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PETROGENESIS OF GABAL RAMEID ALKALINE RING COMPLEX, HOOTH AREA, REPUBLIC OF YEMEN

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ABSTRACT

Gabal Rameid magmatic complex (~ 11km²) represents an excellent example of ring complex of Yemen. It is located in the southeastern part of Hooth town(NW Sana'a). This complex emplaced within Jurassic limestone ofAmran Group reflecting a narrow contact zone of pneumatolytic phase (~ 3.25 km²). The present work represents the first record of the ring complex in Yemen. The studied magmatic complex shows distinct concentric compositional zoning with porphyritic syenite, outer ring sheet (~ 2.75 km²), trachy-syenite, intermediate ring sheet (~ 3.5 km²) and quartz-syenite, inner ring sheet (~ 4.75 km²). A number of different fault styles cut across the ring structure extending (in part) to the pneumatolytic contact zone.

The field relations and petrochemical characteristics of the Gabal Rameid ring complex reflect co-magmatic nature of the entire suite, in which fractional crystallization played an important role in the evolution of the magmatic complex. On the other hand, these rocks are characteristic of intraplate environment of A-type suite evolved in three categories with multi-pulses of emplacement with an OIB-type source.

INTRODUCTION

The Republic of Yemen is located in the southern part of the Arabian Peninsula (Fig. 1). Geukens (1966), Grolier and Overstreet (1978) initiated the regional geology of Yemen. A comprehensive geology of Yemen have been done by many workers (e.g. Heikal, 1987; Ba- Battat, 1991; Robertson Group, 1992; Sakran, 1993 and Beydoun *et al.*, 1998).

Robertson Group (op.cit) summarized eight major Lithostratigraphic units (Fig. 1). which were superimposed upon each other, either depositionally or tectonically as follows:

Top:

Quaternary Volcanics (Pliocene - Recent) comprise mainly basaltic rocks.

Oligo-Miocene Syn-rift (Shahr Group) comprise calstic carbonates in combination with alkaline syenites (ring complexes), which is recorded for the first time in the present work.

Tertiary Pre-rift sediments (Hadramout Group) comprise clastic and shallow marine fades.

Cenozoic Volcanics (Yemen Volcanic Group) comprises basalt-rhyolite suite.

Tertiary granites that emplaced along the marginal Red Sea representing the exposed rocks of a chain of caldera centers.

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Mesozoic sediments include Triassic - Jurassic clastic sediments and carbonates.

Late Proterozoic Wajid Sandstones?

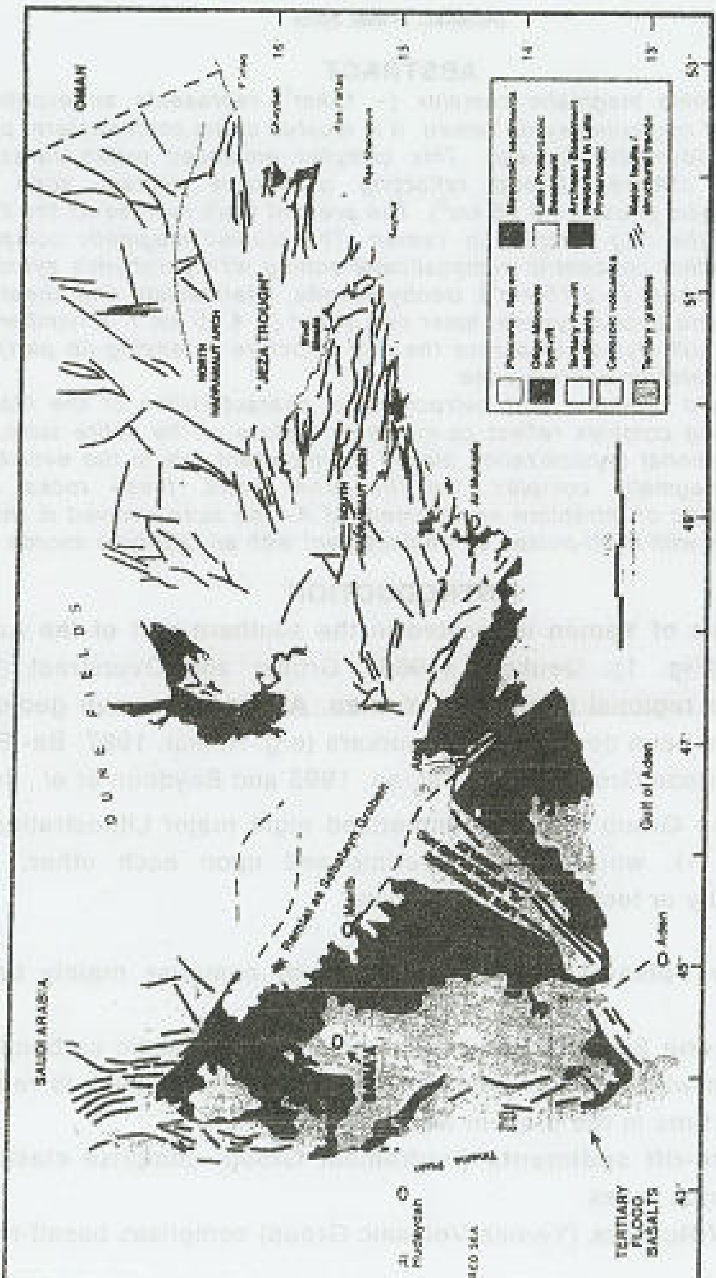


Fig. 1: Geological map of the Republic of Yemen (after Robertson Group PLC 1991). Square indicates the location of the studied area.

Bottom : **Precambrian rocks** include Late Archean to Proterzoic gneisses terrains, Pan-African island-arcs and suture zone.

The occurrences and tectonic environment of such alkaline ring complex in Yemen have been recorded for the first time in the present work. Very few geological studies have been carried out on Gabal Rameid area(Grolier and Over street,1978 and Robertson Group, 1992). They considered Gabal Rameid as a trachyte plug pertaining to Tertiary volcanics.

The aim of this study is to describe the petrochemical characteristics of Gabal Rameid ring complex and to evaluate the magma source, the role of magma differentiation processes, and the tectonic setting of the complex.

Field Aspects

The Gabal Rameid ring complex (Figs. 2 & 3a), located in the southeastern part to the Hooth town (NW Sana'a, Fig. 1) (Latitude 16° 14' 7" N, Longitude 43° 59' 1" E), is emplaced within Jurassic Limestone of Amran Group (Fig. 3b).

Al-Kadsey and Al-Onwa (2002) were the first to note the occurrence of the Gabal Rameid ring complex, and described it as an alkaline trachyte-rhyolitic body.

Gabal Rameid ring complex is a circular structure covers about 11 km^2. It comprises porphyritic seynite outer ring (~ 2.75 km^2) (Fig. 3c), trachy-syenite intermediate ring (~ 3.5 km^2) and quartz-syenite inner ring (~ 4.75 km^2). A number of generally NE and ENE-trending basaltic to aplitic dykes cut across the ring structure and its host rocks.

Gabal Rameid complex (Fig. 2) is probably related to the Tertiary rifting process. The contacts among the ring sheets within the complex are almost vertical ,while the contacts of the inner part of the complex are steeply dip towards the center.

On the other hand, the contact between the outer ring structure of the complex and limestone host is characterized by zone of neumatolytic phase forming replacement zones (Fig. 2) as follows:

1. Zone of dark silicate minerals (unmappable) such as garnet and chlorite (contact silicates) associated with minor fluorite and tourmaline crystals.
2. Zone of light silicate minerals (unmappable) such as wollastonite, vesuvianite associated with minor constituents of hematite and goethite.
3. Thermal influence zone (3.25 km^2) reflects multi-coloured marble of good quality and strong dolomitization (Fig. 3c).

4. The host limestone (nearly horizontal to low-inclined beds) exhibits a various degrees of weathering and slickenside striations. The mineralized pneumalytotic phase is very small, irregular and various, therefore it is very difficult to explore and estimate.

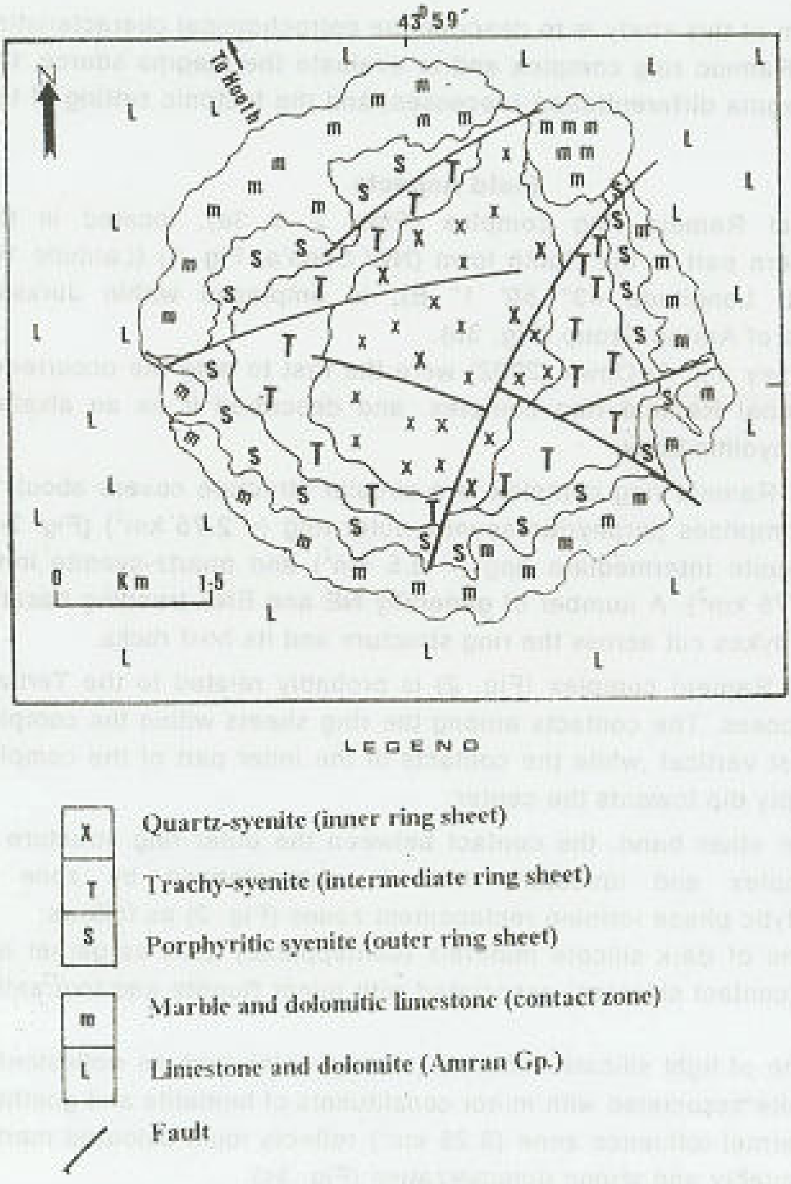


Fig.2 : Geological map of G. Rameid ring complex, Hooth area, Yemen .

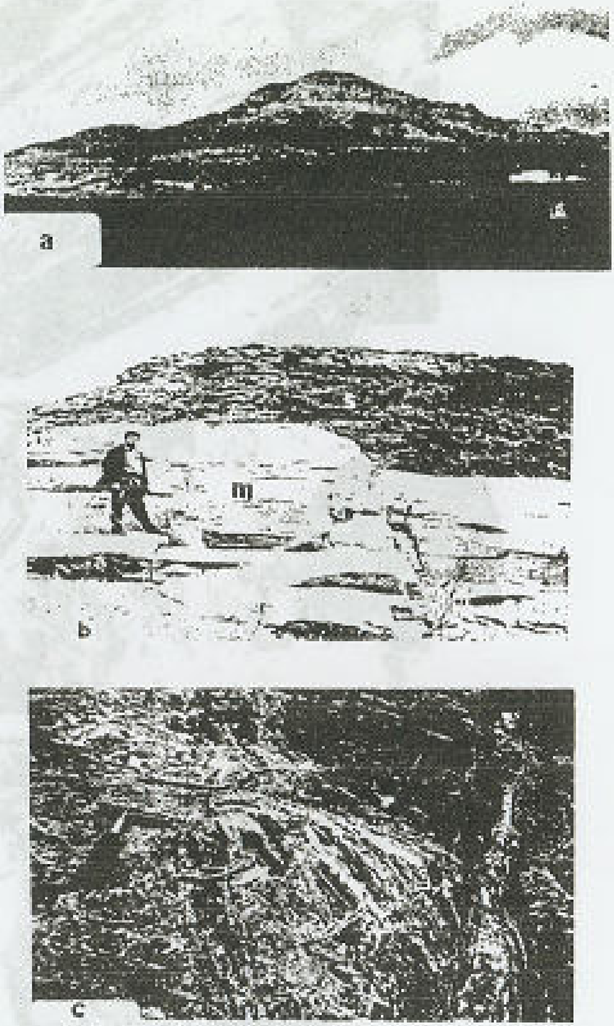


Fig. 3 : a) Panoremic view showing G. Rameid ring complex.Photolooking NNW. b) Sharp contact between marble-dolomitic limestone (m) and the maginal part of the study ring complex (S). c) Pophyritic syenitic outer ring sheet (margin)of the study ring complex.

Petrographic Features

Most lithologies of the Gabal Rameid ring complex show a single phase (mesoperthite) and are therefore hypersolvus. Rare, early formed oligoclase (Fig. 4a) crystals are found only in the upper ring sheet (porphyritic syenite).

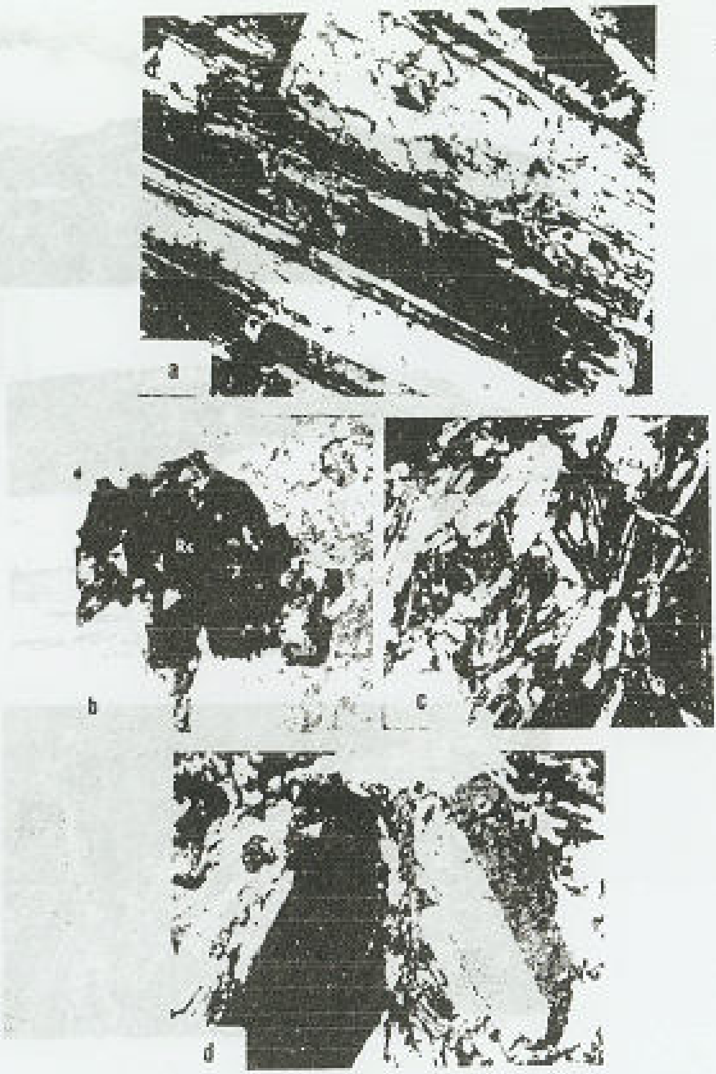


Fig. 4: Photomicrographs of the study ring complex.

a) Larghe crystal of plagioclase embedded in syenitic groundmass. Porphyritic syenite. C.N., X 100.

b) Riebeckite clots (Rc) in trachy-syenitic intermediate ring sheet. PL., X150.

c) Typical trachytoid texture in trachy-syenitic ring sheet. C.N., X 150.

d) Alkali feldspar invades quartz in quartz-syenitic inner ring sheet. C.N., X 100.

The porphyritic syenite is fine grained groundmass (Fig.4a) in which phenocrysts are alkali feldspar, abundant bluish-green riebeckite and minor hedenbergite pyroxene.

The trachy-syenite shows several textural varieties representing a trachytic flow texture (Fig.4b) . Patch and String perthite are most common. A clots of riebeckite (Fig. 4b) are strongly distributed within a trachytoid texture (Fig. 4c). Annitic biotite, zircon, apatite, astrophyllite and fluorite are the main accessory phases. In addition, orthoclase microperthite shows Carlsbad and baveno twinning (Fig.4d) .

The quartz syenite (Fig.4c) is texturally similar to the porphyritic syenite but differs from it by the high degree of transformation of its mafic minerals to opaques.Astrophyllite commonly replaces amphibole .

Major and Trace Elements Geochemistry

Major and trace element abundances and the calculated CIPW norms are given in Table 1. The rocks classify as syenite in the alkalis vs. silica diagram after Cox *et al*. 1979. All rock types plot within the alkaline field (Fig. 5).

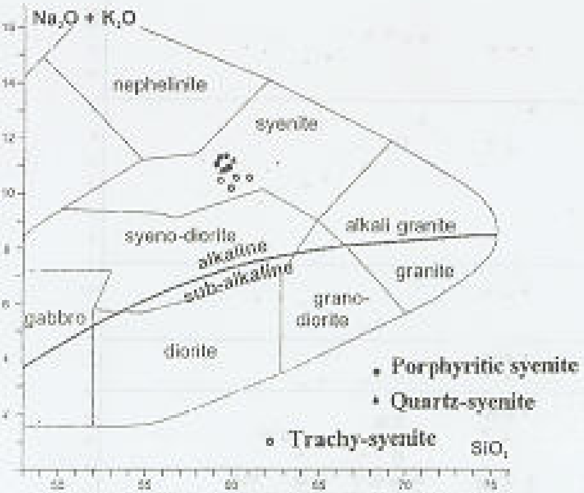


Fig. 5: SiO_2 vs. Na_2O + K_2O variation diagram after Cox et al. (1979). Alkaline/subalkaline division after Miyashiro (1978).

The concentration patterns of the different elements from the marginal (porphyritic syenite) to the central lithology (quartz syenite) shows various trends of evolution (Fig. 6).

The first group is represented by the porphyritic syenite showing an evolution trend towards higher CaO, MgO, FeOt, normative colour index, Sr, P_2O_5 and TiO_2. The second group contains trachy-syenite. It is enriched in FeOt, Al_2O_3, Zr, Y, Sr, Rb and alkalis but the colour index generally decreases (Fig. 6a &b).

a.

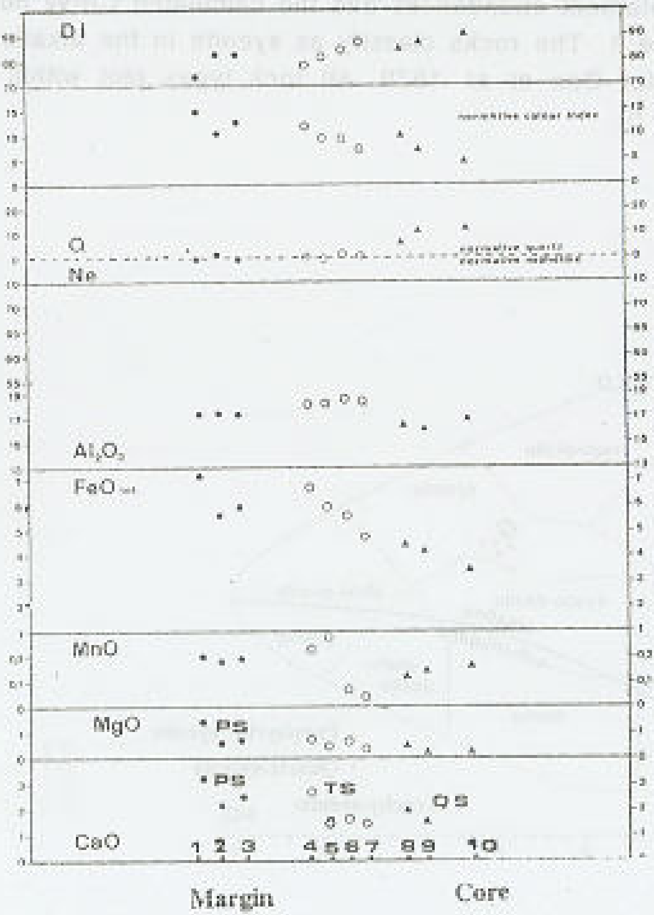


Fig. 6: a) Variation in differentiation index (DI), normative colour index, and normative quartz and nepheline percentage. Numbers are sample numbers . PS : Porphyritic syenite ; TS : trachy-syenite ; QS : quartz-syenite/ b) Trace element concentration ratios .

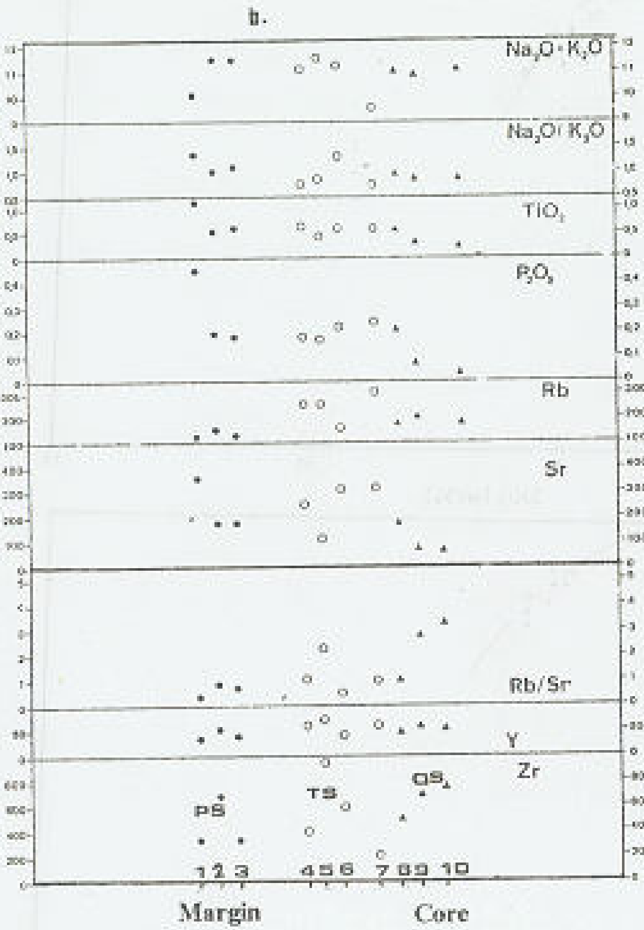


Fig. 6 (continued)

The third group comprises quartz syenites is characterized by silica contents > 61% and clear trend in the concentration of the most elements (Fig. 6a & b). This trend is most evident by the gradual increase in silica, quartz content and differentiation index values and decrease in colour index, FeOt, Al_2O_3, MgO. Rb.Sr.TiO_2 and total alkalis.

Each of the three lithologic groups was implaced in such magmatic pulses, which had already been in a solidified state as shown by the contact relationships. Also, the negative correlation between some trace element ratios and SiO_2 (Fig. 7) indicates that the magmatic complex has undergone different stages of evolution.

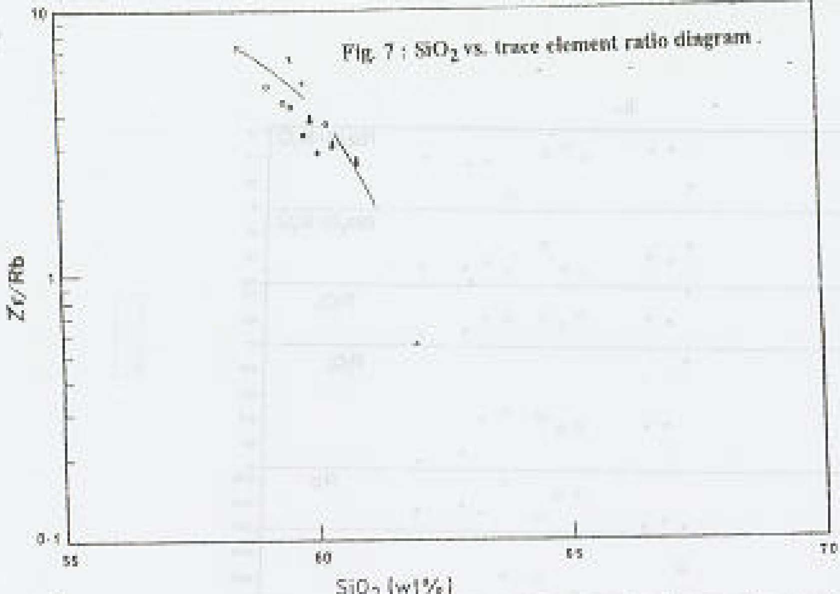
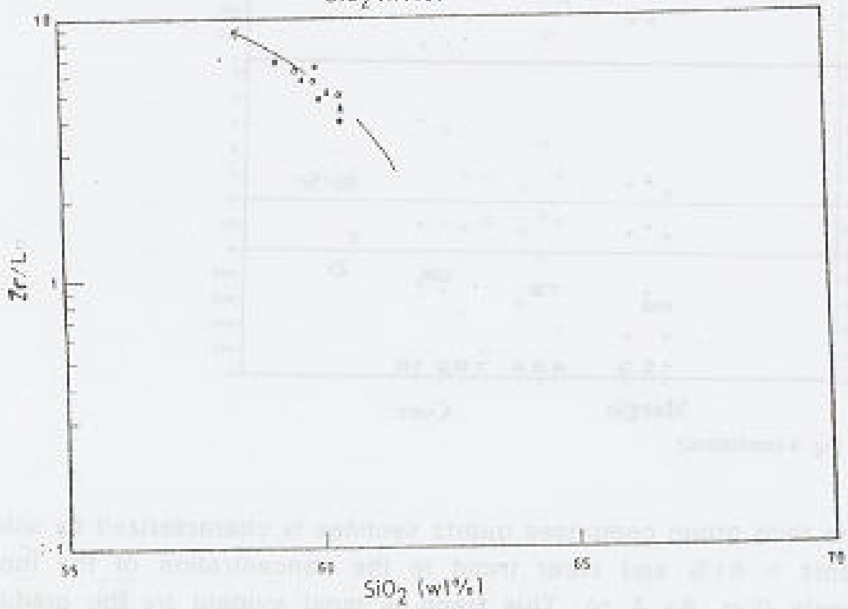


Fig. 7 : SiO_2 vs. trace element ratio diagram .



Rare-earth elements

In the early porphyritic syenite, the total REE concentrations decrease with increasing distance from the margin of the intrusion (see Table 1). The porphyritic syenite show scatter trend (Fig. 8), whereas trachy-syenite and quartz seynite characterize a negative correlation (Fig. 8).

Thus, there is a clear relationship between total REE concentration and evolution of separate magmatic pulses, with the lower REE concentrations characterizing the more evolved and relative younger lithologies within each pulse (see arrows in Fig. 8).

chondrite-normalized REE patterns are subparallel and largely uniform within each lithologic unit within the complex (Fig. 9). All samples show enrichment in LREE and depletion in HREE and display pronounced fractionation.

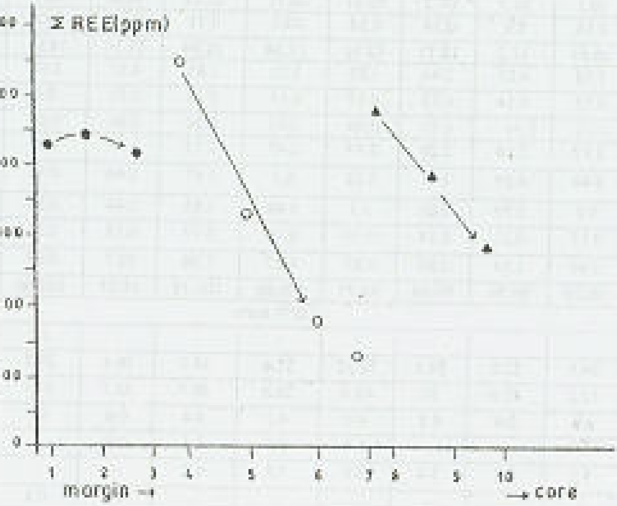


Fig. 8 : Total REEs . Arrows indicate individual evolution trends due to apatite fractionation .

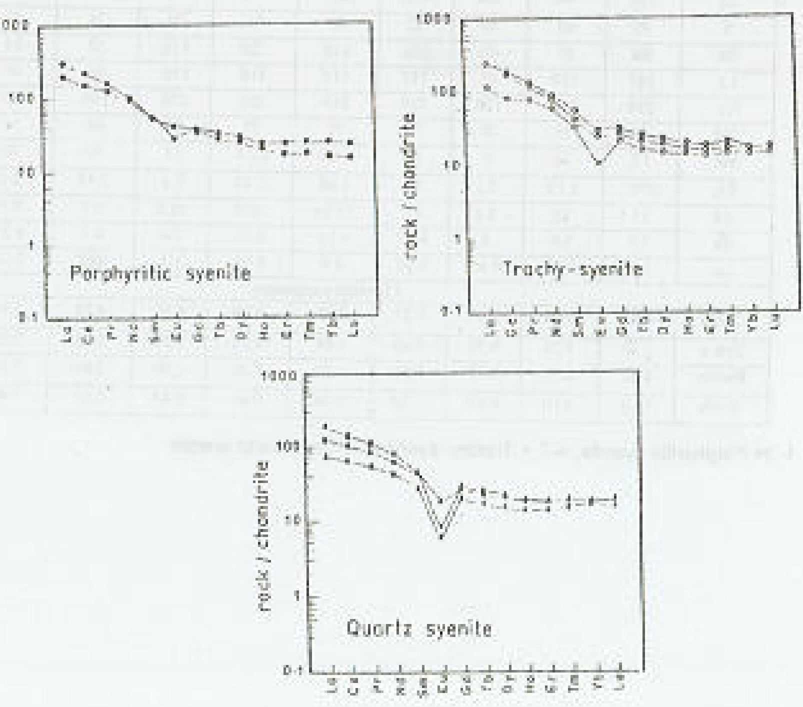


Fig. 9 : Chondrite-normalized REEs spidergrams. Normalization values are after Taylor and McLennan (1985).

Table 1: Major, trace and rare earth elements concetrations and CIPW norm vaules of whole rock smaples of G. Ramied ring oomplex , Hooth area, Republic of Yemen

Sample	1	2	3	4	5	6	7	8	9	10
Major elements (wt%)										
SiO_2	59.5	58.7	61.2	59.61	60.51	60.12	58.4	61.1	61.2	61.58
TiO_2	0.56	0.6	0.34	0.54	0.63	0.51	0.44	0.62	0.37	0.62
Al_2O_3	16.65	17.2	18.71	17.32	17.24	18.34	18.14	18.61	18.34	16.2
FeO	3.18	4.22	2.46	1.85	3.02	2.85	4.55	2.61	0.74	2.34
MnO	0.15	0.14	0.12	0.17	0.18	0.18	0.27	0.1	0.05	0.5
MgO	1.71	1.94	0.35	0.54	0.68	0.56	0.46	0.66	0.34	2.25
CaO	3.12	3.94	2.28	2.14	2.45	2.17	1.44	1.66	1.51	1.53
Na_2O	6.44	6.24	6.41	5.72	6.1	5.85	5.44	6.36	6.14	4.1
K_2O	4.2	3.77	5.61	5.7	5.44	5.85	5.44	6.36	6.14	4.1
P_2O_5	0.17	0.21	0.14	0.19	0.18	0.17	0.17	0.22	0.11	0.24
LOI	0.94	1.14	0.86	0.87	0.82	1.04	10.7	0.97	1.44	0.78
Total	99.09	99.76	99.98	98.77	100.66	100.15	97.77	101.06	100.45	100.1
CIPW norm										
Q	-	-	-	-	-	-	-	1.2	0.1	14.5
Or	24.5	22.5	34.6	33.02	32.4	34.7	36.4	28.8	34.2	33.4
Ab	52.2	47.6	50	48.4	50.4	49.7	43.7	54.1	52	34.5
An	4.8	8.4	6.8	4.9	4.2	8.4	6.4	6.7	5.4	6.2
Ne	-	-	-	1.4	2.3	2.4	0.9	-	-	-
Di	7.2	8.2	3.4	2.8	5.8	1.2	-	-	1.0	-
C	-	-	-	-	-	-	0.5	0.4	-	0.6
Trace and REE's elements (ppm)										
Rb	171	140	130	150	130	170	256	160	220	280
Sr	340	350	250	175	180	225	115	310	190	380
Ba	900	580	540	760	770	777	430	1000	780	450
Zr	770	790	370	490	350	510	1100	700	680	320
Y	70	60	40	92	40	51	70	34	42	32
Nb	50	55	60	120	118	125	150	57	94	40
La	140	110	65	113	113	118	150	90	90	45
Ce	230	210	120	220	216	210	276	164	161	76
Nd	70	75	47	74	72	77	95	64	56	42
Sm	12	14	9	13	11.9	12.4	17	10	10	8
Eu	0.93	1.12	3.2	2.5	2.48	2.44	1.4	2.47	2.1	0.87
Gd	11	12	8.2	11	11.14	10.9	14.2	9.2	8.9	7.1
Yb	7.5	5.6	3	6.17	6.18	6.11	7.4	4.1	4.25	3.4
Lu	1.1	0.86	0.45	0.89	0.9	0.92	1.1	0.62	0.64	0.5
Chemical parameters										
Zr/Rb	4.50	5.64	2.85	5.27	2.69	3.00	4.30	4.38	3.10	1.14
Zr/La	5.50	7.18	5.70	7.00	3.04	4.32	7.33	7.78	7.56	7.11
Rb/Nb	3.42	2.55	2.17	1.25	1.10	1.36	2.04	2.80	2.34	7.00
Y/Nb	1.14	1.10	0.67	0.34	0.34	0.41	0.47	0.60	0.45	0.80

1-3= Porphyritic syenite, 4-7 = Trachy- syenite , 8-10= Quartz syenite

Geotectonic Setting

In the Nb-Y diagram after Pearce *et al.* (1984). The rocks of the Gabal Rameid ring complex plot within the field of within plate-granites (Fig.10), typical of Al-type suite (differentiates of mantle-derived alkaline basalt emplaced in an intraplate or rift zone setting) (Fig. 11).

On the other hand, the slight variation of Y/Nb ratio (0.34-1.14) suggests that the primary source of the Gabal Rameid complex was an alkaline within-plate basalt (Frisch and Abdel-Rahman, 1999).

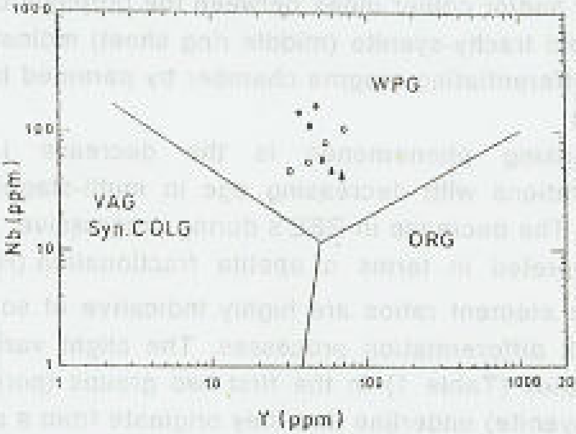


Fig.10 : Y vs. Nb diagram after Pearce et al. (1984) for tectonic settings classification.

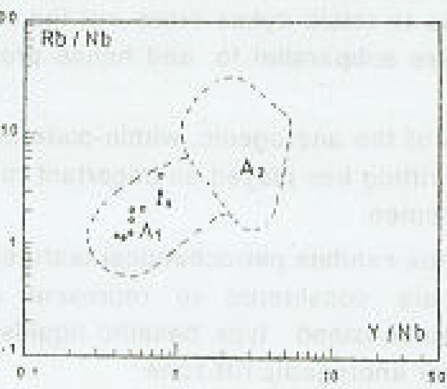


Fig. 11 : Y/Nb vs. Rb/Nb diagram after Eby (1992) for distinction of A-type granitoids . A1 : anorogenic settings with an OIB -type source ; A2 : post-orogenic settings .

Petrogenesis

The field aspects, petrographic features and chemical characteristics of the Gabal Rameid ring complex reflect the co-magmatic nature of the entire suite. However, there is no simple differentiation trend, and all data point to a complex history with multi-magmatic pulses. Fractional crystallization played an important role in evolution of the magma. Differentiation ascent, and emplacement of the magma pulses probably occurred within a narrow time span.

A similar fractionation trends involving the silica, alumina or total iron contents and/or colour index between the porphyritic syenite (outer ring sheet) and trachy-syenite (middle ring sheet) indicate that replenishing of the differentiating magma chamber by parented basaltic magma had occurred.

A striking phenomenon is the decrease in the total REE concentrations with decreasing age in multi-stages of the rock suite (Fig. 8). The decrease in REE's during progressive evolution can only be interpreted in terms of apatite fractionation (Henderson,1984).

Trace element ratios are highly indicative of source characteristics and melt differentiation processes. The slight variation of Zr/Rb and Zr/La ratios (Table 1) in the first two groups (porphyritic syenite and trachy-syenite) underline that they originate from a similar parental melt and that fractional crystallization can account for the different rock types.

CONCLUSIONS

The formation environment and petrogenesis of the Gabal Rameid ring complex are summarized as follows:

1- Gabal Rameid alkaline complex is characterized by syenitic rocks. Several mafic to felsic dykes cross cut the ring complex and its host rocks. they are subparallel to, and hence probably related to the Red Sea rift.

2- Formation of the anorogenic, within-plate magmatic body shows that the Red Sea rifting has played an important role in the formation of ring complex in Yemen.

3- The complex exhibits petrochemical features characteristic of Al-type suite, which are considered to represent differentiates of mantle-derived oceanic-island type basaltic liquids (OIB source), which are also typical for anorogenic rift zone.

4- Trace elements and REE's geochemistry reflect the co-magmatic nature of this complex that emplaced in multi-pulses of three stages of evolution.

5- This work represents the first record of the ring complexes in Yemen.

Acknowledgments: M. A. Al-Kadasey (Yemen) and A. Al-Onwa (Yemen) initiated this study in the frame of B. Sc. Project at Sana'a University (2002). The field mapping of Gabal Rameid ring complex was carried out by the second author.

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نشأة المعقدة الحلقية القلوية لجبل رميض، منطقة حوث ، الجمهورية اليمنية

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يعتبر جبل رميض (١١ كم٢) مثالا ممتازا للمعقدات الحلقية القلوية في اليمن حيث يقع في الجزء الجنوبي الشرقي لمنطقة حوث (شمال غرب صنعاء) .

ومما هو جدير بالذكر أن هذا العمل يعتبر الأول من نوعه لتسجيل المعقدات الحلقية في اليمن . تتداخل تلك المعقدة الحلقية في صخور الحجر الجيرى (الجوراسى) لمجموعة عمران مكونة نطاق تماس (٢,٢٥ كم٢) وتتكون تلك المعقدة من عدة انطقة حيث تمثل صخور السيانيت البورفيرى النطاق الخارجي ثم النطاق المتوسط من التراكي – سيانايت واخيرا الكوارتز – سيانايت ممثلا للنطاق الداخلي للمعقدة.

أوضحت الدراسات والعلاقات الحقلية والبتروكيميائية لتلك المعقدة أن كل الأنطقة الحاوية لها ذات أصل صهيرى واحد حيث تمثل عملية التبلور الجزئي العامل الرئيسي لتطور تلك المعقدة. من الناحية التكتونية تمثل معقدة رميض مثالا واضحا لبيئة داخل الألواح حيث تشمل ثلاث مراحل ونبضات متتالية من الانبثاق ذات أصول بازلتية قوسية محيطية.