

syono = 0778735

olivine gabbros, 74%; nepheline syenites + essexites + syenodiorites, 20%; ijolites + melteigites + urtites, 4.2%; carbonatites, 1.8%) suggesting that the parental ankaratritic magma body fractionated essentially under closed system conditions.

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PETROLOGICAL AND GEOCHEMICAL STUDIES OF ALKALINE ROCKS FROM CONTINENTAL BRAZIL,

5. THE MORRO REDONDO ALKALINE COMPLEX, STATE OF RIO DE JANEIRO

P. Brotzu<sup>1</sup>, L. Beccaluva<sup>2</sup>, A. Conte<sup>3</sup>, M. Fonseca<sup>4</sup>, C. Garbarino<sup>5</sup>, C.B. Gomes<sup>6</sup>,  
 G. Macciotta<sup>7</sup>, R.L. Mansur<sup>4</sup>, L. Melluso<sup>2</sup>, L. Morbidelli<sup>3</sup>, E. Ruberti<sup>6</sup>,  
 J.B. Sígolo<sup>6</sup>, G. Traversa<sup>8</sup>, J.B. Valença<sup>4</sup>

- 1. Dipartimento di Scienze della Terra, Università di Cagliari, Italy
- 2. Dipartimento di Scienze della Terra, Università di Napoli, Italy
- 3. Dipartimento di Scienze della Terra, Università di Roma "La Sapienza", Italy
- 4. Instituto de Geociências, Universidade Federal do Rio de Janeiro, Brazil
- 5. Istituto di Giacimenti Minerari, Università di Cagliari, Italy
- 6. Instituto de Geociências, Universidade de São Paulo, Brazil
- 7. Istituto di Scienze della Terra, Università di Catania, Italy
- 8. Dipartimento di Scienze della Terra, Università di Perugia, Italy

The Morro Redondo alkaline complex is located about 160 km west of Rio de Janeiro and east of the larger alkaline complexes of Itatiaia and Passa Quatro. It crops out over an area of 8 km<sup>2</sup> within the gneissic Precambrian basement. K/Ar dating give an age around 66 Ma (Ribeiro Filho & Cordani, 1966).

The complex is composed of dominant medium- to coarse-grained nepheline syenites in the eastern sector and by mainly altered phonolitic breccias in the central-west (Valença et al., 1983). Some micro-essexitic rocks have also been found at the contact with the Precambrian basement to the east, most probably representing a border facies of the intrusion. Phono-tephritic to peralkaline

phonolitic dykes cut nepheline syenites.

According to the R1R2 classificative diagram (De La Roche et al., 1980) (Fig. 1), the intrusive rocks are classified as nepheline syenites except for the samples mentioned above. Based on the modal composition of the felsic minerals, the intrusion plots in the APF diagram (Streckeisen, 1976) from nepheline-plagiocsyenites, nepheline-bearing syenites, and alkali syenites to nepheline syenites (Fig. 2).

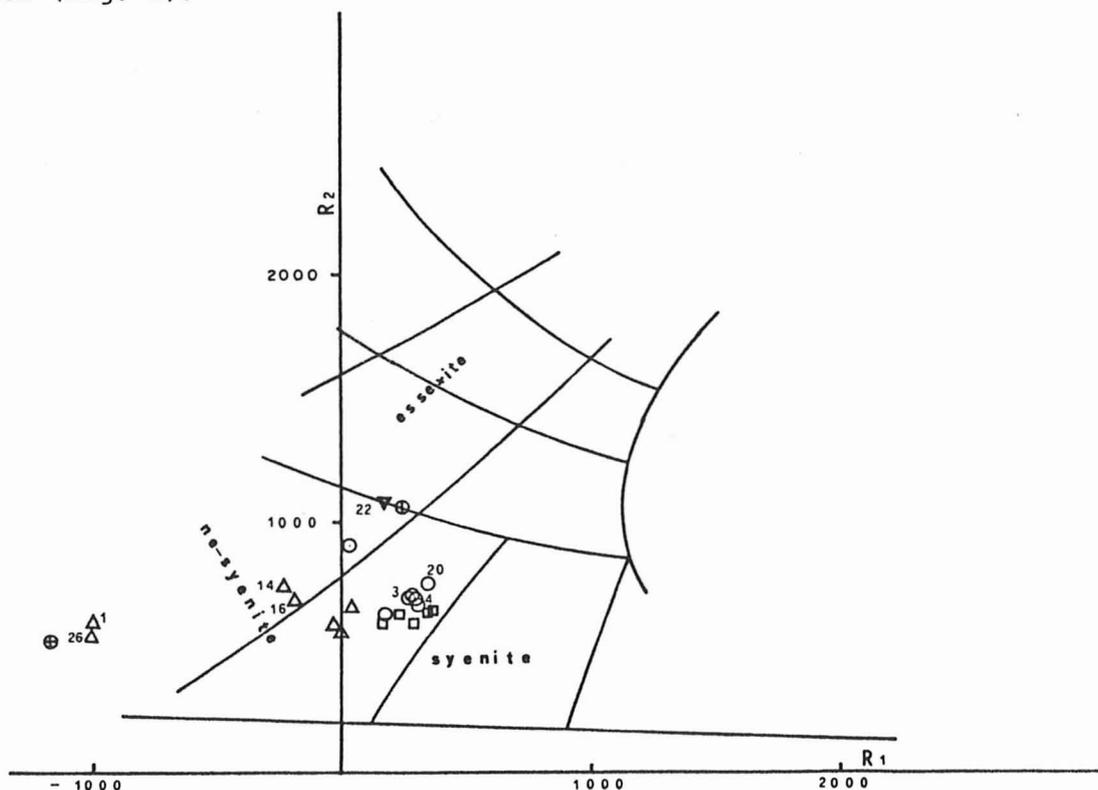


Figure 1 -- Morro Redondo rocks plotted in classificative chemical diagram (R1-R2) proposed by De La Roche et al. (1980). Symbols for rock-types, which apply to the Figures are: essexites=  $\nabla$  , nepheline-bearing syenites=  $\circ$  , nepheline-bearing alkali syenites=  $\square$  , nepheline syenites=  $\Delta$  , phonotephritic dykes=  $\odot$  , and peralkaline phonolitic dykes=  $\oplus$  .

Petrographically, fine-grained essexites are characterized by euhedral plagioclase (21%;  $An_{39-29}$ ), corroded Ti-salitic clinopyroxenes (8%) mantled by poikilitic brown kaersutite amphibole (13.6%), alkali feldspar (38%;  $Or_{72-78}$ ), nepheline (8%), biotite (6%), apatite (1.1%), sphene (1.3%) and Ti-magnetite (3%;  $Ulv_{34-59}$ ).

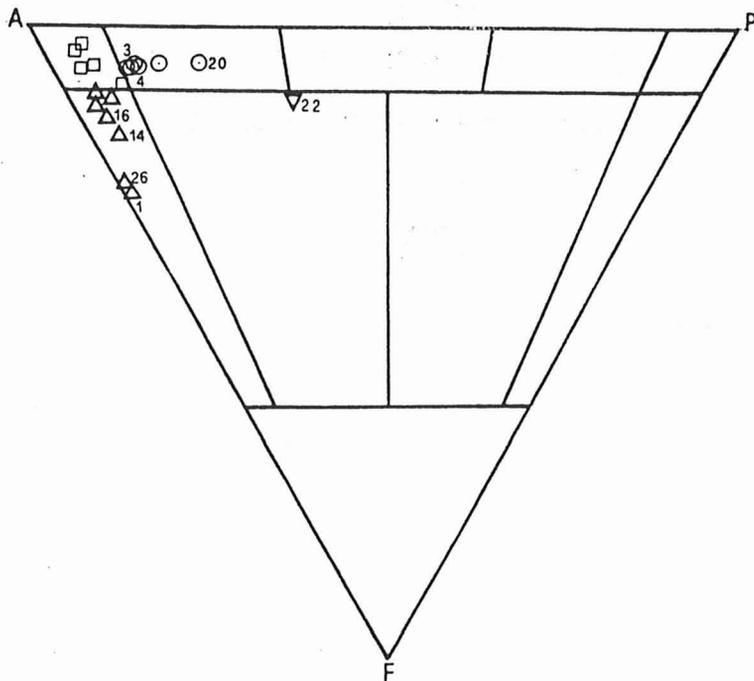


Figure 2 -- Morro Redondo rocks plotted in classificative modal diagram APF (Streckeisen, 1976).

The nepheline-bearing syenites show hypidiomorphic usually equigranular texture, locally displaying incipient layering with concentration respectively of nepheline and amphibole + plagioclase. In some samples cumulitic texture with euhedral to subhedral feldspar are evident. The modal compositional range is: perthitic and cryptoperthitic orthoclase (64-58%;  $Or_{68-57}$ ), plagioclase (15-7%;  $An_{28-20}$ ), kaersutitic mantled by deep green pargasitic amphibole (15-13%), nepheline (6-4%), biotite (4-1%), relict Ti-salitic clinopyroxene (2-0.7%), sphene (3.1-1%), apatite (0.5-0.4%) and Ti-magnetite (1.8-1.2%;  $Ulv_{34-20}$ ).

Nepheline-bearing alkali syenites differ from previous rocks mainly in the lower plagioclase (5.4-2.5%;  $An_{26-18}$ ) and higher orthoclase content (78-71%;  $Or_{60-55}$ ) indicating important alkali feldspar cumulus processes.

Nepheline syenites are dominantly composed of perthitic orthoclase (74-67%;  $Or_{66-60}$ ), plagioclase (5-2.5%;  $An_{25-20}$ ), nepheline (14-10%), ferroan-pargasitic amphibole (14-10%), Ti-magnetite (2.4-1.5%;  $Ulv_{42-28}$ ), sphene (2.4-1.5%) and apatite (0.5-0.2%). The most differentiated nepheline syenites of this group are characterized by higher nepheline content (26-25%), sometimes in subeuhedral crystals, green hastingsitic amphibole and more potassic orthoclase (71-69%;

Or<sub>82-77</sub>) and by the complete absence of plagioclase. Concomitantly, the clinopyroxene (1%) composition varies from Ti-salite to Fe-salite in the most differentiated rocks.

The whole crystallization sequence is in the following order: salitic clinopyroxene and plagioclase, kaersutitic to pargasitic and hastingsitic amphibole, biotite, alkali feldspar, nepheline and Fe-salite; the accessory phases (Ti-magnetite, sphene and apatite) crystallize throughout the whole sequence.

Phonotephritic rocks are mainly represented by weakly porphyritic types. The phenocryst assemblage consists of alkali feldspar (Or<sub>76-57</sub>), kaersutitic amphibole, Ti-salitic clinopyroxene, nepheline and/or noseana, sphene, apatite and Ti-magnetite. The same minerals, excluding the amphiboles, are present in the microcrystalline groundmass.

Peralkaline phonolitic rocks range from subaphyric to weakly porphyritic textures with alkali feldspar (Or<sub>80-70</sub>) and hastingsitic amphibole as dominant phenocryst phases. The groundmass consists of alkali feldspar, nepheline and acicular amphiboles.

Elemental variations of 24 representative samples suggest an evolution of the whole rock sequence essentially through crystal fractionation processes as also indicated by the persistence and composition of the minerals (Fig. 3). From essexites (22) to nepheline syenites (16, 14, 26, 1), Ca, Ti, Mg, Fe, and P decrease, whereas Na/K, Si, Al, Na, K/Rb, Zr, and Nb increase. Sr and Ba increase up to the least fractionated nepheline syenites (16, 14), then decrease abruptly together with Si, in the most fractionated ones (1, 26) which display, in addition, a mild peralkaline character (A.I. 1.01-1.03). Accordingly, phases such as clinopyroxene, amphibole, apatite, sphene and opaques, together with increasing quantities of plagioclase and alkali feldspar, should have been removed from essexitic to nepheline syenitic magmas, as also suggested by petrographical evidence.

The departure of many nepheline-bearing syenites and alkali syenites from



the liquid line of descent (higher K and Si and lower Na and Al contents) clearly

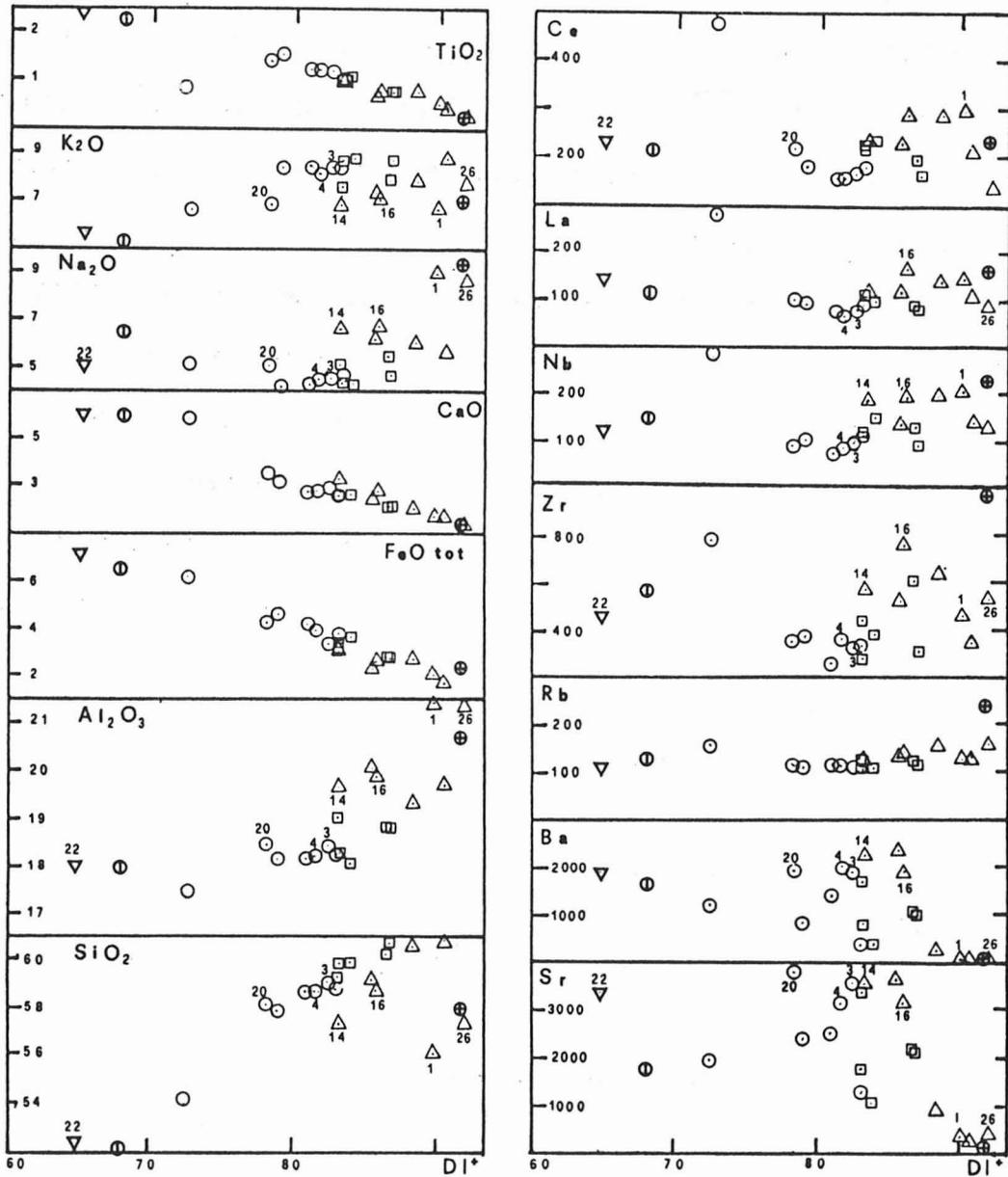


Figure 3 -- Binary diagrams showing major and trace element variations vs.  $DI^*$  for the intrusive rocks from Morro Redondo.  $DI^* = DI + Ns + Ac$ . Symbols as in Figure 1.

indicates the widespread occurrence of K-alkali feldspar cumulus processes. Assuming that the least fractionated liquid may be represented by the microessexite sample (22), mass balance calculations indicate that the least differentiated nepheline syenites (16, 14) could have been produced by 58% removal of solid phases consisting of amphibole (16%), plagioclase (15%), alkali feldspar (15%), biotite (7%), clinopyroxene (1%), apatite (2%), sphene (1.5%) and

Ti-magnetite (1%). The most evolved peralkaline nepheline syenites (1, 26) and phonolites could have been produced, in turn, by fractionation of 57% solid phases as alkali feldspar (33%), plagioclase (12%), amphibole (8%), sphene (1.6%), apatite (0.6%) and Ti-magnetite (0.45%). The subtracted solid shows a chemical composition close to nepheline-bearing syenites (20, 3, 4) most of them having cumulus of alkali feldspar.

Rare earth element patterns are characterized by a strong positive fractionation for all the analysed rocks ( $La_n/Yb_n$  26-56) and by a significant positive Eu anomaly in most nepheline-bearing syenites (3, 4) in relation to feldspar accumulation. Removal of minor phases such as sphene (1.6%) and apatite (1.4%) produces light REE depletion and modification of intermediate REE patterns from positively fractionated in the least evolved syenites to flat in the most differentiated peralkaline ones (Fig. 4).

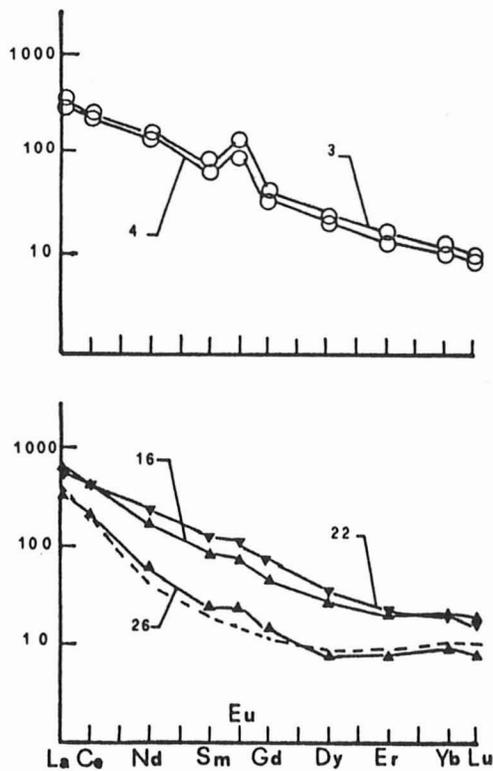


Figure 4 -- Chondrite normalized REE patterns for essexites (22), nepheline-bearing syenites (3,4), and nepheline syenites (16,26). Rayleigh fractionation modelling (dashed line) indicates that the observed REE pattern variation from essexitic magmas to the most fractionated nepheline-syenitic melts could be

accounted by removal of 1.6% of sphene + 1.4% apatite + 30% of alkali feldspar + 16% of plagioclase + 16% of amphibole.

All petrological data, including the compositional trends in both whole rocks and minerals, suggest the probable derivation of the least differentiated essexitic magmas from more primitive ankaratritic parental melts as observed for other Brazilian alkaline complexes (e.g. Piratini, Juquiá, Fortaleza). These alkaline basic magmas could have been generated by a low degree partial melting of enriched mantle source deep in the subcontinental lithosphere.

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#### PETROLOGICAL AND GEOCHEMICAL STUDIES OF ALKALINE ROCKS FROM CONTINENTAL BRAZIL.

##### 6. THE PHONOLITE-TEPHRITE SUITE FROM FORTALEZA, STATE OF CEARÁ

L. Beccaluva<sup>1</sup>, A. Almeida<sup>2</sup>, M. Barbieri<sup>3</sup>, P. Brotzu<sup>4</sup>, M. Coltorti<sup>5</sup>,  
A. Conte<sup>3</sup>, C. Garbarino<sup>6</sup>, C.B. Gomes<sup>7</sup>, G. Macciotta<sup>8</sup>,  
L. Morbidelli<sup>3</sup>, E. Ruberti<sup>7</sup>, G. Traversa<sup>9</sup>

1. Dipartimento di Scienze della Terra, Università di Napoli, Italy
2. Instituto de Geociências, Universidade Federal do Ceará, Brazil
3. Dipartimento di Scienze della Terra, Università di Roma "La Sapienza", Italy
4. Dipartimento di Scienze della Terra, Università di Cagliari, Italy
5. Istituto di Mineralogia, Università di Ferrara, Italy
6. Istituto di Giacimenti Minerari, Università di Cagliari, Italy
7. Instituto de Geociências, Universidade de São Paulo, Brazil
8. Istituto di Scienze della Terra, Università di Catania, Italy
9. Dipartimento di Scienze della Terra, Università di Perugia, Italy

The Fortaleza alkaline district consists of a number of phono-tephritic plugs, smooth domes and dykes (oriented around NE-SW directions) occurring within a radius of 50 km from the city of Fortaleza (Fig. 1). Except for the