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CONTENTS OF DISK

First evidence for expressive Neoproterozoic intraplated mafic rocks and magma mixing in post-collisional A-PA type granites, Southern Brazil: Geochemistry and U-Pb (zircon), Nd-Sr-^{18}O(zircon) isotope investigations.

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New and recent geological investigations around Piên-Tijucas suture zone, between Luis Alves and Curitiba Microplates (Basei *et al.*2000) led to mapping of Palermo, Agudos do Sul and Rio Negro A-PA type Granites with expressive expositions of alkaline felsic ans mafic rocks and, associated mafic and felsic hybrid rocks. The suture zone is formed by subduction arc-related Piên-Mandirituba deformed calc-alkaline I-type granite belt and serpentinized supra subduction zone (SSZ) obducted mantle rocks with intrusive Neoproterozoic (650-630 Ma) very high Cr and Ni tholeitic gabbros.

The Piên-Mandirituba calc-alkaline I-type Granite Belt is constituted by three main granite suites. The older emplaced pre-collisional suite is constituted by deformed to highly deformed amphibole and biotite-rich, magmatic epidote-absent quartz-monzodiorites and granodiorites formed between 620 and 610 Ma. The second sincollisional granite suite is constituted by deformed and slightly deformed low content amphibole-biotite-magmatic epidote-bearing, quartz-monzodiorites, granodiorites and leucogranodiorites emplaced between 605 and 595 Ma. The third, also sincollisional, granite suite is deformed to highly deformed biotite ± amphibole monzogranites. The deformation age of the three non-cogenetic granite suites of this granite belt is between 605-595 Ma. The granite rocks of the Piên-Mandirituba Granite Belt are meta-aluminous to slightly peraluminous, high K calc-alkaline, generally with high Ba, high Sr and low Rb contents.

Palermo, Agudos do Sul and Rio Negro Granites are components of the expressive Neoproterozoic volcanic and plutonic alkaline-peralkaline Serra do Mar Suite (Kaul 1997), emplaced in extensional post-collisional and anorogenic settings along the central portion and northern border of the Luis Alves Microplate and southern border of the Curitiba Microplate. Magma mixing evidence is rare ou absent in the other components of the Serra do Mar volcanic and plutonic suite.

The Palermo Granite, formed between 595-585 Ma, is mainly constituted by medium to coarse grained, non deformed A-type amphibole-biotite and biotite monzo-syenogranites, and subordinately slightly peralkaline (PA-type) quartz-monzonites/quartz-syenites with sodic amphibole and pyroxene, intraplated alkaline mafic rocks and associated felsic and mafic hybrid granite rocks.

The Rio Negro Granite, formed between 595-585, Ma is mainly constituted by mafic and felsic hybrid granite rocks and associated alkaline mafic rocks and non deformed A-type biotite monzo-syenogranites. The peralkaline rocks are absent in the Rio Negro Granite.

The A-type monzo-syenogranites of Palermo and Rio Negro and, A-type leucogranodiorites of Agudos do Sul Granite are high silica (SiO_2 70-80%), aluminous (meta-aluminous to slightly peraluminous) with low Sr, low Ba, high Rb content and high Ga, Zr, Hf, Nb and Y contents and, high LREE and HREE with high Eu negative anomalies. The slightly peralkaline quartz-monzonites/quartz-syenites (SiO2 = 60-65 %) of Palermo Granite presents very low Sr, low Ba, high Rb, very high Zr, Hf and Y, and LREE and HREE enrichment with high Eu negative anomalies.

The alkaline mafic rocks emplaced within Palermo and Rio Negro Granites forms, by mixing with the adjacent A-type monzo to syenogranites, a great variety of mafic (hybrid monzodiorites/hybrid monzogabbros, hybrid quartz-monzodiorites to hybrid quartz-monzonitos) and felsic (hybrid quartz-monzodiorites, hybrid quartz-monzonitos to hybrid monzogranitos) hybrid rocks. The mafic and felsic hybrid rocks are mainly characterised by the presence of typical mixing textures such as, quartz-ocelli with or without interstitial perthite mantled by pyroxene, amphibole and biotite, chaotic acicular apatite, rounded and elliptical mafic (biotite, amphibole/pyroxene) concentrations. The mixing textures are absent in the alkaline mafic rocks. The lithochemical and ^{18}O isotope investigations on these hybrid rocks and the mixing components suggest no genetical links between monzo-syenogranites and alkaline mafic rocks.

The alkaline mafic rocks are mainly monzogabbros (Figure 1) with amphibole and biotite high contents They are mainly emplaced in Rio Negro Granite and subordinately in Palermo Granite and always causing, in both granites, magma mixing with production of hybrid mafic and felsic granite rocks. Additionally, small monzogabbros dikes are also emplaced within the adjacent Luis Alves Microplate.

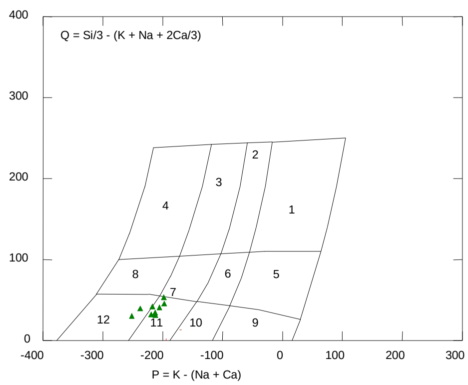

Figure 1 - P-Q diagram (Debon & Lefort 1983) for alkaline mafic rocks of Palermo and Rio Negro Granites. 1- Granites, 2- Monzogranites, 3- Granodiorites, 4- Tonalites, 5- Quartz-Syenites, 6- Quartz-Monzonites, 7- Quartz-Monzodiorites, 8- Quartz-Diorites, 9-Syenites, 10- Monzonites, 11- Monzodiorites/Monzogabbros, 12- Diorites/Gabbros-

The monzogabbros are grey to dark grey, fine grained and isotropic. They are constituted by plagioclase (andesine-labradorite), biotite (red brown to brown), amphibole (olive green to dark green), clinopyroxene (rarely titano-augite mainly augite, augite-aegirine) and rare orthopyroxene and olivine. The perthite and quartz are low content and interstitial. The accessories minerals are zircon (+ badeleyite?), apatite, titanite and magnetite. The most zircon crystals in these rocks are rarely prismatic euhedric crystals, generally incomplete prismatic crystals and mainly anedric crystals with exotic and indefinite forms and great size variety, chaotically distributed in these rocks. The textural mineral relations with other minerals in these rocks and anedric crystals forms suggest late crystallisation and fast cooling of zircons. The alkaline mafic rocks present interstitial texture characterised by disordered and synchronic crystallisation of pyroxene and plagioclase and, late interstitial biotite and amphibole. The principal mafic mineral phases generally forms sympletitic or coronitic textures characterised by the presence of orthopyroxene/clinopyroxene, rarely olivine, in the cores passing to amphibole and amphibole/biotite in the edges suggesting magmatic replacement of pyroxene by amphibole and this later by biotite.

The monzogabbros (SiO_2 content 48 to 55%) of Palermo and Rio Negro granites are alkaline (Na_2O = 3-4%, K_2O = 1-2.2 %, Na_2O/K_2O=1.8-2.5). These rocks are lithochemically characterised by high Ba (1000 ppm), Rb (30-60 ppm), high Sr (600-400 ppm) high Ga (15-20 ppm), high Zr (100 to 350 ppm), Nb (8-18 ppm), high Y (30-60 ppm), and, LREE and HREE enrichment without Eu anomalies. The trace elements Zr and Y (Figure 2) and other trace elements contents of the monzogabbro clearly indicate within plate signatures for these mafic rocks of Palermo and Rio Negro Granites.

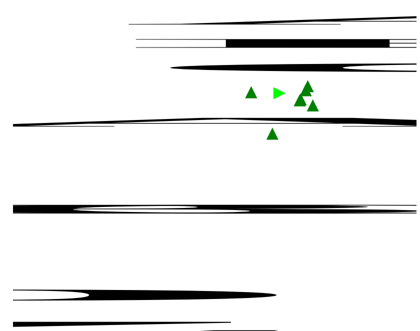

Figure 2- Zr X Zr/Y diagram (source: Pearce and Norry 1979) for the alkaline mafic rocks of Palermo and Rio Negro Granites.

The U-Pb isotopic results obtained in zircons extracted from biotite monzogabbros of Rio Negro Granite indicated, in concordia diagram (Figure 3), upper intercept age of 584+7.2/-7.1 Ma

(MSWD = 0.18) interpreted as the crystallisation and cooling age of all alkaline mafic rocks.

The difference between U-Pb zircon and K-Ar biotite ages of these monzogabbros with U-Pb zircon and K-Ar biotite ages (581-572 Ma) of the monzo-syenogranites of Palermo (593 ± 12 Ma) and Rio Negro (593.1 ± 6.3 Ma) Granites indicate that these monzogabbros are lately emplaced and early fast cooling.

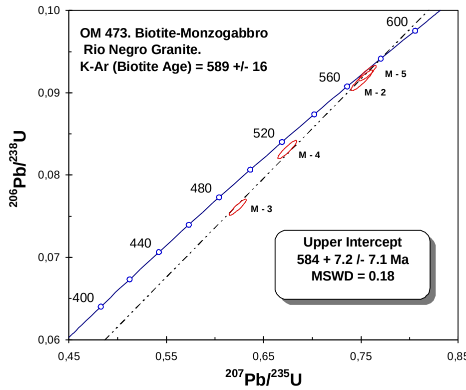

Figure 3 - concordia diagram showing the U-Pb isotopic data for zircons of alkaline mafic rocks emplaced within Rio Negro Granite.

Sm-Nd isotopic data indicated similar negative $\in Nd^{(T)}$ values and Paleoproterozoic depleted mantle ages (T_{DM}) for monzo-syenogranites (–11.72, 2.299 Ga), hybrid quartz-monzodiorite (-11.75, 2.415 Ga), hybrid monzonites (-11.29, 2.161 Ga) and alkaline mafic rocks (-11.57 to -11.42 , 2.292 to 2.237 Ga) of the Rio Negro Granite. Monzo-syenogranites of the Palermo Granite have slightly more negative $\in Nd^{(T)}$ values, between – 13.53 and -14.43 and depleted mantle ages between 2.1 and 2.35 Ga. The $\in Nd^{(T)}$ values and depleted mantle ages for the hybrid quartz-monzonite are -10.96 and 2.13 Ga), peralkaline quartz monzonite are -12.46 and 2.0 Ga and for the biotite monzogabbro of Palermo Granite are -5,43 and 2.05 Ga. The $\in Nd^{(T)}$ values for the monzogabbros of Palermo Granite are lower, by 5 to 6 $\in$ units, than the monzogbbros of Rio Negro Granite and this difference indicate low crustal contamination component in the monzogabbros of Palermo Granite. Only the same $\in Nd^{(T)}$ for the monzo-syenogranites and monzogabbros of the Rio Negro Granite suggest high crustal contamination or probably generation of A-type monzo-syenogranites by melting of contaminated monzogabbros.The $Sr^{87}/Sr^{86(T)}$ ratios are similar (~0.707) for A-type monzo-syenogranites of Palermo and Rio Negro and, for the alkaline mafic rocks and hybrid rocks of the Rio Negro Granite are respectively 0.70585 and 0.70456.

The Nd isotopic characteristics of many continental flood basalts and continental rift zone basalts Menzies (1992) and Saunders et al (1992), are due to (a) interaction of asthenospheric melts with old lower or upper crust, (b) melting of enriched continental lower lithosphere with crustal contamination, (c) mixing of enriched and depleted mantle source, (d) upwelling of deep mantle plumes containing recycled components or combinations of these processes (a-d).

Zircons generally preserve magmatic $\delta^{18}O$ values. Magmas with no supracrustal input generally have a uniform oxygen isotope ratio that is distinct from magmas that assimilated or were generated directly from supracrustal or infracrustal sources (Valley et al 1994 and King et al. 1998).The $\delta^{18}O$ of the bulk mantle has been estimated to be $5.5^{o}/_{oo}$ based on mantle peridotites (Mattey et al. 1994). Mid-ocean ridge basalts (MORB) has an extremely homogeneous $\delta^{18}O$ value of 5.7 $^{o}/_{oo}$ (Harmon & Hoefs 1995) similar to most ocean island basalts "OIB" (Eiler et al. 1997), that higher than subduction related basalts (6.0-6.8 $^{o}/_{oo}$) and continental intraplate basalts (6.1 for alcali basalts and 7.1 for tholeitic basalts). We analyzed the $^{18}\delta O$ $^{o}/_{oo}$ in the same zircons dated by U-Pb method. When the $\in Nd^{(T)}$ indicate mantle-crust interactions and crustal contamination during the genesis of the mafic alkaline rocks intraplated in the Palermo and Rio Negro Granites, the average $\delta^{18}O$ (Zircon) of 5.5 $^{o}/_{oo}$ in these rocks are similar to the $\delta^{18}O$ $^{o}/_{oo}$ of the bulk mantle (Mattey et al. 1994) and not indicated crustal contamination or contribution during fractionations. The monzo-syenogranites of the Palermo and Rio Negro Granites present an average δO^{18} (Zircon), between 5.1 and 4.7, and are lower than the alkaline mafic rocks. This probably exclude the possible generation of A-type monzo-syenogranites by melting of the intraplated monzogabbros.

Late to post collisional extensional settings with upwelling of asthenospheric or mantle derived melts (decompression melting) and underplating and intraplating of this mantle-derived mafic melts caused heating of the lower crust (central and northern settings of the Luis Alves Microplate), and production of many high temperature and low pressure felsic A-PA melts, that are mixed with the intraplated and contaminated mafic melts. The appropriate setting for this tectonic-thermal scenery is around this pre sutured and probable delaminated region.

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