EARLY CRETACEOUS MAGMATIC ACTIVITY IN SOUTHEAST URUGUAY: TRACE ELEMENT AND Sr-Nd ISOTOPIC CONSTRAINTS

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INTRODUCTION

During the early Cretaceous, in concomitance with the opening of the South Atlantic Ocean, the South American Plate was affected by a huge volcanic and plutonic event, with the formation of products with a wide chemical compositional spectrum. In this study we present major and trace element as well as Sr-Nd isotopic analyses for early Cretaceous (~132 Ma) basic to sialic rocks from SE Uruguay.

The description of the igneous products is divided into two parts. The first one deals with sialic volcanic rocks outcropping near São Miguel, Lascano, Rio Salamanca and Arequita areas, whereas the second part is devoted to the intrusive plug and ring dyke complex of the Valle Chico suite.

SIALIC ROCKS OF SÃO MIGUEL, LASCANO, RIO SALAMANCA AND AREQUITA

The mineral paragenesis of the sialic rocks is essentially anhydrous and is represented by plagioclase, alkali feldspar, quartz, iron oxides ± clinopyroxene, whereas the scarce basic rocks sampled consist of plagioclase (An=85-45%), clinopyroxene and, rarely, olivine. Alkali feldspars of the sialic rocks are sanidine, with orthoclase content ranging from 60 to 30%. Clinopyroxenes are essentially augites ($Wo_{42}En_{45}Fs_{13}$ to $Wo_{38}En_{15}Fs_{47}$). The Uruguayan sialic rocks can be classified as: rhyodacite, alkali rhyolite and quartz latite; the rarer basic rocks are hawaiite and olivine tholeiite. Compared to the sialic volcanic rocks of the Serra Geral Formation (Paraná Basin), the Uruguayan samples have a higher silica content, possibly related to some degree of alteration (silicitization) of the products.

Primitive mantle-normalized multielement diagrams evidence, for the sialic samples negative anomalies in Eu, Sr, Nb, P, Ti and, sometimes, in Ba, which can be related to fractional crystallization processes. The olivine tholeiite shows negative anomalies in Th, K and Ti, positive anomaly in Ba and is enriched in LREE, with an overall pattern resembling typical HIMU-OIBs. The sialic rocks of different localities can be distinguished on the basis of interelemental ratios (e.g., LILE/HFSE) such as Ti/Zr, Nb/Y, K/Ti and Rb/Nb.

The possibility of an origin from fractional crystallization process (in closed system) starting from a basaltic parental melt has been tested considering as parental magma the olivine tholeiite of Mariscala. The evolution of basaltic melts to rhyolite has been modelled with major elements mass balance after removal of about 86% of a gabbroic cumulate (pl+ol+cpx+mt+il). However, such a model cannot mimic the trace element concentration of sialic rocks. In particular, the HFSE (Nb, P, Hf) content of rhyolites is lower than those of the calculated liquid, whereas Rb and K are higher. Better results are obtained proposing a two-stage model: a first step is fractionation with evolution from basalt to quartz latite and then from quartz latite to rhyolite. However, also in this case, LILEs are higher whereas HFSEs and HREEs are lower in the rhyolites than in the calculated liquids.

The hypothesis which takes into account the origin by partial melting from basaltic (or granulitic) lithologies has been tested considering the composition of experimental liquids obtained starting from basic (basaltic to granulitic) compositions. A comparison with experimental melts has shown that the Uruguayan rocks have K_2O and FeO too high and Al_2O_3, CaO and Na_2O too low to be considered the product of anatexis of any basic source.

An origin related to AFC processes has been also tested. As parental liquids the olivine tholeiite of Mariscala has been chosen, whereas as crustal contaminant has been chosen a Proterozoic granite from Amazonas Craton. Trace element and isotopic evidences suggest that the combination of assimilation + fractional crystallization is the most viable process in order to explain the genesis of the volcanic rocks of the Arequita Formation. The highest LILE and HFSE concentration in quartz latites compared to rhyolites speak for the absence of genetic relationships between these two rock groups.

Open system processes are suggested also by the radiogenic Sr and unradiogenic Nd isotopic ratios of the Uruguayan rhyolites. Alkali rhyolites and quartz latites from Rio Salamanca and Arequita show the lowest $^{87}Sr/^{86}Sr$ (down to 0.70904) and the lowest $^{143}Nd/^{144}Nd$ (down to 0.511891) among the Uruguayan rocks. On the other hand, samples from Serra São Miguel and Lascano plot on a Sr-Nd isotopic space along a line in the enriched quadrant, with $^{87}Sr/^{86}Sr$ ranging from 0.71227 to 0.72391 and $^{143}Nd/^{144}Nd$ from 0.512287 to 0.511945. The olivine tholeiite show less radiogenic Sr and more radiogenic Nd. It is possible to propose a mechanism of fractional crystallization coupled with assimilation of crustal material which could be the upper crust in the case of Serra São Miguel and Lascano (samples shifted towards more radiogenic Sr) and the lower crust for Rio Salamanca and Arequita (samples with the lowest $^{87}Sr/^{86}Sr$).

IGNEOUS COMPLEX OF VALLE CHICO

The igneous complex of Valle Chico is made up of volcanic and plutonic rocks cropping out over an area of about 250 km^2; a dyke swarm cross-cuts the intrusive lithologies. The intrusive rocks are syenite (~9 %), quartz syenite (~9 %), quartz monzonite (~14 %), granite (~9 %) and alkali feldspar granite (~5 %). The volcanic rocks and the dykes are trachyte (~6%), quartz latite (~31 %) and alkali feldspar rhyolite (~17 %).

Textures of the syenites, quartz syenites, granites and alkali feldspar granites are hypidiomorphicic and, less commonly, autoallotriomorphic with large to mega-crystals (up to 4 cm in size) of perthitic and sometimes poikilitic alkali feldspar, occasionally in granophyric relation with quartz. Interstitial phases are quartz, rare plagioclase, amphibole, clinopyroxene, chloritized biotite, apatite, zircon and opaque minerals. Quartz monzonites are inequigranular, sometimes glomeroporphyritic with subhedral to anhedral plagioclase, sometimes with reaction rims. Interstitial phases are the same as above.

Among the volcanic and subvolcanic rocks, trachytes and alkali feldspar rhyolites are holo- to hypocrystalline with porphyricity index ranging from nearly 0 to 30%. Phenocrysts of alkali feldspar and quartz are common, while groundmass phases are quartz, alkali feldspar, chloritized biotite, apatite, opaque minerals and rare amphibole. Quartz latites are porthyritic to glomeroporphiritic rocks with sieved euhedral to anhedral plagioclase; plagioclase is pecilitic for the presence of opaques and clinopyroxenes. Groundmass phases are clinopyroxene, opaque minerals, quartz, apatite, plagioclase and alkali feldspar.

Alkali feldspar composition ranges from almost pure albite to Or_{48}, whereas plagioclase ranges from oligoclase to andesine. Clinopyroxene has low Na content and can be classified as Fe-augite to hedenbergite; only rarely Na-rich types (aegirine content up to 70%) have been found. Similarly rare is the presence of scarce pigeonite ($Wo_{12}En_{37}Fs_{51}$). Opaque minerals are ilmenite (Ilm > 95 %) and ulvospinel-magnetite s.s. (Ulv = 5-95 %). Amphiboles belong to calcic and sodic-calcic groups and are classified as richterite, katophorite, Fe-winchite, edenite and Fe-edenite.

Both plutonic and volcanic rocks show potassic character with K_2O content up to 8 wt%. TiO_2, Fe_2O_3, CaO, MgO and P_2O_5 of both plutonic and volcanic rocks are negatively correlated with D.I.

Primitive mantle-normalized multielemental plots show fractionated concentration of incompatible trace elements. All the plutonic rocks show strong negative peaks of Sr and Ti, together with negative peaks of Nb and Nd, and positive peaks of Rb and Pb; syenite and alkali feldspar granite show negative peaks also in Ba. Eu/Eu* negative anomalies range from 0.78 (quartz latite) to 0.09 (alkali feldspar rhyolite) The same geochemical features can be evidenced for the volcanic rocks as well. Quartz latite, trachyte, quartz trachyte and alkali feldspar rhyolite show negative anomalies in Sr, Ti and Eu, suggesting plagioclase and opaque minerals as the main fractionating phases. The amplitude of the negative anomalies grows from the less differentiated (quartz latite) to the most SiO_2-rich types (alkali feldspar rhyolite).

$^{87}Sr/^{86}Sr$ ranges from 0.7045 (quartz trachyte) to 0.7170 (alkali feldspar rhyolite) and $^{143}Nd/^{144}Nd$ ranges from 0.5117 (alkali feldspar granite) to 0.5121 (quartz trachyte). Also in this case, an active role of continental crust in the genesis of the volcanic and plutonic rocks of Valle Chico is evidenced by the Sr-Nd isotopic ratios.

Up to now the Valle Chico massif has been considered of alkaline affinity. However, on the basis of 1) the constant SiO_2 oversaturated character of the Valle Chico rocks, 2) the petrography and mineral chemistry (aegirine content of clinopyroxene mostly below 40% by weight; rare presence of pigeonite; amphibole belonging to the calcic or sodic-calcic groups) and 3) the chemical similarity with rhyolitic products of the Paraná-Etendeka CFB province, our results indicate that the most probable association for these igneous rocks can be ascribed to the tholeiitic or transitional series, rather than the alkaline one.

Major and trace element composition of the early Cretaceous volcanic and plutonic products of SE Uruguay evidence a close similarity, thus allowing to propose similar mantle sources variously contaminated by upper crustal material. This contamination is likely the effect of magma ponding at crustal levels and the contaminant can have either the composition of lower crustal lithologies (capable to shift the original isotopic ratios towards unradiogenic $^{143}Nd/^{144}Nd$ and moderately radiogenic $^{87}Sr/^{86}Sr$) or upper crustal lithologies (shifting the original isotopic ratios towards unradiogenic $^{143}Nd/^{144}Nd$ and strongly radiogenic $^{87}Sr/^{86}Sr$).