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A review of carbonatitic magmatism in the Paraná-Angola-Etendeka system

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Early and Late Cretaceous carbonatitic complexes from southern Brazil occur along the main tectonic lineaments of the South America platform. A similar situation is recognized for the Angolan and Namibian occurrences in Africa. In general, the alkaline-carbonatite complexes show intrusive/subintrusive, subcircular or oval shaped structures and are indicative of high upwelling energy. However, lava flows, single dykes and dyke networks may be also found. Processes of liquid immiscibility from trachytic-phonolitic liquids, starting from parental alkaline mafic magmas are believed to have generated carbonatitic liquids, as suggested by field relationships and geochemical characteristics. Ca-, Mg- and Fe-carbonatites are widespread even in the same complex. The remarkable scatters of the incompatible elements is mainly due to 1) the control of accessory phases, e.g. apatite, pyrochlore, fluorcarbonates and fluorite, and 2) the repeated overprinting of hydrothermal over magmatic processes.

Geochemical characteristics have been systematically determined for carbonatite samples from selected outcrops in Paraguay, Brazil, Angola and Namibia (Eastern Paraguay: Rio Apa, Amambay, Sapucai; Southern Brazil: Alto Paranaíba, i.e. Catal„o, Salitre, Tapira, etc.; Ponta Grossa Arch, i.e. Barra do Itapirapu„, Jacupiranga, Juqui·, Mato Preto, etc.; Lages and Anit·polis; Angola: Bailundo, Langonjo, Lupungola„ Sulima and Tchivira-Bonga; Namibia: Dicker Willem, Kalkfeld, Ondurakorume, Okurusu, Osongombo and Otjisazu). The occurrences comprise three main chronogroups, i.e. 1) Early Cretaceous (Eastern Paraguay; Brazil, Ponta Grossa Arch and Anit·polis; Angola and Namibia); 2) Late Cretaceous (Brazil, Ponta Grossa Arch, Lages and Alto

Paranaíba; Namibia); 3) Paleogene, Brazil and Namibia . Two principal types of associated alkaline rocks are represented, i.e. plagioleucitites l.s. (Eastern Paraguay; Brazil: Ponta Grossa Arch; Angola and Namibia) and kamafugites l.s. (Brazil: Alto Paranaíba and Lages; Namibia).

Significant variations in O-C isotope compositions are found in primary carbonates, the variations being mainly due to isotope exchange between carbonates and H2O-CO2-rich fluids, whereas magmatic processes, i.e. fractional crystallization or liquid immiscibility, probably affect the (18O and (13C values by not more than 2â. The isotope exchange model implies that the most significant isotopic variations took place in a hydrothermal environment, e.g. in the range 400-80∞C, involving fluids with CO2/H2O ratio ranging from 0.8 to 1. Two main paths of (18O-(13C fractionation are originated by subvolcanic and surface conditions, respectively. Weathering and groundwater fluids, therefore, appear to be important, as well as meteoric water, which yielded samples strongly enriched in light carbon owing to contamination by a biogenic component. The behaviour of trace elements (e.g. Sr and REE) is consistent with the above conclusions.

Sr-Nd-Pb systematics highlight heterogeneous mixtures between HIMU and EMI mantle components, likewise to the associate alkaline rocks and the flood tholeiites of the Paraná-Angola-Namibia Province. This is also consistent with Re-Os systematics on selected mafic samples from the Alto Paranaíba alkaline-carbonatite province.

The data relative to the noble gases suggest that the source(s) are similar to other mantle derived magmas (e.g. HIMU and MORB) and that the carbon of carbonatites is unlikely to be subduction-related carbon, and support a C-O fractionation model starting from mantle-derived sources.

The bulk of the geochemical data shows that mostly of the occurrences contain an enriched isotopic signature. In general, Sr-Nd-Pb-Os isotopes and trace elements data from potassic rocks suggest that the associated carbonatites and primary carbonates reflect the composition of the source mantle. In particular, the combined O-Sr systematics and Sr-Nd-Pb-Os isotopic data indicate that the carbonatite system is dominated by mantle component(s) without appreciable crustal contamination. Thus, in spite of the great variation shown by C-O isotopes, Sr-Nd-Pb-Os isotopic systematics could be related to an isotopically enriched source where the chemical heterogeneities reflect a depleted mantle "metasomatized" by small-volume melts and fluids rich in incompatible elements. These fluids are expected to have promoted crystallization in the mantle of K-rich phases that gave rise to a veined network variously enriched in LILE and LREE. The newly formed veins (enriched component) and peridotite matrix (depleted component) underwent a different isotopic evolution with time as reflected by the carbonatitic rocks.

These conclusions may be extended to the whole Paraná-Angola-Etendeka system, where isotopically distinct parent magmas were generated following two main enrichment events of the subcontinental lithospheric mantle at 2.0-1.4 and 1.0-0.5 Ga, respectively, as also supported by Re-Os systematics. The mantle sources preserved the isotopic heterogeneities over a long time, suggesting a non-convective lithospheric mantle beneath different cratons or intercratonic regions. The area distribution shows that the time-integrated isotopic enrichment of the carbonatites and associated alkaline rocks decreases from West (Eastern Paraguay) to East (Angola and Namibia), and it is related to age decrease of the alkaline magmatism, i.e. from Early Cretaceous to Paleogene.

Overall the data indicate that the alkaline-carbonatitic magmatism originated from a significant but small scale heterogeneous subcontinental mantle. In this scenario, the Tristan da Cunha, Walvis Ridge-Rio Grande Rise and Victória-Trindade hotspot tracks might reflect the accomodation of stresses in the lithosphere during rifting, rather than continuous magmatic activity induced by mantle plumes beneath the moving lithosphere.

Notably, these conclusions are consistents also with the tholeiitic magmatism from the South American Platform (SAP), where all the data indicate that mantle source heterogeneity was well establiished at leat since Late Archean times, as documented by the Precambrian and Mesozoic SAP tholeiites which have similar compoxsitional featutres, particularly the tholeiites cropping out on the same craton. The concentration of the Precambrian and Mesozoic SAP tholeiitic magmatism towards cratonic/mobile belt boundaries suggests that an important role in its genesesis was played by upper mantle "edge drive convection " geodynamics. In particular, it is notable that the mantle "netasomatic’ processes might be related to ancient subduction-related processes (e;g; Trajsamazonian and Brasiliano events).