Sci. J. Fac. Sci. Minufia Univ., 2009, XXIII, 75-90

COMPARATIVE STUDY BETWEEN THE CORE AND MARGIN OF HORNBLENDITE DYKE, EASTERN DESERT, EGYPT

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ABSTRACT

The youngest Pan-African magmatic event in Wadi Nugrus is represented by hornblendite dyke swarms cross-cut both monzogranite and isotropic gabbros. The hornblendite dykes vary in thickness from 1 to 10 m, and are up to 1 km long with vertical dip and strike generally N-S. The dykes display features of flow differentiation, leading to increased grain size (5 cm long) in the core as well as absence of plagioclase.

The studied hornblendite samples from core to margins have a basaltic composition**,** calc-alkaline affinity and emplaced within ocean floor basalt (OFB) regime. The study reflect chemical differences from margin to core, due to fractional crystallization where the magma at the margin are characterized by enrichment in CaO, Na_2O, Ni, Cu, Co, Cr, Zn and V relative to the core. On the other hand, the core samples are marked than margin samples by an increasing in MgO, Nb, Pb, Ga, Rb and Y contents. The margin samples are affected by partial melting and crustal contamination.

The partial melting processes result in higher concentrations of incompatibles (Rb, K) and lower contents of compatible elements (i.e Fe, Mg, Cr, Ni). The negative Nb anomalies (normalized to primitive mantle) are best attributed to crustal contamination. The studied hornblendite dykes can be produced by 10% - 18% batch melting of a lherzolite source (pyrolite composition with 11 ppm Zr and 2000 ppm Ni followed by > 50% fractional crystallization of olivine).

Keywords: Nugrus, lamprophyre, hornblendite, core and margins.

INTRODUCTION

Nugrus area consists of several lithostratigraphical units affected by metamorphic events and plutonic cycles. The metamorphic mafic-ultramafic rocks (preidotites, serpentinites, pyrexenites and metagabbros) are associated with low-grade metamorphic volcano-sedimentary terrains (Saleh, 1998 and Ibrahim et al., 2000) related to subduction processes (Island-arc and or active continental margin). The main metamorphic event occurred between 810-780 ma (Kroner et al., 1991). The metamorphic basement rocks in Nugrus area were intruded by syntectonic granites, isotropic gabbros and late-tectonic granites. The youngest events in the Arabian – Nubian Shield are composed of three main phases of dyke intrusion; (1) Late Precambrian metamorphosed dykes; (2) Late Precambrian non-metamorphosed dykes; and (3) Neogene dykes (Eyal and Eyal, 1987). Generally, the dykes follow largely the well recognized Precambrian trends in the Eastern Desert of Egypt specially Auolitic trend (NE - SW), Red Sea trend (NNW - SSE) and Tethyan trend (E - W).

Recently, Ibrahim et al., (2006 & 2007) recorded the occurrence of lamprophyre dykes bearing-REE, U and base metals mineralization in Abu Rusheid area (5 Km east the study area) and cross-cut cataclastic rocks. The youngest Pan-African magmatic event in Wadi Nugrus is represented by hornblendite dyke swarms cross-cut both monzogranite (late-tectonic granites) and isotropic gabbros (unlayerd). The investigated dykes were sampled along both their core (4 samples) and the margins (8 samples) in order to comparative between them based on differences in petrological and geochemical characters.

GEOLOGIC SETTING

The study area (at Wadi Nugrus) is located at 40 km southwest of Marsa Alam City on the Red Sea coast at intersection between longitude 34° 41` 30`` E and latitude 24° 37`` N. The sequence of the Precambrian rock units of Wadi Nugrus area (Fig. 1) are arranged as follows: (1) layered metagabbros, (2) ophiolitic mélange (consists of mafic-ultramafic fragments set in metasediment matrix); (3) syntectonic granites, (4) isotropic gabbros, (5) late-tectonic granites and (6) post-granite dykes and veins. The layered metagabbros are thrusted over the ophiolitic mélange (Ibrahim et al., 2001).

Isotropic gabbros occupy a total area about 4 km^2, coarse-grained and comprise olivine gabbro and hornblende gabbro (Saleh, 1998) with graditional contacts. Olivine gabbro constitute of plagioclase (>55 in vol. %), augite (35 in vol. %), olivine (5 -10 in vol. %) and accessories with opaques (=5 in vol. %). Cumulate textures are observed e.g. orthocumulate, adcumulate and poikilitically. Hornblende gabbros are mainly composed of plagioclase (An_{50-62}), hornblende, subordinate amount of augite and opaques. Normal zonation is rarely observed in some large plagioclase crystals. Small plagioclase crystals sometimes poikilitically enclosed in augite and/or hornblende forming ophitic texture. Some of the hornblende crystals enclose relics of augite confirming its secondary origin of being pseudomorph after augite.

B- Late-tectonic granites (monzogranites) cover a small area (1 km^2) with intrusive contacts against the older rocks and mainly composed of quartz, potash feldspars (microcline perthite and orthoclase, orthoclase perthite), plagioclase and biotite. Secondary minerals are represented by chlorite and sericite. Zircon, apatite, allanite and opaques are accessories.

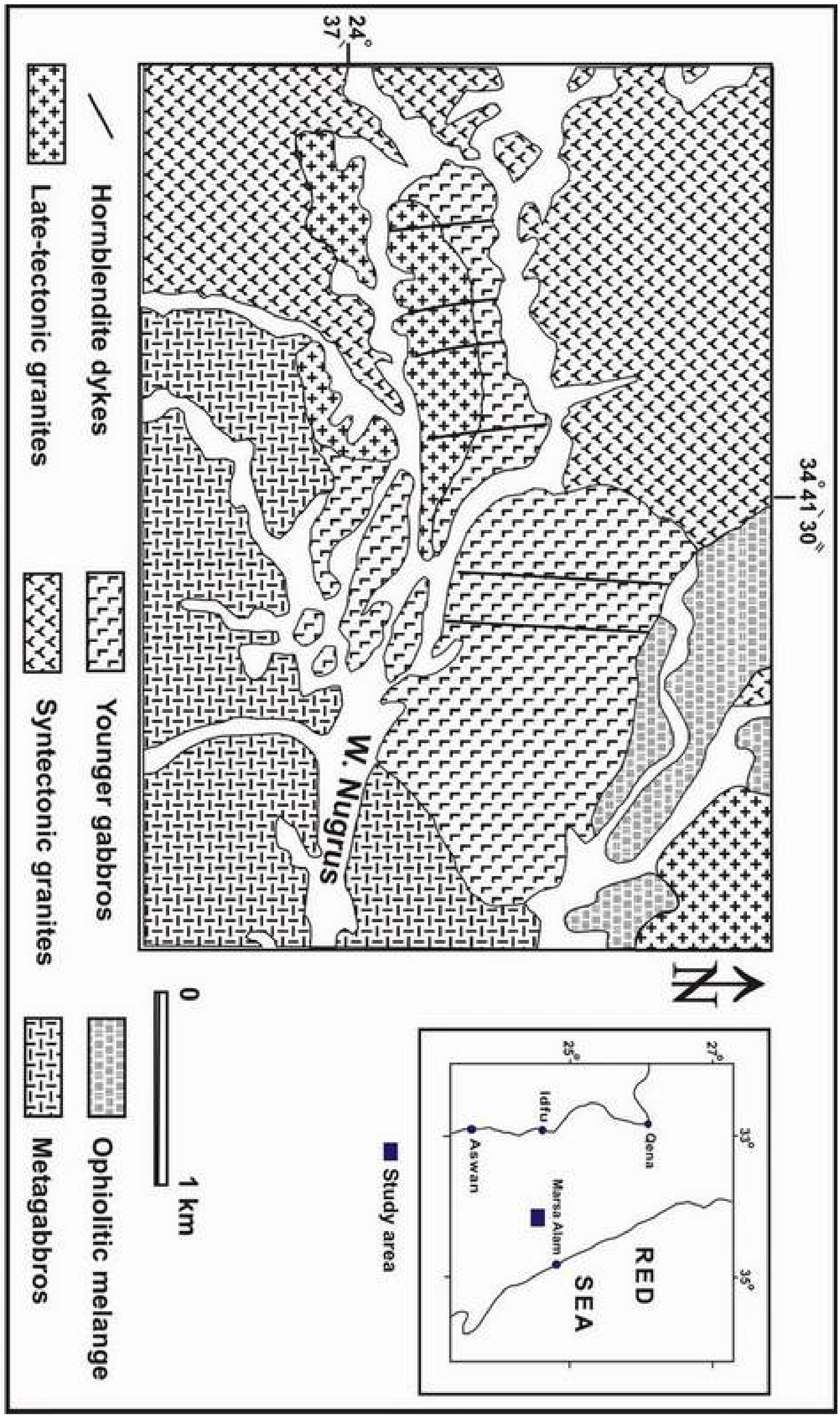

Fig. (1): Geologic map of the studied area, modified after Saleh (1998).

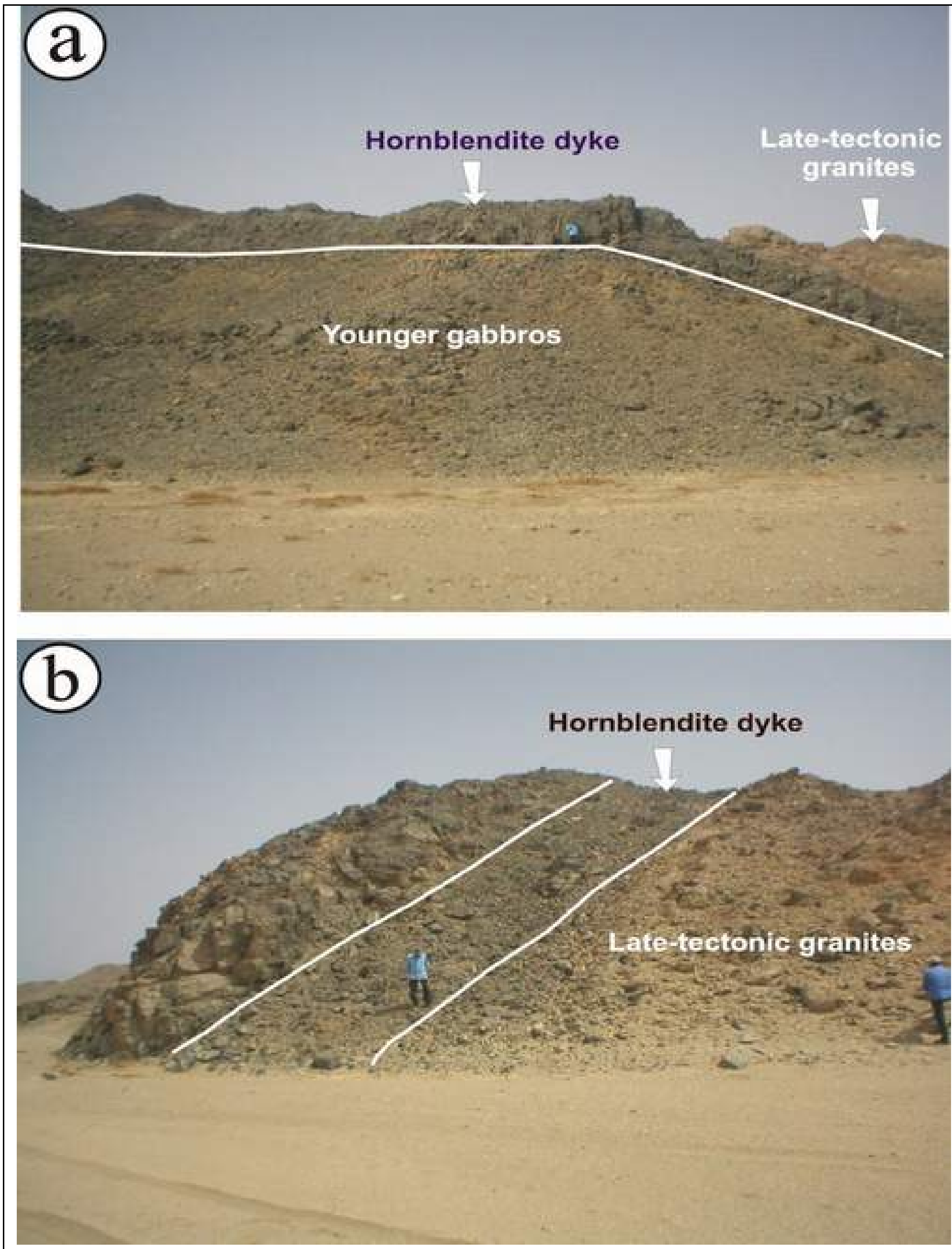

Fig. (2): Hornblendite dykes emplaced and cross-cut (a) younger gabbros and (b) late-tectonic granites, Abu Rusheid area.

C- Hornblendite dykes vary in thickness from 1 to 10 m, and are up to 1000 m long. The thickest dykes usually show chilled margins against both late-tectonic granites and isotropic gabbros up to 50 cm thick. They are vertical and strike generally N-S. The thick dykes display features of flow differentiation, leading to increased grain size (5 cm long) towards the core with completely absence of plagioclases.

Petrographically, the hornblendite dykes are coarse-grained, hard, massive and grayish-green colour. The core of hornblendite dykes is mainly composed of hornblende, tremolite, tremolite-actinolite and plagioclase (<10 %) , whereas the margins of the dykes constitute of hornblende, plagioclases (oligoclase and andesine in composition), tremolite and tremolite-actinolite. Opaques mantled by sphene (Fig. 3a), quartz and apatite are the main accessories in the core samples, while opaques and sphene (Fig. 3b) are only recorded in the margin samples. Hornblende crystals show simple twinning and corroded the plagioclases (Fig. 3c) and partially altered to chlorite (Fig. 3d) and iron-oxides especially along cleavage planes. Hornblende crystals show zonation due to the overgrowths of post cumulus material over the cores and crosscut by veinlets of quartz (Fig. 4e). Tremolite forms fine columnar crystals, whereas tremolite-actinolite forms fiber. They usually colourless and show faintly pleochroic from colourless to pale yellow. Plagioclase crystals are altered to sericite espatially in the margin samples (Fig. 3f).

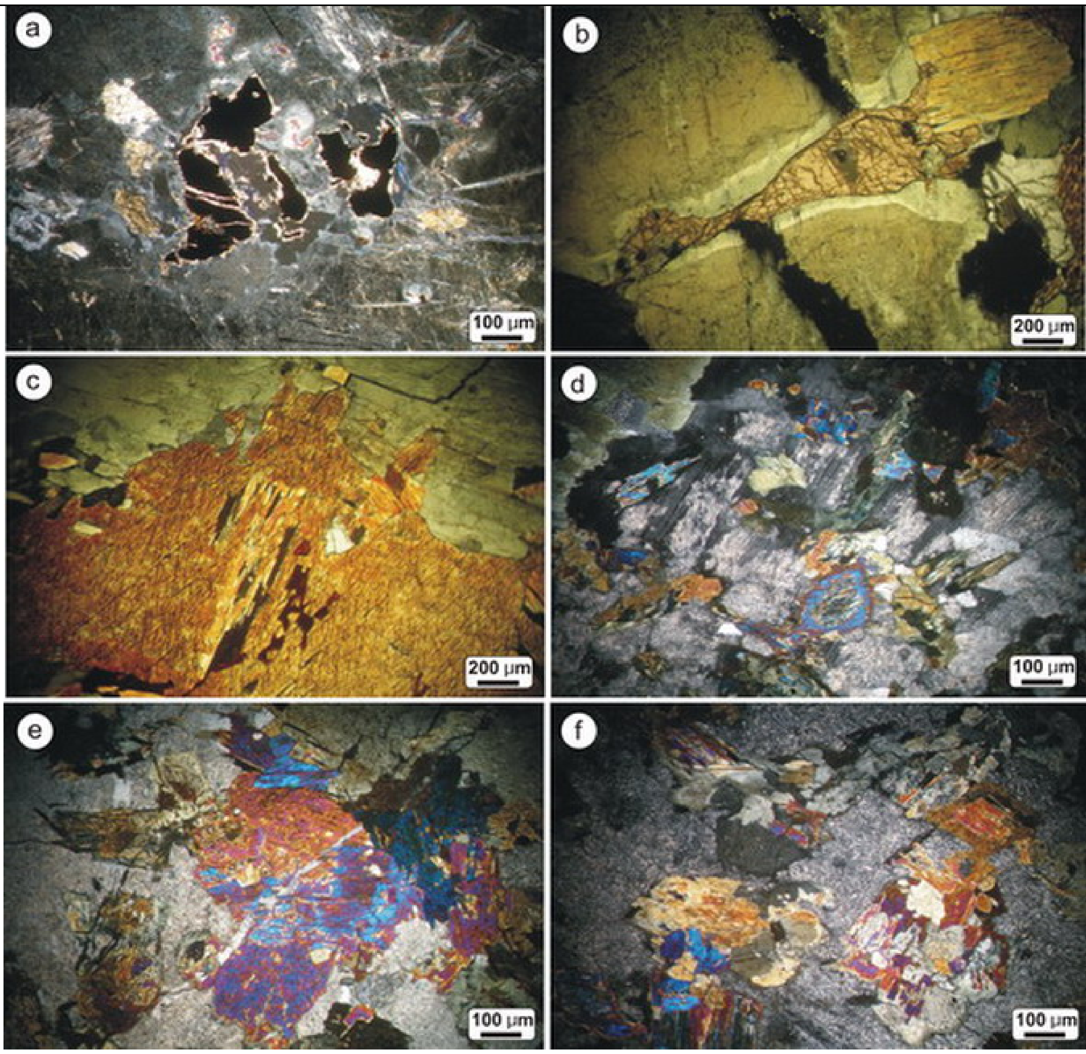

Fig. (3) : (a) Opaques mantled by sphene included in hornblende, core sample, (b) Irregular sphene associated opaques, margin sample, (c) Hornblendes are corroded the edge of plagioclases, core sample (d) Hornblede is altered to chlorite while the plagioclase are altered to serecite, margin sample, (e) Veinlets of quartz crosscut the hornblende, margin sample (f) Plagioclase altered to sericite, margin sample.

GEOCHEMISTRY

Representative analyses samples from core (4 samples) and margins (8 samples) of the hornblendite dykes are presented in Table 1. The samples were analyzed in the laboratories of the Nuclear Materials Authority (NMA) for major elements by the wet chemical and atomic absorption (with < 1 % error). Some trace elements are determined using the X-ray fluorescence technique (with 1-5 % error).

Table (1): Chemical analyses of major oxides (wt %) and some trace elements (ppm) of the studied hornblendite dykes, Abu Rusheid area.

Sample	Core of dykes				Margins of dykes							
	C-1	C-2	C-3	C-4	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8
SiO_2	50.9	51.2	49.7	50.1	50.8	50.5	51.15	50.2	51.50	48.12	49.27	49.43
TiO_2	0.98	0.9	1.1	0.91	1.10	0.90	1.01	1.20	1.35	1.60	1.88	1.55
Al_2O_3	5.2	5.8	6.8	6.5	17.61	17.23	14.5	18.0	17.8	9.96	11.40	10.92
Fe_2O_3	1.6	1.7	1.4	1.5	2.0	2.2	2.4	2.50	2.0	2.10	2.20	2.80
FeO	5.4	6.5	6.0	5.2	8.2	10.00	11.12	8.10	7.3	8.30	13.50	11.90
MnO	0.02	0.02	0.01	0.04	0.02	0.01	0.02	0.01	0.05	0.02	0.03	0.05
MgO	18.0	17.2	17.8	17.2	2.88	6.44	8.06	4.80	6.44	10.8	7.60	10.04
CaO	8.1	7.0	6.6	7.5	6.53	6.85	6.29	10.10	7.85	14.0	10.20	7.80
Na_2O	1.0	1.1	1.2	1.0	3.10	2.96	2.70	3.07	3.00	2.47	1.40	2.36
K_2O	4.0	3.5	3.7	3.8	0.63	0.02	0.94	0.68	0.78	0.73	0.80	0.7
P_2O_5	0.29	0.26	0.25	0.3	0.22	0.39	0.32	0.41	0.19	0.20	0.30	0.29
H_2O	0.2	0.25	0.27	0.18	0.17	0.08	0.10	0.44	0.3	0.11	0.18	0.05
T.O.M.	0.7	0.6	0.65	0.75	0.52	0.45	0.63	0.66	0.38	0.90	0.49	0.95
H_2O+	3.2	3.8	3.9	3.7	1.15	1.26	1.14	0.16	0,96	0.58	0.83	0.70
Total%	99.59	99.83	99.38	98.58	99.13	100.31	100.41	100.32	99.9	99.9	100.09	99.52

Trace elements in ppm

Zr	45	16	78	76	114	115	95	105	88	87	87	73
Y	66	65	94	103	14	17	17	14	16	19	13	18
Sr	21	18	14	8	417	943	569	862	464	285	464	294
Rb	760	715	892	1080	4	5	3	5	3	2	3	2
Nb	220	213	317	316	3	4	3	5	3	5	4	5
Cu	29	30	26	25	55	31	47	38	57	47	55	39
Ni	7	7	7	7	142	151	119	144	149	165	155	169
Co	7	7	8	7	45	44	46	45	47	52	47	51
Cr	10	11	11	9	358	348	318	344	390	476	416	484
Zn	41	32	46	52	100	98	117	69	119	136	112	118
Ga	82	46	90	97	5	19	2	3	7	25	2	29
Ba	2	29	3	47	94	47	71	60	91	106	28	60
Pb	69	43	46	39	33	5	13	9	4	14	20	3
V	10	9	10	9	534	522	224	513	252	291	268	282

On the basis of SiO_2 versus (Na_2O + K_2O) after Cox et al., (1979), all the hornblendite dyke samples (core or margins) have a basaltic composition (Fig. 4). The samples show more evolved lithologies including Hawaiite and Tephrite basalts.

Rock (1991) used Nb/Pb versus V/Cr for discriminated between calk alkaline lamprophyre (CAL), alkaline lamprophyre (AL), lamporitic lamprophyre (LL) and ultra mafic lamprophyre (UML). The variation diagram reveals that the margin hornblendite dyke samples show calc-alkaline affinities (Fig. 5).

On the basis of Al_2O_3 (wt%) versus CaO (wt%) to discriminate between lamprophyre (Group III), kimberlite (Group II) and lamproite (Group I) after Foley et al., (1987). The hornblendite dyke samples lie within lamprophyre field (group III) (Fig. 6).

The studied hornblendite dykes reflect chemical differences from margin to core. The magma at the margins is characterized by enrichment in CaO, Na_2O, Ni, Cu, Co, Cr, Zn and V relative to the magma at the core. On the other hand, the core samples are marked than margin samples by an increasing in MgO, Nb, Pb, Ga, Rb, Zn and Y contents (Fig. 7).

The tectonic setting, according to Pearce (1975), Meschede (1986) and Pearce and Cann (1973) indicate that, the both core and margin samples fall within ocean floor basalt (OFB), within plate tholeiitic (AII, C) and within plate (D) fields (Figs. 8, 9 & 10 respectively).

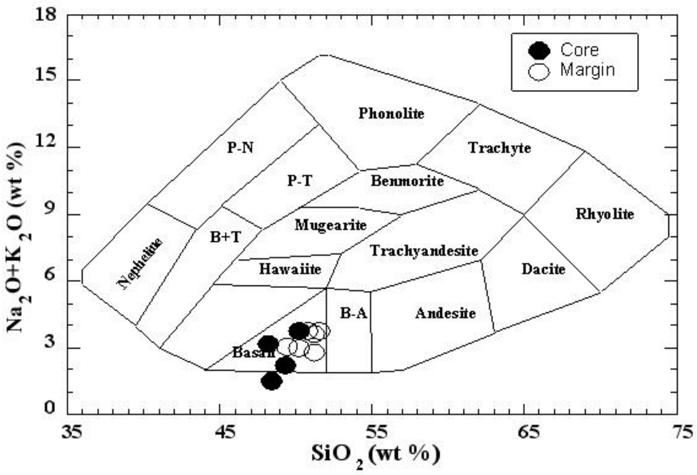

Fig. (4): Alkali oxides (wt %) versus SiO_2 (wt %) of Cox et al. (1979). B+T= Basalts and Tephrites, F-T=Fonalitic Tephrites, F-N= Fonalitic Nephelenites.

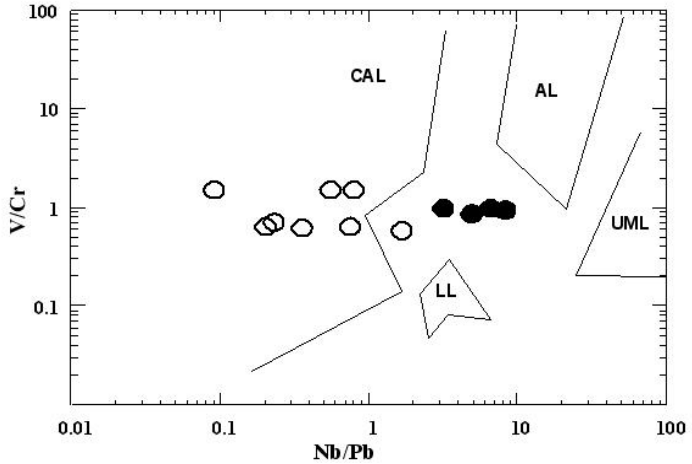

Fig. (5): V/Cr versus Nb/Pb after Rock (1991) for discriminated between CAL= calk alkaline lamprophyre, AL= alkaline lamprophyre, LL= Lamporitic lamprophyre and UML= ultra mafic lamprophyre. (Symbols as in Fig. 3)

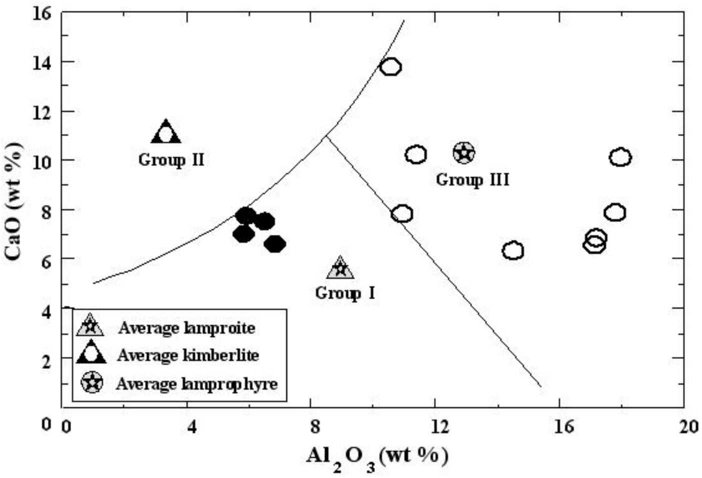

Fig. (6): Al_2O_3 versus CaO diagram after Foley et al., (1987) showing studied samples are plotting in both Group-I (lamproite) and Group-III (lamprophyre). (Symbols as in Fig. 3)

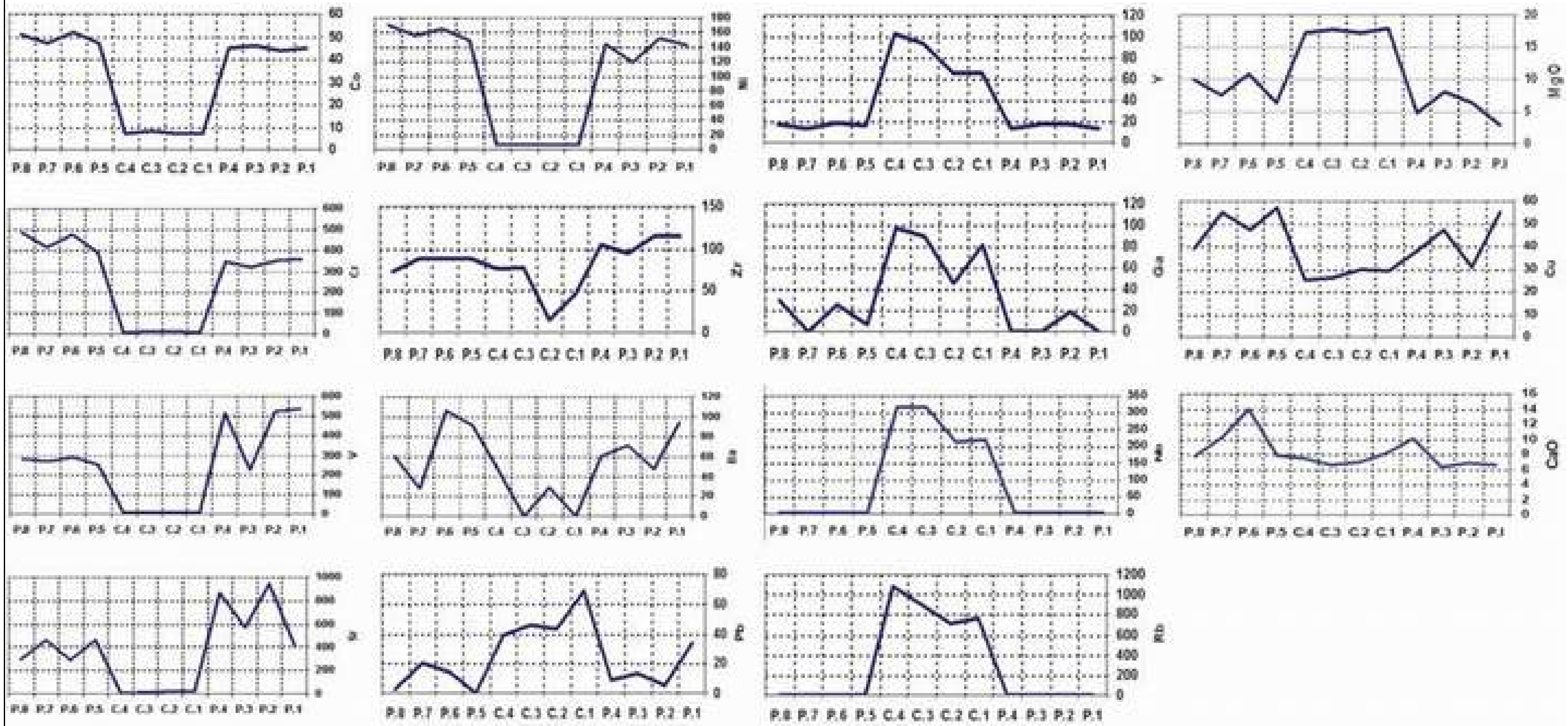

Fig.(7): Distribution of some major and trace elements along hornblendite dyke as well as the adjacent wall zones, Abu Rusheid area.

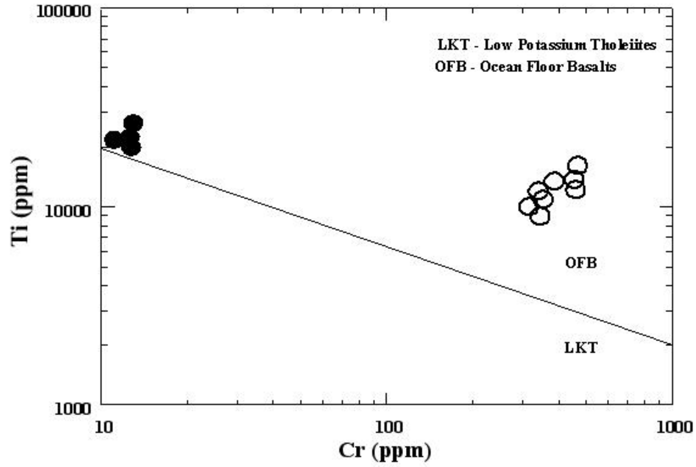

Fig. (8): Ti (ppm) versus Cr (ppm) diagram after Pearce (1975) for hornblendite dykes. (Symbols as in Fig. 3)

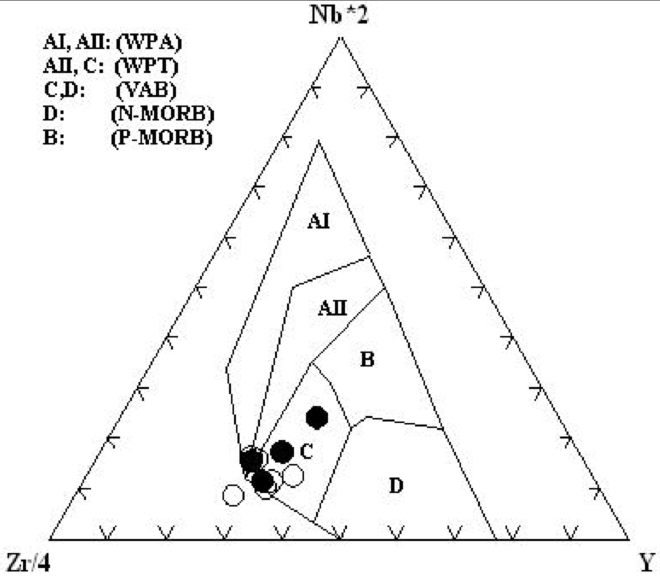

Fig. (9): The Zr/4-2Nb-Y ternary diagram after Meschede (1986) for hornblendite dykes. (Symbols as in Fig. 3)

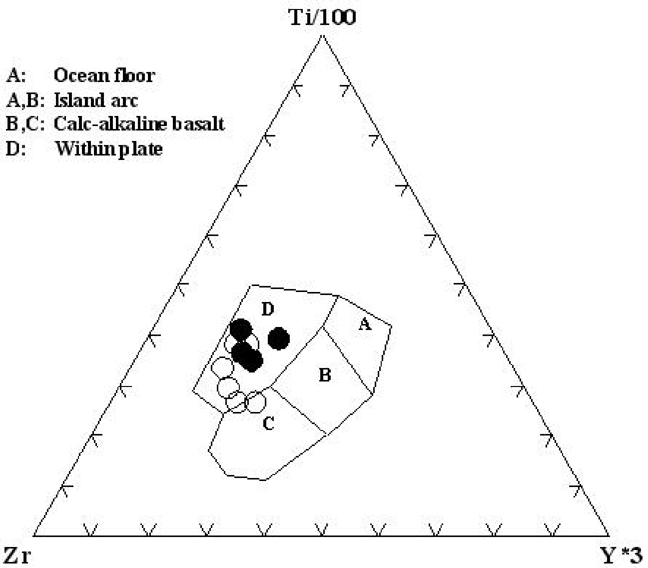

Fig. (10): Zr-Ti-Y diagram after Pearce and Cann, (1973) for hornblendite dykes. (Symbols as in Fig. 3)

PETROGENESIS

The source of basic dykes has been ascribed to: 1) a high degree of fractionation (Fodor, 1987), 2) a low degree of partial melting (Dupuy et al; 1988) and 3) a crustal contamination (Fodor, Op.cit).

The ratio between two highly incompatible elements (e. g. K/Rb, K/Ba) is not significantly affected either by fractional crystallization or by the low degree of partial melting of the basaltic suites, and these ratios reflect those in the magma source (Saunders et al., 1988). The significant variations in these ratios either in core or margin samples imply, therefore, a degree of heterogeneous of magma source (Table 2) and attributed to crustal contamination.

The studied hornblendite dykes are of moderate Ti-contents. The coexistence of both high and low TiO_2 magmas (case study) has also been interpreted as due to mantle heterogeneity (Bellieni et al., 1990).

Table (2): Comparison between the core and margin of the studied hornblendite dykes, Abu Rusheid area.

	K/Rb	K/Ba	Ba/Rb	Rb/Sr	K/Nb	Ba/Nb	Ti/Zr	P/Zr	Zr/Nb	Ti/Nb	Ti/Y
Core	36	1556	0.02	54	117	0.07	108	20	0.2	22	71
Margin	1826	78	23	0.005	1369	17.5	84	12	31	1985	496

The more or less inverse correlation between Sr and Rb (Table 1) in both core and margin samples can be attributed to effects of fractional crystallization dominated by the removal of plagioclase (Whalen, 1985) from the core as well as Fe- Ti- oxides toward the margins of the hornblendite dykes, which resulted in decreasing Sr and Ti in the core samples relative to margin ones.

Primary mantle derived alkali basalts or tholeiitic melts normally have Mg index (mg*= 100*(MgO/40.3) / (MgO/40.3 + FeO/71.85 + Fe_2O_3/79.85) of 0.68 - 0.75 and Ni contents of 300-500 ppm (Sun and Hanson, 1975; Frey et al; 1978). None of core or margin samples meet these conditions (not of primary mantle melt).

The normalized incompatible trace elements abundance patterns in which the order of the primitive source (Hofmann, 1988) are illustrated in Fig. (11). The latter shows a relative depletion in Ba and Sr in core samples ,as well as, enrichment in Rb, K, Nb and Y compared with margin samples. The negative Nb anomalies (normalized to primitive mantle) in margin samples are best attributed to crustal contamination

(Hofmann and Stein, 1994). The Nugrus hornblendite dykes have geochemical characters, reflecting their derivation from a subcontinential lithospheric mantle source.

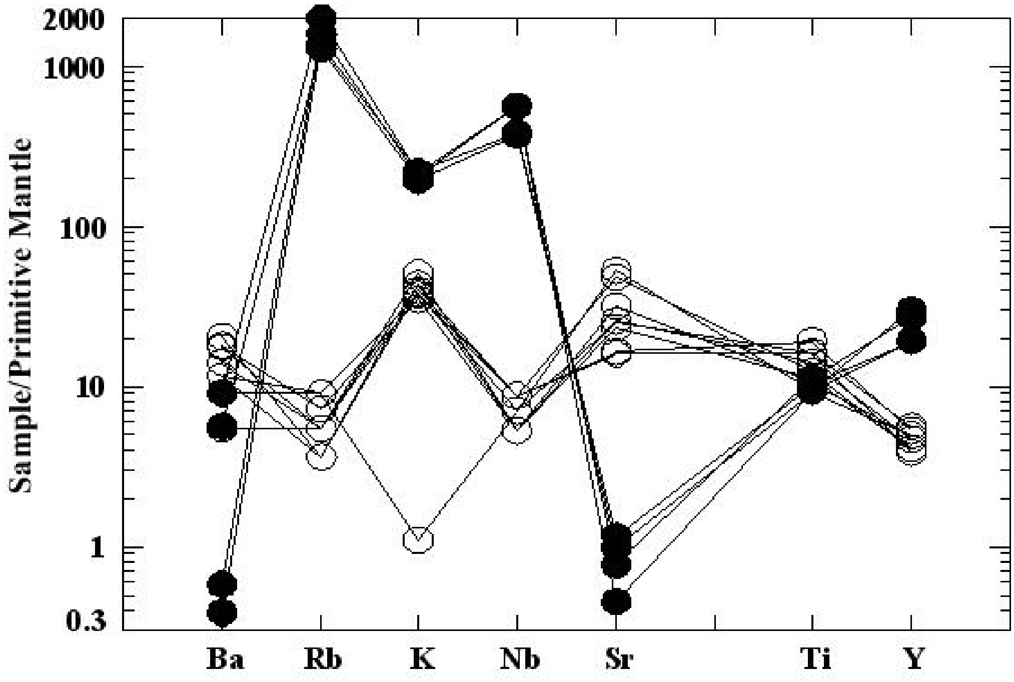

Fig. (11): Incompatible element abundances, normalized to primordial mantle values (McDonough and Sun, 1988) for basic dykes. (Symbols as in Fig. 3)

The partial melting process should not only result in higher concentrations of incompatibles (Rb, K) but also yield lower contents of compatible elements (i.e Fe, Mg, Cr, Ni), which is obviously the case study (Table 1) in the core samples. The contamination by any partial melt should increase the LILE (K, Rb) concentration and probably some of the HFSE (Nb, Y) in the core samples.

The assimilation of partial melt and/or metasomatic fluids during the core formation will enrich both Nb up to (317 ppm) and Rb up to (1080 ppm). The composition of the lower crust does not allow the production of a partial melt or fluid, which is enriched in Nb and depleted in LILE (Friz – Topfer, 1991).

Model based on Ni-Zr (Figure 12; after Condie et al 1987) suggests that the studied Nugrus hornblendite dykes can be produced by 10% - 18% batch melting of a lherzolite source (pyrolite composition with 11 ppm Zr and 2000 ppm Ni followed by > 50% fractional crystallization of olivine). Any melt generated by 10% - 18% melting of a mantle may show alkaline basaltic nature but due to differentiation of such magma prior to its emplacement, the studied hornblendite dyke samples show basaltic nature.

SUMMARY AND CONCLUSIONS

The youngest Pan-African magmatic event in Wadi Nugrus is represented by hornblendite dyke swarms cross-cut both Late-tectonic granites (monzogranite) and isotropic gabbros. The studied hornblendite samples (core or margins) have a basaltic composition, calc-alkaline affinity and emplaced within ocean floor basalt (OFB) regime.

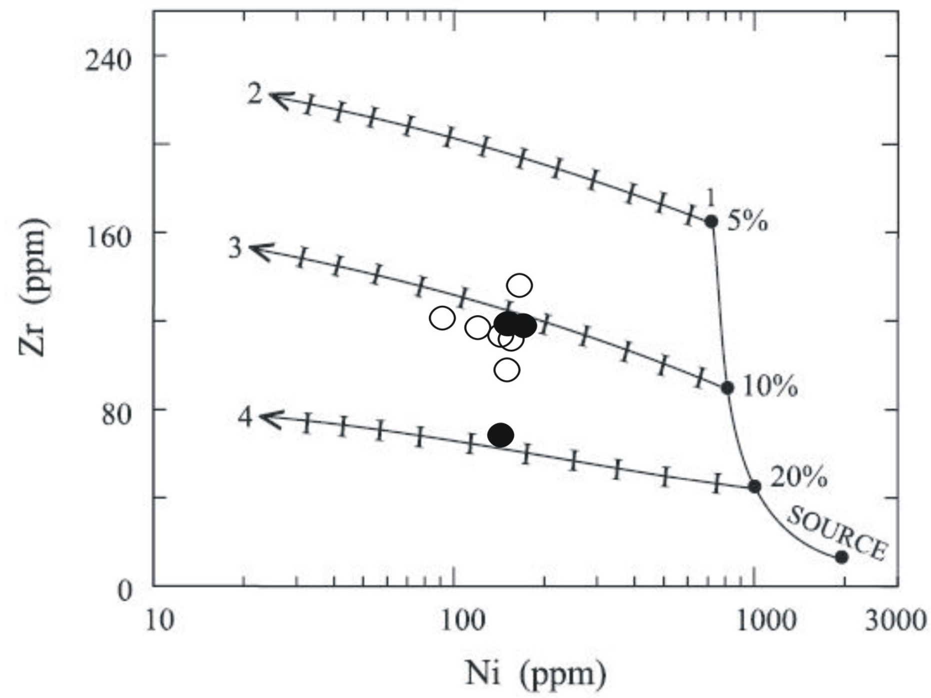

Fig. (12): Petrogenetic model based on Zr and Ni (after Condie et al 1987). (1) Batch melting curve at 1500◦C (1 atm. equivalent) with degrees of melting noted in per cent. Melting relation of assumed lherzolite mantle source (11 ppm Zr and 2000 ppm Ni) is as given by Rajamani et al (1985); (2, 3 and 4): olivine fractionation curves with per cent of olivine removal noted in 5% increments. (Symbols as in Fig. 3)

The study reflect chemical differences from margin to core, due to fractional crystallization where the magma at the margins of the hornblendite dykes is characterized by enrichment in CaO, Na_2O, Ni, Cu, Co, Cr, Zn and V relative to the core. On the other hand, the core samples are marked than margin samples by an increasing in MgO, Nb, Pb, Ga, Rb, Zn and Y contents. The margin samples are affected by partial melting and crustal contamination. The partial melting process results in higher concentrations of incompatibles (Rb, K) and lower contents of compatible elements (i.e Fe, Mg, Cr, Ni). The negative Nb anomalies (normalized to primitive mantle) are best attributed to crustal contamination. The studied hornblendite dykes can be produced by 10% - 18% batch melting of a lherzolite source (pyrolite composition with 11 ppm Zr and 2000 ppm Ni followed by > 50% fractional crystallization of olivine).

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