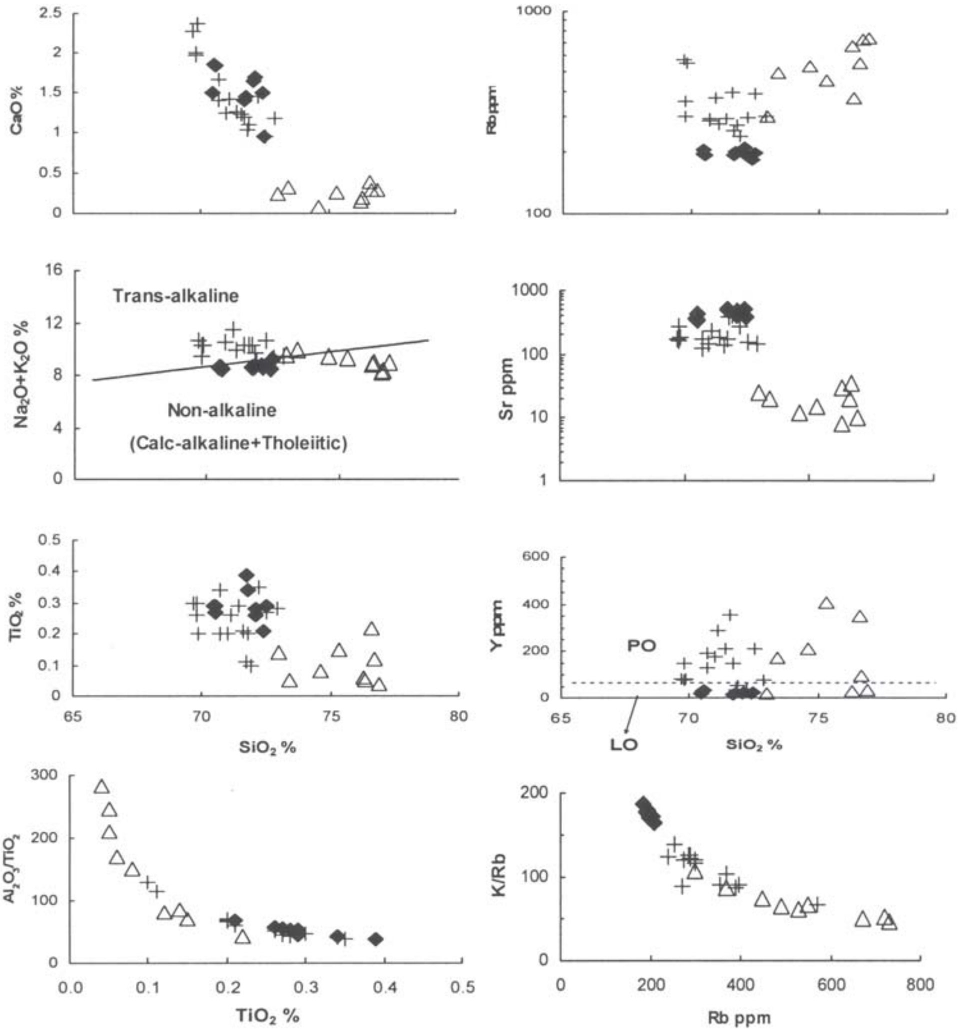

Fig. 1. Selected major, trace and elemental ratios in Harker variation diagram for the Kilkbob granitoids. The dashed line separating late-orogenic (LO) from post-orogenic (PO) granites after Rogers, Greenberg (1990). Fields of non-alkaline and trans-alkaline are after Middlemost (1997). Solid rhomb: granodiorites, + : monzogranites-syenogranites, Δ : alkali-feldspar granites.

DISCUSSION AND CONCLUSIONS

The geochemical data of the granodiorites indicate that these rocks are I-type orogenically related. The granodiorite is characterized by the presence of complexly zoned and twinned plagioclase cores, the presence of dioritic xenoliths and poikiloblastic biotite crystals with oxide phases. These features suggest that the study granodiorite was generated by batch partial melting of a dioritic source, most probably the metagabbro-diorite in the study area. The multi-element abundance diagram shows that for granodiorite the negative Sr, Nb, P, and Ti anomalies, indicate the effects of plagioclase, titanite, apatite, titanomagnetite and ilmenite removal, respectively. Thus, the granodiodiorite was firstly generated by partial melting of dioritic source then was modified by a fractional crystallization process.

To demonstrate that the Kilkbob granitoids are genetically related, this is well obvious from the curvilinear trends exhibited by the harker variation diagram (Fig. 1), and also confirmed from the well curvilinear trends illustrated by K/Rb vs. Rb and Al_2O_3/TiO_2 vs. TiO_2 (after Garcia *et al.* 1994), which indicate that fractional crystallization is the dominant process in the evolution of the Kilkbob granitoids. On the other hand, the gradual increase of Rb/Sr and Rb/Ba from the granodiorite to the AFG through the monzogranite-syenogranite, indicate that these granitoids are genetically related by fractional crystallization. The derivation of the monzogranites-syenogranites and the AFG from the granodiorite and the monzogranite-syenogranite magmas, respectively, by fractionation was verified by using the least squares balance calculations (Wright, Doherty 1970). The results of modeling are summarized in two stages, the first stage indicates that the monzogranite-syenogranite can be obtained from the granodiorite by 14.33 % crystal fractionation with a residual liquid (daughter) of 85.67 %. The crystallizing phases are 50.67 % plagioclase, 42.39 % K-feldspars, and 6.92 % amphibole. The second stage indicates that the AFG can be generated from the least evolved monzogranite-syenogranite by 35.66 % crystal fractionation with a residual liquid (daughter) 64.34 %. The fractionated phases are 66.23 % plagioclase, 29.98 % K-feldspar, 2.17 % sphene and 1.6 % apatite. The low values of the sum of residuals in the first and second stages (2.7 and 1.1, respectively), indicate a good fit.

Compressional (650-610 Ma) and extentional (610-520 Ma) tectonic regimes associated with crustal thickening and thinning in the Arabo-Nubian Shield (ANS), resulted in the intrusion of I-type calc-alkaline and LIL-enriched melts with A-type characteristics, respectively. The transition period from late-orogenic to post-orogenic magmatism in the ANS was 15-6 Ma (Beyth *et al.* 1994). Accordingly, the evolution of the Gabal Kilkbob younger granitoids may be predicted as follows: during the compressional processes, an oceanic island-arc led to the formation of a basic magma that was fractionated to give the metagabbro-diorite in the study area. The granodiorite was generated by partial melting from the metagbbro-diorite. Fractional crystallization processes then control the evolution of the more evolved monzogranite-syenogranite and the AFG varieties.

The authors express their deep thanks to Prof. Dr. A. M. El-Bouseily, for his critical reviewing the manuscript. Also, deep thanks to the staff members in the Nuclear Materials Authority during field and lab works.

REFERENCES

BATCHELOR R.A., BOWDEN P. 1985: Petrographic interpretation of granitoid rocks using multicationic parameters. *Chem. Geol*., 48, 43-55.

BEYTH M., STERN R.J., ALTHERR R., KRONER A. 1994: The late Precambrian Timna igneous complex, southern Israel: evidence for comagmatic-type sanukitoid monzodiorite and alkali granite magma.- *Lithos*, 31, 103-124.

EL-GABY S., LIST F.K., TEHRANI R. 1988: Geology, evolution and metallogenesis of the Pan-African Belt in Egypt.In (S. El-Gaby, S.,R.D. Greiling, *R.D., eds*.) The Pan-African Belt of the North East Africa and Adjacent Areas. Vieweg Verlag,Wiesbaden, 17-68.

GARCIA D., FONTEILLES M., MOUTTE J. 1994: Sedimentary fractionation between Al, Ti, and Zr and the genesis of strongly peraluminous granites. *J. Geol*., 102: 411-422.

HUSSEIN A.A., ALI M.M., EL-RAMLY M.F. 1982: A proposed new classification of the granites

of Egypt. *J. Volcan. Geoth. Res*., 14, 187-198.
KRONER A. 1984: Late Precambrian plate tectonics and orogeny: a need to redefine the term Pan-African. In (Klerkx J., Michot J. eds.) Geologie Africane. *African Geol.*, 23-28.
MIDDLEMOST E.A.K. 1997: Magmas, rocks and Planetry Development. *Longman, Harlow*, 299 pp.
PEARCE J.A., HARRIS N.B.W., TINDLE A.G. 1984: Trace element discrimination diagrams for the tectonic interpretation of granitic rocks. *J. Petrol*., 25, 956-983.
ROGERS J., GREENBERG J. 1990: Late-orogenic, post-orogenic, and anorogenic granites: distinction by major elements and trace element chemistry and possible origins. *J. Geol*. 98: 291-309.
STRECKEISEN A., LE MAITRE R.W. 1979: A chemical approximation to the modal QAPF classification of the igneous rocks. *N. Jb. Mineral. Abh*. 136: 169-206.
WRIGHT T.L., DOHERTY P.C. 1970: A linear programing and least squares computer method for solving petrological mixing problems. *Geol. Soc. Amer. Bull*., 81, 1995-2008.