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# MAGMATISMO BASICO E SORGENTI DI MANTELLO: ASPETTI PETROLOGICI E GEODINAMICI



Istituto di Mineralogia - Università di Ferrara



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Congresso SIMP - Ferrara, 28-30 Ottobre 1991

# GEOCHEMISTRY OF MESOZOIC K-ALKALINE COMPLEXES FROM CENTRAL-EASTERN PARAGUAY

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The Mesozoic alkaline activity in Central-Eastern Paraguay consists of a group of complexes, plugs and associated dikes which were emplaced 120 Ma ago (Capaldi, unpublished data) into the central area of the Asunciòn-Sapucai graben (Fig. 1).

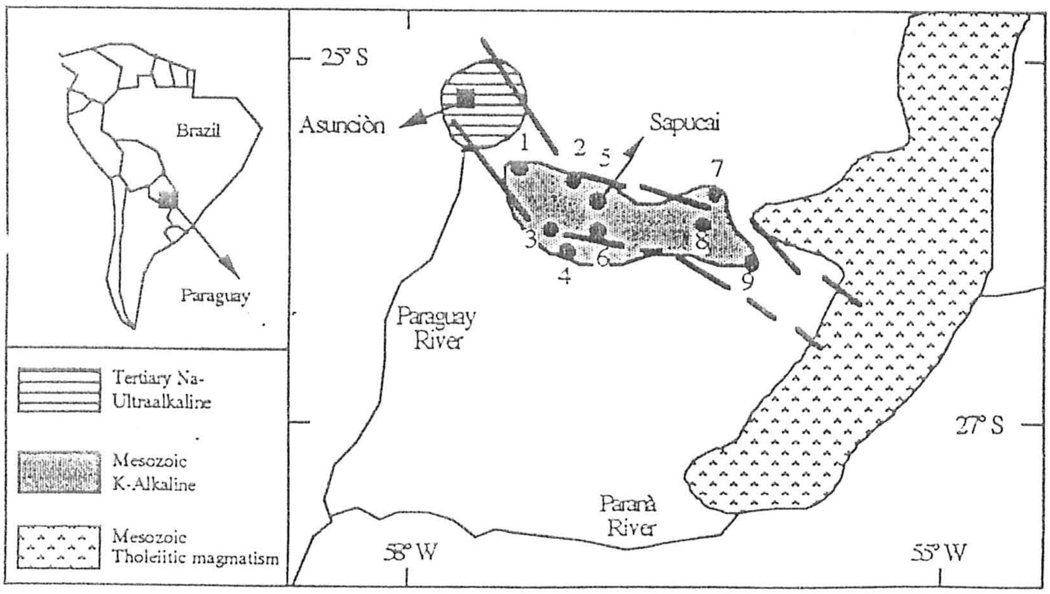


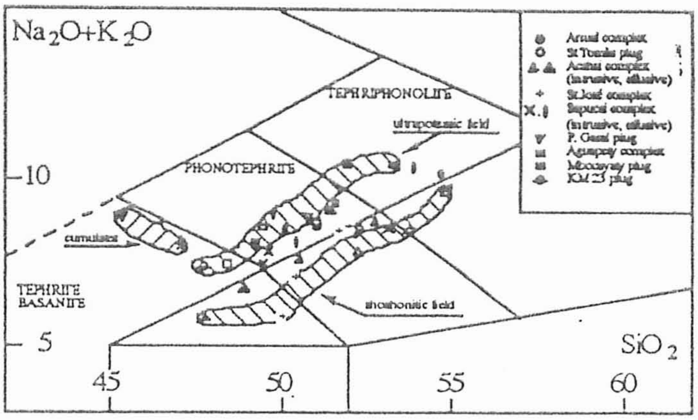

Fig. 1 - Sketch map showing the Asunciòn-Sapucai graben and the main occurrences of magmatic rock-types. Number of K-complexes and plugs, as in Table 1.

The alkaline rock-types, intruded into the continental Silurian sandstones of the Caacupé Formation (Bellieni et al., 1986 and therein references), vary from trachybasalts and basanites to phonolites and peralkaline phonolites and their intrusive equivalents, i.e. alkaline gabbros and theralites to nephelin syenites.

The emphasis of this study will be on the geochemistry of basic-intermediate rock-types sampled in nine complexes and plugs of Asunciòn-Sapucai graben

(ASU) and systematically showing metaaluminous tendency (i.e. $(Na_2O+K_2O)/Al_2O_3$ molar ratio < 1).

Fig. 2 - Total alkali - $SiO_2$ diagram with sub-divisions from Le Maitre (1989). The dashed fields as inferred from Peccerillo & Taylor (1976) and Foley (1987). Source of data: this work and Comin-Chiaramonti & De Min (unpublished averaged analyses)



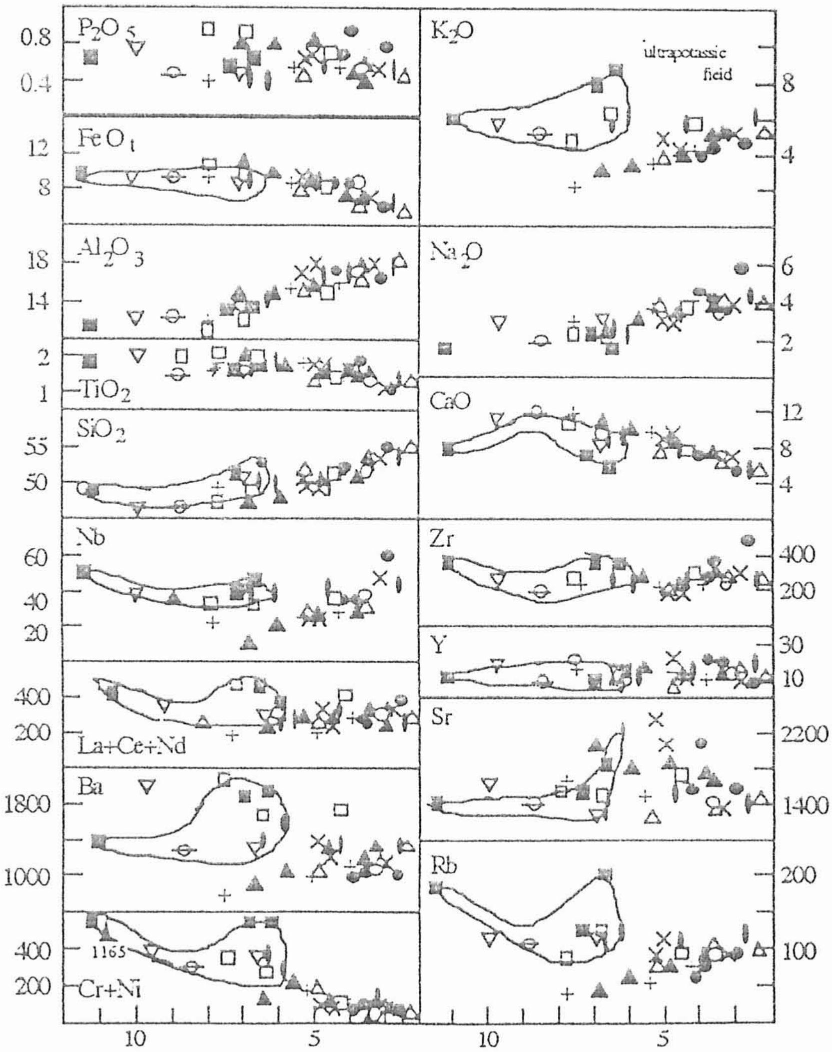

Representative and averaged analyses are plotted in TAS and variation diagrams (Figs. 2 and 3, respectively) and selected analyses are reported in Table 1.

Table 1

| | 1 Amarl | 2 St Tomas | 3 Acahay | | 4 St José | | 5 Sapucai | | 6 Garay | 7 Aguapety | 8 Mbocayaty | 9 CerroKm23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PS 204 | 3090 | 3341 | 3344 | PS 233 | PS 237 | PS 30 | PS 31 | PS 245 | PS 264 | PS 263 | 25(a) |
| $SiO_2$ | 54.97 | 52.17 | 47.41 | 52.32 | 51.55 | 49.85 | 49.35 | 53.90 | 45.11 | 49.35 | 53.26 | 47.03 |
| $TiO_2$ | 1.21 | 1.34 | 2.02 | 1.52 | 1.61 | 1.85 | 1.78 | 1.43 | 2.06 | 1.95 | 1.81 | 1.60 |
| $Al_2O_3$ | 17.27 | 17.71 | 15.00 | 16.23 | 17.02 | 13.02 | 18.12 | 18.29 | 13.11 | 13.19 | 14.32 | 12.98 |
| $Fe_2O_3$ | 1.02 | 1.27 | 1.65 | 1.30 | 1.24 | 1.44 | 1.30 | 0.99 | 1.42 | 1.47 | 1.11 | 1.49 |
| FeO | 5.84 | 7.24 | 9.41 | 7.43 | 7.06 | 8.23 | 7.42 | 5.67 | 8.10 | 8.42 | 6.32 | 8.50 |
| MnO | 0.15 | 0.18 | 0.18 | 0.16 | 0.15 | 0.18 | 0.16 | 0.14 | 0.19 | 0.17 | 0.11 | 0.18 |
| MgO | 3.12 | 3.71 | 6.89 | 5.24 | 4.29 | 7.68 | 4.87 | 2.84 | 9.75 | 6.76 | 6.57 | 8.70 |
| CaO | 5.24 | 7.34 | 11.06 | 7.66 | 8.01 | 11.80 | 8.94 | 5.64 | 10.55 | 9.28 | 5.41 | 11.71 |
| $Na_2O$ | 6.09 | 3.91 | 2.78 | 3.99 | 4.53 | 3.36 | 3.15 | 4.63 | 3.41 | 2.60 | 2.10 | 2.43 |
| $K_2O$ | 4.36 | 4.62 | 2.80 | 3.69 | 3.97 | 2.20 | 4.22 | 5.95 | 5.53 | 5.93 | 8.38 | 4.90 |
| $P_2O_5$ | 0.73 | 0.51 | 0.80 | 0.46 | 0.56 | 0.38 | 0.68 | 0.51 | 0.77 | 0.88 | 0.61 | 0.47 |
| $Fe_2O_3$ | 4.13 | 3.02 | 3.47 | 4.99 | 2.48 | 3.03 | 3.02 | 3.22 | 4.45 | 2.56 | 3.30 | 3.76 |
| FeO | 2.82 | 5.47 | 7.50 | 4.00 | 5.78 | 6.62 | 5.67 | 3.55 | 5.15 | 7.24 | 4.11 | 6.27 |
| LOI | 2.51 | 1.71 | 1.03 | 1.04 | 1.20 | 0.99 | 0.83 | 0.88 | 1.23 | 1.25 | 2.17 | 0.99 |
| Σ | 99.47 | 99.69 | 99.17 | 100.17 | 99.31 | 99.27 | 98.90 | 99.22 | 99.31 | 99.29 | 99.38 | 99.28 |
| mg# | 0.488 | 0.477 | 0.566 | 0.557 | 0.520 | 0.629 | 0.539 | 0.472 | 0.682 | 0.589 | 0.649 | 0.646 |
| A.I. | 0.85 | 0.65 | 0.51 | 0.65 | 0.69 | 0.61 | 0.54 | 0.77 | 0.88 | 0.81 | 0.87 | 0.72 |
| $K_2O/Na_2O$ | 0.72 | 1.18 | 1.01 | 0.93 | 0.88 | 0.66 | 1.34 | 1.29 | 1.62 | 2.28 | 3.99 | 2.02 |
| Cr | 42 | 22 | 115 | 155 | 57 | 153 | 37 | 25 | 288 | 241 | 429 | 250 |
| Ni | 25 | 13 | 44 | 50 | 22 | 47 | 15 | 9 | 109 | 56 | 131 | 60 |
| Sc | 10.9 | - | 36.5 | 23.9 | 25.8 | 39.4 | 26 | 9.9 | 36.8 | 32.4 | 56.3 | - |
| Rb | 103 | 100 | 53 | 92 | 81 | 41 | 116 | 128 | 114 | 136 | 203 | 115 |
| Sr | 1562 | 1409 | 1856 | 1224 | 1555 | 1597 | 1853 | 514 | 1624 | 1507 | 1811 | 1385 |
| Zr | 498 | 267 | 224 | 225 | 277 | 282 | 213 | 291 | 279 | 252 | 382 | 207 |
| Nb | 62 | 41 | 16 | 31 | 34 | 28 | 26 | 48 | 41 | 38 | 48 | 39 |
| Ta | 8.4 | 5.1 | 1.8 | 2.3 | 2.6 | 1.5 | 1.4 | 1.8 | 3.1 | 2.8 | 3.2 | - |
| Ba | 1094 | 1186 | 1003 | 1117 | 1142 | 729 | 1268 | 1425 | 1958 | 1741 | 1995 | 1331 |
| Th | 24.5 | 11.9 | 15.6 | 4.8 | 9.1 | 8 | 8.5 | 12.7 | 6.6 | 6.2 | 9.8 | 9 |
| U | 6 | - | 4.5 | 1.3 | 2.4 | 1.8 | 1.9 | 2.9 | 1.7 | 1.9 | 3.1 | - |
| Y | 15.9 | 19 | 15.6 | 11.4 | 15.2 | 23 | 15 | 26.3 | 22 | 18.4 | 19 | 15 |
| La | 106.4 | 79 | 58.7 | 68 | 81.1 | 52 | 66.2 | 98.9 | 106.3 | 83 | 108 | 71 |
| Ce | 209.6 | 146 | 144.9 | 147 | 154.7 | 106 | 129.1 | 151.4 | 177.5 | 163.5 | 197 | 146 |
| Pr | 20.3 | - | 14.7 | 12.9 | 15 | - | 12 | 19.3 | 27 | - | - | - |
| Nd | 68.7 | 60 | 59.4 | 44.1 | 54.2 | 50 | 45.3 | 60.3 | 78.4 | 66.3 | 65 | 59 |
| Sm | 16.6 | 9.4 | 11.8 | 12.1 | 13 | 10 | 13.7 | 14.9 | 21.3 | 11.1 | 12.9 | 9.6 |
| Eu | 2.7 | 1.9 | 3.1 | 2.4 | 2.6 | 1.9 | 2.5 | 2.6 | 2.5 | 3 | 2.5 | 2.6 |
| Gd | 3.1 | 3.9 | 4.7 | 6.4 | 4.1 | 5 | 7.3 | 5.5 | 5.5 | 5.8 | 4.3 | 5.4 |
| Tb | 0.53 | - | 0.77 | 0.71 | 0.6 | 0.8 | 0.9 | 0.67 | .0.93 | 0.7 | 0.79 | 0.61 |
| Dy | 3.2 | 3.6 | 4.1 | 3.09 | 3.21 | - | 3.25 | 3.29 | 3.7 | 3.78 | 3.5 | 3.7 |
| Ho | 0.8 | - | 0.84 | 0.65 | 0.72 | - | 0.79 | 0.72 | 1.13 | - | - | - |
| Er | 2.11 | 1.81 | 1.62 | 2.01 | 1.77 | - | 2.27 | 2.01 | 2.2 | 1.47 | 1.2 | 1.3 |
| Tm | 0.29 | - | 0.26 | 0.27 | 0.28 | - | 0.28 | 0.35 | 0.34 | - | - | - |
| Yb | 1.6 | 1.48 | 1.4 | 1.41 | 1.62 | 1.6 | 1.3 | 1.53 | 1.3 | 1.16 | 1 | 1.1 |
| Lu | 0.23 | 0.21 | 0.225 | 0.247 | 0.268 | 0.25 | 0.222 | 0.257 | 0.249 | 0.112 | 0.12 | 0.14 |
| $^{87}Sr/^{86}Sr$ | 0.70718(6) | 0.70800(6) | | | 0.70720(32) | | | | 0.70777(?) | 0.70745(2) | 0.70773(2) | 0.70737(3) |
| $R_0$ (120Ma) | 0.70685 | 0.70694 | | | 0.70694 | | | | 0.70742 | 0.70700 | 0.70718 | 0.70696 |

Three main groups are apparent (Fig. 2): i) "Shoshonitic" (SHO) rock-types, common in the western complexes and plugs; ii) "ultrapotassic" (UK) rock-types (association III of Foley et al., 1987), dominant in the eastern complexes; iii) rock-types (K) intermediate between the above groups, widespread in the whole region.

Fig. 3 - Variations of major and selected trace elements in ASU alkaline rock-types with MgO as index of differentia-tion. Symbols as in Fig. 2.




In general, mg-values as well as Ni and Cr contents are relatively low and the rock-types with mg-values which might be appropiate for primary mantle melts show cumulus textures. Notably, the major and trace element variations in a single complex or plug are controlled by removal or accumulation of clinopyroxene ± olivine ± biotite ± Ti-magnetite ± plagioclase ± foids. However fractional crystallization does not explain the chemical differences between SHO+K and UK groups (Fig. 3). Note that in SHO+K rock types Rb, Ba and Nb have high positive correlations with $K_2O$ and MgO, whereas Zr and Y display similar contents, 300 (±100) and 18 (±8) ppm, respectively, in both SHO+K and UK groups. In general, the scattered elemental variations suggest distinct magma reservoirs at shallow levels. The chemical differences may be due to different

$H_2O$ and $O_2$ (F,P) activities responsible for the crystallization of biotite+apatite ± amphibole (cf. Comin-Chiaramonti et al., 1991).

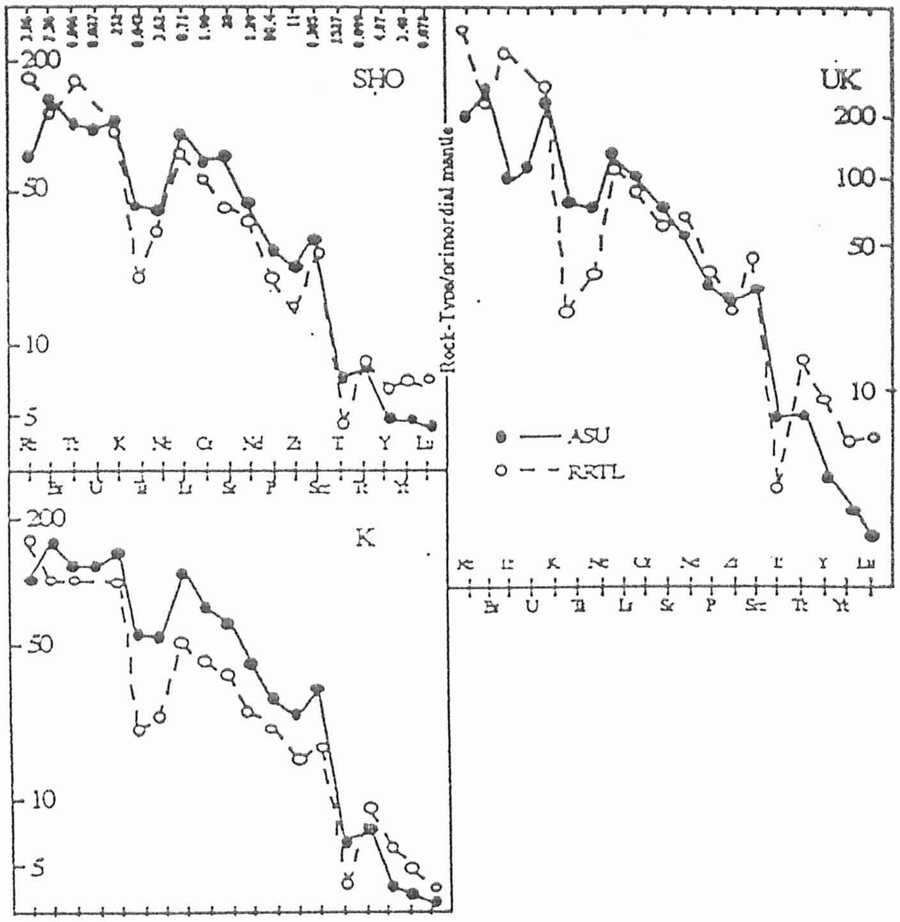



Fig. 4 - Primordial mantle normalized diagrams for ASU (Asunciòn-Sapucai) and RRTL (Roman Region) averaged analyses (SHO, K, UK; shoshonitic, K-alkaline and ultrapotassic rock-types). RRTL source data: Civetta et al. (1987); Beccaluva et al. (1991).

The observed geochemical trends for K-magmatism in Eastern Paraguay are quite similar to those of "Roman Region Type Lavas" (RRTL, Barton, 1979; Civetta et al., 1987; Beccaluva et al., 1991), where SHO, K and UK rock-types are believed to be originated from mantle peridotites variably contaminated by subducted crustal materials.

The spidergrams of Figure 4 show, for similar rock-types, similar negative spikes for Ta-Nb, Zr, Ti and positive spikes for Sm and Tb. The major differences regard the contrasting ratios relative to Rb/Ba, a negative anomaly for Th (U) in Paraguay rock-types which also have higher LREE/HREE (Y) ratios. Ba/Nb vs. La/Nb plot (Fig. 5) shows that ASU, RRTL, primordial mantle and E-MORB define an array which does not include the bulk continental crust.

In the Nb/Zr vs Th/Zr (Fig. 5) the K-magmatism of Paraguay (ASU) plots in the "subduction setting" of Beccaluva et al. (1991) even if it is related to extensional rifting. This suggests that the ASU chemical characteristics can be due to "metasomatized" mantle peridotites with Nb-bearing residual phase(s). This can explain the relatively high and constant $^{87}Sr/^{86}Sr$ initial ratios (av. 0.7071 ± 0.00003) of ASU magmatims, without the intervention of substantial crustal contamination.

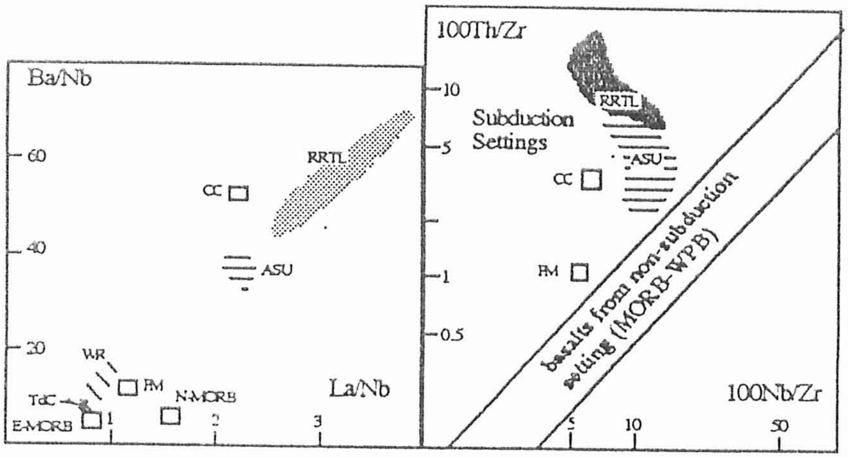



Fig. 5 - Ba/Nb vs La/Nb and 100Th/Zr vs 100Nb/Zr diagrams for averaged fields for ASU and RRTL (cf. Fig. 4). Source of data: this work (ASU, cf Table 1) and Civetta et al. (1987) + Beccaluva et al. (1991) for RRTL and MORB+WPB. CC: continental crust (cf Weaver, 1991); WR: Walvis Ridge (Humpheris & Thomson, 1983); TdC: Tristan da Cunha (Le Roex et al., 1990); PM: Primordial Mantle (Wood et al., 1979); N-MORB and E-MORB, from South Atlantic (Sun et al., 1979).

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