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The 8th Hutton Symposium on Granites and Related Rocks

PT.001

Timing of the partial melting in the Socorro-Guaxupé Nappe, Brazil: constraints from in-situ monazite and zircon dating of migmatites and garnet-bearing leucosome

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Linking geochronological information from zircon and monazite to petrological data can ideally provide a direct assessment of the duration of metamorphic processes and events. The growth of monazite under high-grade conditions tends to define a narrower age distribution than zircon within the same rock, because pre-metamorphic inheritance is less common. Integration of full thin-section compositional maps with high-resolution X-ray compositional maps has the potential to link dates obtained from distinct monazite compositional domains to specific metamorphic reactions. This approach is used to investigate high-grade metasedimentary rocks from the Socorro-Guaxupé Nappe (MG) Brazil, to place constraints on the timing of the partial melting. The Socorro-Guaxupé Nappe represents the root of a magmatic arc emplaced at the active margin of the Paranapanema plate during the Neoproterozoic. High-temperature metamorphism recorded by granulites and migmatites is a result of the Ediacaran collision between the Paranapanema and the São Francisco plates during the southern Brasília orogeny. Studied rocks include a stromatic metatexite, a schollen migmatite (leucosome and host garnet-biotite gneiss) and mafic granulite within the segregated leucosome. Three distinct REE patterns are recognized within leucosome, suggesting fractional crystallization in the evolution of an anatectic melt. Mesosome exhibits the highest REE contents and is characterized by negative Eu anomaly ($Eu/Eu^* = 0.4-0.8$). The $^{87}Sr/^{86}Sr_{(625Ma)}$ and $\epsilon_{Nd(625Ma)}$ values of leucosome and mesosome range from ~ 0.706 to 0.709 and from -7 to -8 , respectively, suggesting Sr and Nd isotopic homogenization during partial melting. U-Pb zircon dates from the analyzed samples show a large spread from *ca.* 600 to 720 Ma. The younger dates ranging from 600 to 630 Ma are interpreted to date major episodes of melt crystallization after granulite-facies metamorphism. The older dates from 640 to 720 Ma may be related to inheritance. Mafic granulite yields zircon ages from 600-650 Ma. Inherited zircon cores with oscillatory zoning from mafic granulite have higher Th/U ratios (0.7-1.2) than CL-bright rims and recrystallized domains (0.02-0.5). Migmatites are characterized by zircons with low Th/U ratios and by abundant monazite in a variety of textural settings (locally up to 3mm large euhedral grains within leucosome). Zircon growth related to the partial melting event typically has lower Th/U ratios as monazite scavenges Th. Monazite mapping and chemical dating revealed complex zoning patterns. Y-rich resorbed monazite cores (14000-26000 ppm) occur mainly as inclusions in garnet and most likely correspond to the pre-garnet stages of prograde metamorphism at *ca.* 630 Ma. Monazite crystallized from melt is Th-rich (60000-125000 ppm) and Y-depleted (<4000 ppm) due to growth in the presence of peritectic garnet at 620-600 Ma. High-Y rims (7000-12000 ppm) can be related to retrograde garnet-breakdown between 618 and 594 Ma. High-Th rims (70000-100000 ppm) are interpreted as a late recrystallization event at 608-592 Ma. The main growth stage of monazite is related to melt crystallization. Thus, monazite is a valuable tool in deciphering distinct episodes of metamorphism, partial melting and crystallization in arc-related metasedimentary rocks compared to zircon, as monazite grains grow entirely during the metamorphic event and inheritance is only seen in zircon.



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Controls on the geochemistry of leucogranites produced by water-fluxed melting of a granitic protolith

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Granites and quartzo-feldspathic gneisses have the potential to produce large volumes of granitic magma in the continental crust during water-fluxed melting. If partial melting occurs via a reaction such as plagioclase + quartz + K-feldspar + H₂O = melt, then the melt produced may have a distinctive composition because neither biotite nor amphibole is a reactant. The melt generated is expected to be leucocratic; moreover it remains leucocratic even if contaminated by its source, because quartz and plagioclase are the most abundant phases in the residua from granitic protoliths. Thus, magmas from granitic sources should differ from those from pelitic rocks in which ferromagnesian phases are more abundant.

We investigate the petrogenesis of the Kinawa Migmatite, part of a reworked Archaean Tonalite-Trondhjemite-Granodiorite (TTG) terrane in the São Francisco Craton, Brazil. This migmatite formed when a leucocratic meta-granodiorite partially melted and generated a considerable volume of leucogranitic magma.

The migmatite consists principally of three types of diatexite: grey, schlieren and homogeneous. Grey diatexites [SiO₂ 70 to 73 wt.%; FeO*+MgO+MnO+TiO₂ (FMMT) 3 to 5 wt.%] have a low modal abundance of K-feldspar, but high modal plagioclase, quartz and biotite relative to the protolith; therefore these diatexites are interpreted to be the residuum after water-fluxed partial melting by the reaction plagioclase + quartz + K-feldspar + H₂O = melt, during which biotite remained stable. Geochemical mass balance indicates the degree of partial melting was between 0.35-0.4. Schlieren diatexites [SiO₂ 72 to 75 wt.%; (FMMT) 1.15 to 4.3 wt.%] are heterogeneous and composed of biotite-rich schlieren, which represent residuum, alternating with pink coarse-grained quartzo-feldspathic domains, interpreted to have crystallised from melt. The homogeneous diatexites [SiO₂ 73 to 75.65 wt.%; (FMMT) 0.49 to 3 wt.%] are leucocratic, have no schlieren and are characterised by an igneous microstructure in which euhedral to subhedral plagioclase (An₂₅) forms a framework. Microcline in these rocks contains rounded inclusions of plagioclase and quartz; the former typically have compositions (An₃₀) similar to plagioclase in the residual grey diatexites, and thus are interpreted to be residual crystals carried in the melt.

Crystal fractionation can explain the broad geochemical trends of the homogenous diatexites and the leucosomes, but it cannot explain all the features. Geochemical modelling shows that incomplete segregation of melt from its residuum is also evident in the schlieren diatexites, which contain the largest (up to 50 %) residual component. A similar, but smaller contamination effect can also be traced in the homogeneous diatexites. Although these diatexites correspond to a magma containing a high fraction of anatectic melt, entrainment of up to 15% residual plagioclase and 9% quartz results in geochemical compositions that are different from those expected for a pure melt (e.g., higher CaO + Na₂O contents). Thus, the compositional trends in leucogranites generated by water-fluxed melting of a granitic protolith are controlled by both incomplete segregation and crystal fractionation.



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PT.003

Isotopic disequilibrium in granites: implications for the melting process and petrogenetic models

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Understanding granite petrogenesis is an important part of unravelling crustal processes and growth; however, recent research has demonstrated that commonly utilised isotope systems (Sr, Nd and Hf) could behave in a more complex manner during partial melting and crystallisation than is often assumed in petrogenetic models. This study examines a set of diverse granite samples from the Lachlan Fold Belt, southeastern Australia, including low temperature S- and I-type granites and the high temperature I-type Boggy Plains Suite. Comparison of magmatic zircon and bulk rock initial Hf isotope compositions reveal $\Delta\epsilon_{\text{Hf}}^{\text{bulk-zircon}}$ discrepancies ranging from -0.9 to +2.8 ϵ units, thus providing evidence for intra-sample (and hence inter-phase) Hf-isotopic heterogeneity. For the Boggy Plains Suite, the change from $\Delta\epsilon_{\text{Hf}}^{\text{bulk-zircon}} = +0.1$ to +1.9 with progressive evolution from primitive, mafic samples to more evolved, felsic samples is consistent with a previously proposed petrogenetic model involving decoupled assimilation and fractional crystallisation (Ickert 2009, Ickert *et al.* 2011). In contrast, low temperature I- and S-type granites preserve linear variations on Harker diagrams and negligible covariation between O and Hf isotopes in magmatic zircon, which are inconsistent with assimilation or simple mixing hypotheses. In these samples, the bulk-zircon differences observed can be explained by isotopic disequilibrium between the melt and the restite assemblage. Using a range of experimentally determined melting reactions and accessory mineral dissolution equations, the isotopic compositions of melt, source (protolith) and restite have been calculated for a variety of hypothetical melting scenarios, in which the protoliths had acquired an isotopically heterogeneous mineral assemblage by aging in the crust prior to melting. Assuming that magmatic zircon records the melt composition and that the bulk rock (particularly of a mafic granite) images the source, the $\Delta\epsilon_{\text{Hf}}^{\text{bulk-zircon}}$ values measured for I-type granites (0.4-2.8) can largely be explained by disequilibrium amphibole dehydration melting of meta-igneous protoliths that have aged in the crust for 0.5-1.0 billion years before melting. For S-type magmatism the data and models suggest greater complexity. The majority of S-type melting scenarios modelled (muscovite and/or biotite dehydration melting) predict negative $\Delta\epsilon_{\text{Hf}}^{\text{source-melt}}$ values, and although samples from one of the studied suites are consistent with this ($\Delta\epsilon_{\text{Hf}}^{\text{bulk-zircon}}$ values -0.4 to -0.9), most record positive values (+0.2-1.1). A recently proposed hypothesis in which magmatic zircon acquires its Hf isotope composition both from the melt and from the inherited zircon population (Villarsos *et al.* 2012, Farina *et al.* 2014) can explain why measured $\Delta\epsilon_{\text{Hf}}^{\text{bulk-zircon}}$ values could become positive in such rocks. This hypothesis is currently being tested by a detailed comparison of zircon core and rim compositions from a restite-rich S-type granite. The results of this study imply that great care should be taken in the interpretation of isotopic compositions of zircons in granite and that mafic members of granitic suites, not zircons, may provide the most reliable constraint on the protolith isotopic composition.



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Partial melting and magma generation in the Mesoarchean (ca. 3.0 Ga) TTG gneisses of the Xingu Complex, Carajás Province, Amazon Craton.

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The Xingu Complex is composed of migmatized orthopyroxene-diopside gneisses of tonalitic to granodioritic composition with *boudins* of amphibolites. These rocks are juxtaposed by mafic granulite gneisses from the Pium Complex, which are also variably migmatized. Geological and geochemical characteristics of the Xingu Complex gneiss are similar to those of sodic TTG suites with intermediate HREE content, including: (i) the association of polyphasic orthogneiss with mafic enclaves and leucosome; (ii) Na₂O content between 4.36 and 4.66%; (iii) K₂O/Na₂O ratio of 0.21 to 0.53; (iv) Al₂O₃ content between 15 and 16% for rocks with more than 70% of SiO₂; (v) Yb content of 0.18 to 1.23 ppm; (vi) (La/Yb)_N between 12 and 49; (vii) Sr/Y values between 43 and 168 ppm; (viii) Nb-Ta and Ti negative anomalies; (ix) no significant Sr anomalies and absence of Eu negative anomalies (Eu/Eu* = 0.81 to 2.1); and (xi) V/Sc values between 6 and 15. The crystallization age of the gneiss protolith was dated at 3,066 ± 6.6 Ma (U-Pb SHRIMP IIe zircon core analysis from paleosome). Its genesis was related to melting of hydrated metabasalts under compatible conditions with garnet, hornblende and rutile stability in the restite. The successive granulite facies metamorphism was synchronous to the development of a low angle gneissic banding (S₁) with N70E/40NW to N24E/50NW direction and down-dip stretching lineation. S₁ banding was affected by isoclinal folds with subvertical axial foliation (S₂) with WNW-ENE trend and by E-W strike-slip ductile shear zones (C₁). The first partial melting event occurred at 2,959 ± 15 Ma (U-Pb SHRIMP IIe in zircon core from the leucosome) and reflects the biotite dehydration reaction to form peritetic orthopyroxene (Bt + Qtz + Kfs = Opx + melt; ~800 °C) in the thermal peak of the metamorphic trajectory of the Xingu Complex gneiss. The products of anatexis include *patch* and stromatic metatexites and *schlieren* and *schollen* diatexites, in which the leucosomes show granoblastic texture. The second anatetic event was related to crosscutting coarse-grained undeformed leucosomes formed at ca. 2.86 Ga. The geochemical, geochronological and metamorphic data from the Xingu Complex gneiss reinforce the importance of active tectonic margin process in the genesis of the Mesoarchean continental crust. The preliminary metamorphic evaluation indicates also that the Xingu and the Pium complexes could represent part of the exhumed lower crust of the northern Carajás Province, probably reworked during the granite genesis events recognized in the area between ca. 2.96 and 2.86 Ga.



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**Lithospheric mantle melting during continental collision: crustal growth or crustal recycling?
A case study from the Variscan French Massif Central**

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The post-collisional stage of orogenies arguably represents the most favorable geological setting for the preservation of continental crust, but the extent to which new crust is formed in this setting remains debated. Post-collisional magmatism is characterized by the emplacement of voluminous granitoid magmas which potential sources cover a wide spectrum, including not only the middle and lower continental crust, but also the lithospheric mantle and the asthenosphere. Consequently, in terms of crust evolution, those granitoids range between two end-members: (i) pure recycling of pre-existing crust and (ii) “juvenile” magmatism (i.e. extracted from mantle reservoirs devoid of any crustal remnant). The relative proportion of recycled versus juvenile components in granitoid magmas is then a critical information to grasp how much material is transferred from the mantle to the continental crust at the post-collisional stage and to what extent they participate to crustal growth. We provide new constraints on those issues using whole-rock geochemical and zircon U-Pb-Hf-O isotope data on a range of granitoids from the Variscan French Massif Central. Investigated granitoids belong to three groups, namely: (i) peraluminous two-mica or cordierite-bearing granites (MPG and CPG); (ii) metaluminous, biotite- ± amphibole-bearing granitoids (KCG) and (iii) Mg-K-rich diorites. LA-ICP-MS U-Pb dating of 31 samples from all groups show that they emplaced synchronously during ~35 Ma. All data from MPG and CPG comply with an origin by partial melting of the local nappe pile. Diorites display a marked enrichment in both compatible (Mg, Fe, Ni, Cr) and incompatible (K, Rb, Ba, Sr, REE) elements along with crust-like, non-radiogenic Hf isotope signatures which argue for derivation from an enriched, lithospheric mantle source. Diorite zircons have $\delta^{18}\text{O}$ ranging from mantle-values (ca. +5‰) to up to +10‰, showing that crustal contaminants present in the lithospheric mantle involved a diversity of materials, having experienced a weathering cycle or not, and possibly ranging from upper to lower crustal lithologies as inferred from variable Th/La ratios. Several independent modelling methods, based on Hf contents and isotope compositions of the diorites and their postulated source (metasomatized peridotites), suggest that the crustal component represents 0.8–13 wt.% of the bulk, enriched mantle source. Finally, available data on KCG support an origin by fractionation of diorite magmas and subordinate mixing between the resulting magmas and MPG / CPG melts. Thus, crust recycling during late-orogenic periods does not only take place by direct anatexis of the thickened orogenic crust, but also by melting of metasomatized mantle domains, previously enriched by crustal components stored in the mantle (via subduction and/or delamination). That being said, this process would not be recorded the same way, depending on the chemical behavior of the considered elements. Incompatible elements already enriched in the crust remnants (such as K, Sr, Hf, REE, Th) should be more sensitive to



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recycling than compatible elements with mantle affinities (Mg, Fe, Ni, Cr). Commonly used isotopic tracers are typically incompatible elements that would therefore under-estimate the mass transfer from the mantle to the crust and associated crustal growth at the post-collisional stage.



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PT.006

Ediacaran High-K to Shoshonitic Magmatism in the Pernambuco Alagoas - Domain, NE Brazil: U-Pb and Oxygen SHRIMP Data

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The Pernambuco Alagoas (PEAL) domain shows the major occurrence of granitic batholiths of the Borborema Province, NE Brazil, with Archean to Neoproterozoic range of T_{DM} model ages, giving clues on the role of granites during the Brasiliano Orogeny. SHRIMP U/Pb zircon data for seven granitic intrusions of the PEAL domain, emplaced from early- to post-collision stages, divide the studied granitoids into three groups: 1) granitoids with crystallization ages ca 635 Ma (Serra do Catú pluton), 2) granitoids with crystallization ages 610-618 Ma (Santana do Ipanema, Água Branca, Mata Grande and Correntes plutons) and 3) granitoids with ages of ca. 590 Ma (Águas Belas, and Cachoeirinha plutons). The intrusions of group 1 and 2, except the Mata Grande and Correntes plutons, show Nd T_{DM} model ages ranging from 1.2 to 1.5 Ga, while the granitoids from group 3, and Mata Grande Pluton and Correntes plutons have Nd T_{DM} model ages ranging from 1.7 to 2.2 Ga. The studied granitoids are in part high-K, calc-alkaline, shoshonitic, ultrapotassic and in part transitional high-K calc-alkaline to alkaline. The volcanic arc signatures associated with the Paleoproterozoic T_{DM} model ages are interpreted as inherited from the source rocks. The oldest ages and higher Nd T_{DM} model ages are recorded from granitoids intruded in the southwest part of the PEAL domain, suggesting that these intrusions are associated with slab-tearing during convergence between the PEAL and the Sergipano domains. Zircon oxygen isotopic data in some of the studied plutons, together with the available Nd isotopic data suggest that the Brasiliano orogeny strongly reworked older crust, of either Paleoproterozoic (Rhyacian?) and Tonian ages.

The studied granitoids are coeval with high-K granitoids intruded within the Transversal Zone domain of the Borborema Province and calc-alkaline granitoids of the Sergipano domain. This suggests that these domains belonged to the same crustal block during the Brasiliano Orogeny. Such large volumes of high-K granitoids with crystallization ages older than 600 Ma are not recorded in the Sergipano and Transversal Zone domains, suggesting differences in the crustal evolution of these two areas, when compared to the PEAL domain.



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PT.007

Sources of Neoproterozoic granite magmas in the Embu Terrane, Central Ribeira Belt, Brazil: constraints from geochemistry and Sr-Nd-Pb isotopes

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Neoproterozoic granites forming isolated plutons and some large batholiths are widespread in the Embu Terrane (central Ribeira Belt, SE Brazil). Although covering a wide timespan (780-580 Ma), most occurrences were formed in a short interval at the end of this period (600-580 Ma), with scattered manifestations dated at ~ 780-750 Ma (small occurrences of orthogneiss), ~ 680 Ma (Serra do Quebra Cangalha Batholith) and ~ 640 Ma (Santa Catarina Granite). In spite of the several episodes of granite generation, their compositions are mostly restricted to two main rock types, slightly metaluminous Bt monzogranites and peraluminous Tur±Grt+Bt+Ms leucogranites. A single main pluton of basic to intermediate composition is known (the Aparecida Monzonite), and fine-grained magmatic enclaves, present in only a few Bt monzogranites, are of felsic composition [1]. Therefore, mantle contribution should have been minor, and the granites are mostly products of crust reworking. The exposed granite country rocks of the Embu Terrane comprise dominantly medium-grade metavolcano-sedimentary sequences and a few small windows of gneiss-migmatite basement. Recent U-Pb dating indicates that the main basement exposure (Rio Capivari Complex) corresponds to Paleoproterozoic (~2.2 Ga) migmatites reworking Archean (~2.7 Ga) crust. The age of the supracrustal sequences is poorly constrained between ~1.8 Ga (youngest detrital zircons in metasediments and Nd T_{DM} of metapelites) and ~0.78 Ga (age of intrusive orthogneisses). Sr-Nd-Pb isotope signatures of the granites allow identification of some key characteristics of their magma sources. Many ~600-580 Ma plutons show similar ⁸⁷Sr/⁸⁶Sr_(t) (0.7107 to 0.7132) but important variations in εNd_(t) (from -12 to -18, with less negative values in the Bt monzogranites). More radiogenic ⁸⁷Sr/⁸⁶Sr_(t) (0.7163-0.7276) and less negative εNd_(t) (-7.3 to -12) are typical of granites from the Lagoinha and Serra do Quebra-Cangalha batholiths. Pb isotopes from Bt monzogranites show retarded common Pb signatures (model ages from 550 to 600 Ma), suggestive of the contribution of unradiogenic sources and consistent with the extraction from a crustal reservoir with ²³⁸U/²⁰⁴Pb (μ) ~8.75 and time-integrated U/Th (κ) ratios close to 4.9. Bt-Ms leucogranites show much younger model ages suggestive of an extensive contribution of highly radiogenic material, most likely metasediments, as indicated by higher μ and lower κ ratios (~9.0 and 4.0, respectively). These signatures allow identify four major reservoirs, that may be predominant in a single granite occurrence or be a component in mixing processes: 1) a young upper crust of low κ with radiogenic Pb, high ⁸⁷Sr/⁸⁶Sr_(t) and εNd_(t) (Serra do Quebra Cangalha); 2) a young lower crust and/or old upper crust + juvenile component with high κ and relatively unradiogenic Pb (Santa Catarina pluton); 3) an old upper crust with low κ, radiogenic Pb and low εNd_t (Ms-Bt granites); and 4) an intermediate old lower crust with high κ, non-radiogenic Pb, and intermediate εNd_t (Bt granites).

[1] Alves et al., 2009. JPet. 50, 2221-2247)



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PT.008

Tracking the oxygen fugacity trajectories of enclave-forming melts through plagioclase trace element signatures: a reassessment of experimental data

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It has been experimentally demonstrated that the initial stages of the xenolith assimilation process might involve local and transient perturbations of the magma redox potential, which can lead to preferable stabilization of reduced oxidation states of multivalent elements, especially in cases where granite magmas intrude sulfur and graphite-bearing rocks. As suggested by classic and contemporary experimental studies, the partition of multivalent elements (particularly Eu) into the plagioclase structure is a function of the prevailing fO_2 conditions. Moreover the high Sr and low Rb contents of plagioclase crystals allow tracking of contamination process on the mineral scale, which makes plagioclase a suitable candidate for the investigation of simultaneous contamination and fO_2 perturbation of the granite magmas from which it crystallizes.

We reassessed the available experimental data in order to propose a new regression equation relating Eu multivalent ratios and fO_2 conditions (eg. Drake, 1975; Geochim. Cosmochim. Acta 39, 55-64).

$\log fO_2 = -4.27 (+/-0.24) \times \log(Eu^{2+}/Eu^{3+}) - 11.752 (+/-20)$ $r^2=0.76$ Std error = 1.26 log units

The equation successfully reproduces experimental fO_2 data within 2 log units (with 60% within 1.0 log unit).

We tested the possibility of combining plagioclase trace and isotope data on felsic microgranitoid enclaves (FME) from two granite occurrences. The Mauá pluton intrudes graphite-bearing metasediments that frequently occur as xenoliths within the granite. Multivalent Eu ratios were calculated using the Lattice Strain Model and partition coefficients (D) for Gd and Sr as proxies to $D_{Eu^{3+}}$ and $D_{Eu^{2+}}$, respectively.

Resultant Eu^{2+}/Eu^{3+} ratios define a strong positive correlation with Sr isotope composition, implying a total fO_2 variation of 4 log units. Plagioclase cores are reduced and more contaminated with fO_2 of -12.5 and $^{87}Sr/^{86}Sr = 0.7131$, followed by gradually more oxidized and less contaminated rims ($fO_2 = -8.5$ and $^{87}Sr/^{86}Sr = 0.71046$ (in equilibrium with whole rock data. Sr isotope data from Alves et al., 2009; J.Petrol. 50, 2221-2247). Apparently assimilation of metapelites implied fO_2 reduction and increased radiogenic signatures, and this was followed by a gradual diminution of the contaminant/resident magma ratio, with the recovery of the original redox conditions and isotope signatures.

The second case investigates FME from the Salto pluton, a small granite occurrence that intrudes sulfur- and organic matter-free orthogneisses and bears a negligible amount of xenoliths. Inherited plagioclase (xenocrysts, matrix crystals from FME, and phenocrysts from a host granite) trace element and isotope data were used to calculate multivalent Eu ratios and to track the contamination processes. Sr isotopes vary broadly ($^{87}Sr/^{86}Sr$ from 0.7087 to 0.7121) and exhibit no clear correlation with calculated multivalent Eu ratios. Variations in calculated fO_2 values are discreet and reveal slightly more reduced xenocrysts compared to matrix crystals (average values of -7 and -5.7, respectively), whereas a phenocryst from a host granite shows a broader variation range (-8.1 to -6.2 log units), not correlated to $^{87}Sr/^{86}Sr$ values. The resultant fO_2 variation is roughly within the standard error of Eq. 1. Therefore we consider that assimilation of orthogneisses xenoliths did not imply important perturbation of the magma redox conditions. Interestingly, fO_2 values obtained for



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Salto and Mauá plutons directly reflect the nature of the country-rocks they intrude.



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The effect of zircon entrainment in alkali feldspar on U-Pb geochronology of rapakivi granites of the Wiborg batholith, southeastern Finland

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A detailed petrographic investigation (optical and SEM), micro drill sampling and *in situ* U-Pb (SIMS) and trace element (LAQ-ICP-MS) analysis of zircon from three different rapakivi granite types (pyterlite, wiborgite, and dark wiborgite) of the ca. 1.65–1.62 Ga Wiborg batholith in southeastern Finland was conducted. Zircon inclusions were extracted from within different types of alkali feldspar ovoids (up to 10 cm in diameter) that form the rapakivi texture to compare their characteristics to zircon crystals separated from the groundmass of respective samples and to investigate the effect of zircon entrainment on whole-rock U-Pb age determinations.

U-Pb SIMS-analysis reveals statistical differences in the mean ²⁰⁷Pb/²⁰⁶Pb ages of the inclusion zircon populations of the pyterlite (1635±3 Ma, 2σ, n=15) and wiborgite (1634±3 Ma, 2σ, n=22), when compared to the groundmass zircons (1628±3 Ma, 2σ, n=18 and 1628±3 Ma, 2σ, n=19 respectively). The pattern is similar in the dark wiborgite, but the populations have overlapping mean ²⁰⁷Pb/²⁰⁶Pb ages (ovoids: 1631±3 Ma, 2σ, n=18; groundmass: 1629±3 Ma, 2σ, n=18).

In all three samples, the ovoid inclusion zircon domains with regular chondrite-normalized REE-patterns and oscillatory zoning textures (in BSE images interpreted as primary magmatic growth zoning) record, on average, higher Hf, Th, and U abundances than similar zircon domains in groundmass populations. aTiO₂ and pressure -uncorrected Ti-in-zircon thermometer temperatures (800 to 820 °C) for the oscillatory-zoned zircon domains in all rock types and both population types are similar and well in concordance with zircon saturation temperatures (800–810 °C) calculated from whole-rock compositions.

These observations imply that the alkali feldspar ovoids that form the rapakivi texture have in the case of some rapakivi granites crystallized earlier than their respective groundmasses and, in the case of all analyzed samples, from magmas of similar compositions but with higher levels of incompatible elements. Furthermore, our results show that the previously obtained bulk sample zircon U-Pb analyses from the rapakivi-textured granites of the Wiborg batholith may be substantially affected by entrained zircon populations and lead to overestimates of the actual intrusion ages of the rocks.

The intrusion ages, as represented by the groundmass population U-Pb results, are similar in all studied rock types (ca. 1628 Ma), which may point to a relatively short period of intensive magmatism involved with the emplacement of the Wiborg batholith, possibly preceded by gradual injection of the magmas that crystallized the ovoid material. Higher incompatible element levels in the entrained zircon populations suggest that the magmas



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that crystallized the ovoid material were either more fractionated or generated by lower degrees of crustal partial melting than the magmas that crystallized the groundmasses.

We conclude that, depending on the timing of zircon saturation, entrainment of zircon crystals by major early silicate phases such as alkali feldspar megacrysts (or ovoids in the case of rapakivi granites) may be a significant factor in interpretation of zircon U-Pb data on bulk granite samples. Strong sampling control is therefore warranted for justification of high-precision geochronological data on megacrystic granitic rocks.



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PT.010

Dynamics of formation of giant granitoid batholith in Central Asia as a reflection of the plume activity and shear-pull-apart dislocations of continental lithosphere (geological scenarios and mathematical modeling)

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Large-scale batholiths in Central Asia were intruded on heterogeneous basement during the postcollisional (postorogenic or anorogenic) stage after closure of the Paleo-Asian and Mongol-Okhotsk oceans. Formation of giant batholiths may be caused by: rifting and mantle thermochemical plume, asthenospheric diapirism as a result of slab break-off, and delamination of mantle lithosphere during the postorogenic stage. These mechanisms of extension of continental lithosphere are contradictory and disputable, mainly due to: 1) insufficient knowledge of the relationship of formation of batholiths with rifting and/or shear deformations of the lithosphere; 2) lack of full isotope and geochemical databases. In this report, the following granitoid batholiths will be considered: Altai-Sayan (PZ1), Angaro-Vitim (PZ2?) and Kalba-Narym (PZ3). A new approach is used to characterize processes of partial melting and development of gravitational instabilities in granitic layers of the Earth's crust affected by heating and melting under intrusion of basaltic magma. In the mathematical modeling, three regimes of diapirism, which response to different rheological parameters of mantle and crust, will be considered: 1) single floating of mantle diapir; 2) oscillating mode of rising of mantle magma up to the crustal basement with time period in 2-3 Ma; 3) formation of a large magmatic sill under crustal basement (underplating regime). Numerical modeling by finite elements method showed that in the first two cases of the melting of crustal material above mantle magma chamber causes single float (upwelling) of granite diapir with irregular shape. In the third model the field of decompression partial melting emerge, a substance of which quickly cools when climbing in the mantle. This material because a high viscosity and density can not float to the upper levels of the crust.



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PT.011

Water-fluxed melting of the Camboriú Complex gneisses to produce the Itapema Granite, Santa Catarina, south Brazil

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The Camboriú Complex (CC) in the region of Camboriú-Itapema (southern Brazil) comprises ortho- and para-metamorphic rocks as well as magmatic rocks. The CC metamorphic rocks show evidence of pervasive partial melting at upper amphibolite facies conditions, with the generation of large volumes of neosome (leucosome + residue). Key outcrop observations have led to the determination of an active structural control during melting, as well as the possible genetic relation of these rocks with the plutonic part of the complex, named Itapema Granite (IG). The CC metamorphic rocks comprise a thinly-laminated gneissic sequence of tonalitic to granodioritic composition, commonly interleaved with amphibolite bands and calc-silicate lenses. The IG is a large body of ca. 100 km² of hornblende-biotite granodiorite to monzogranite mostly concordant with the CC banding. It is characterized by a large amount of CC xenoliths (~20 fragments/m²) and strong, sub-horizontal flow banding given by different proportions of mafic minerals (biotite, hornblende, titanite), pegmatites, disrupted xenoliths, and *schlieren*. This banding dips gently SE or NW defining symmetrical, upright folds, mostly with SW shallow-plunging axis, observed in a wide range of scales (cm to tens of m). Different styles and degrees of partial melting are observed in the metamorphic protoliths, as well as a diversity of leucosome migration and collection features. Amphibolites exhibit a larger volume of melt relative to the granitic gneisses, reflecting their fertile character. The granitic gneisses begin to melt along the mm-thick banding, resulting in concordant bands and lenses of leucosome. With progressive melting these leucosomes tend to merge, migrating into syn-magmatic shear zones subparallel to the axial planes of folds. More advanced stages of melting of the gneisses lead to widening of the bands, with larger proportion of bands with igneous texture. In contrast, the massive amphibolites start to melt in isolated patches. Euhedral hornblende and titanite are widespread in leucosomes. They are distinct in form and size from their equivalent in the protoliths, and interpreted to be peritectic minerals, as commonly seen in upper amphibolite facies, water-fluxed melting. In advanced stages abundant melt promotes fragmentation and boudinage of amphibolite bands with accumulation of leucosome in dilatant sites eventually resulting in amphibolite breccia. Meter-thick, subvertical leucogranite dikes are locally observed, comprising abundant amphibolite and gneiss fragments. Textural and compositional diagnostic characteristics of IG are observed in these dikes. Some dikes have both abrupt and diffuse contacts with their leucosome-rich host rocks. Diffuse contacts are represented by a net of leucosome veins from the host rocks which are interpreted to be feeding the dike, while the discordant character of sharp contact dikes attests to magma mobility. These dikes are interpreted as channels of magma mobilized from the migmatites to feed the IG collecting site. We conclude that the nature of the CC melting and magma migration/collection, together with compositional compatibility, including the presence of xenoliths of CC in the granite, and concordant structural pattern of both units, suggest that the IG results from partial melting of



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the CC rocks in the presence of a free aqueous phase.



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PT.012

Geochemical evolution of Paleozoic and Mesozoic rare metal granites and their origin (Baikal region and Mongolia)

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The folded structures by framing the Siberian craton in the Baikal region and Mongolia display extensive development of Phanerozoic granitoids of different ages and geochemical types. Their formation could be related to the Late Paleozoic and Mesozoic age of intraplate magmatism. The granitoids are represented by batholiths, individual massifs, and intrusive-dike belts containing small intrusions and subvolcanic rocks of diverse composition. The following types of granitoids are widespread in the Khamar-Daban magmatic province of the southern part of Baikal region: (a) palingenic calc-alkaline granitoids (the Early Paleozoic Solzan massif, 513-516 Ma), (b) subalkaline granitoids represented by a series from monzodiorite to monzonite, quartz syenite, and leucogranite (the Late Paleozoic massifs, 332 Ma) and (c) the Khamar-Daban province and Mongolia hosting relatively abundant products of rare-metal granitoid magmatism from the Late Carboniferous to the Cretaceous. The rare-metal granitoids in Central Asia occur in various structural zones among Precambrian and Hercynian metamorphic sequences.

Late Paleozoic rare-metal granites resulted in the formation of multiphase intrusions with exposed areas of approximately 10 km² (311–321 Ma) and dikes, which are subvolcanic analogues of granitoids. The early intrusive phases are made up of biotite granites (usually fluorite-bearing), which are changed during the late stage by typical rare-metal (topaz-bearing) amazonite-albite granites. The subvolcanic subalkaline dikes (monzonite porphyry, granite porphyry, and elvan) are followed by ongonite, topaz rhyolite, and topazite. The Daurian-Khentei batholith forms the central part of a huge Early Mesozoic magmatic area. The rocks of the Abdar-Khoshutula series varies from biotite granites of the Khoshutula massif (224 Ma) to the rare-metal granites of the Abdar intrusion (209-212 Ma). The relationship of granite varieties recognized in the Abdar and other massifs (from early leucogranites to late amazonite-albite granites) can point out a possible genesis of all rocks of the intrusions during the evolution of granite melts, which supports the important role of magmatic and fluid-magmatic differentiation.

The geochemical evolution promoted an increase in F, Li, Rb, Cs, Sn, Be, Ta, and Pb and a decrease in Ba, Sr, Zn, Zr, Th, and U contents in rare-metal granites of the final intrusive phases. Similar geochemical evolution and regular decrease in some indicator element ratios, K/Rb, Zr/Hf, Nb/Ta and La/Yb, in the amazonite-albite granites is common for subvolcanic rocks, which indicates the genetic relation of the entire intrusive-dike series of the Baikal Region and Mongolia. The isotope-geochemical data (⁸⁷Sr/⁸⁶Sr = 0.705 – 0.706±8; ε_{Nd} values ranging from – 1.2 to – 2.7) and model ages 1200-1260 Ma indicate that the granite intrusions could be formed by melting of Precambrian continental crust. The obtained isotope characteristics of granitoids of the Bitu-Dzhida massif are consistent with the derivation of primary granitoid melts at the lower levels of continental crust. The accumulation of rare metal in granites is responsible for genetic relation between these Carboniferous and Mesozoic intraplate magmatism and Li, Ta, Sn and W mineralization.

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PT.013

Variscan Granitoid Magma Generation Processes in the Greater Caucasus Collisional Orogen
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The Greater Caucasus represents a Phanerozoic collisional orogen formed along the Euro-Asian North continental margin and stretches on 1200 km, from the Black to the Caspian seas. Currently, it is an expression of continental collision between the Arabian and Eurasian lithospheric plates. Two major stages are distinguished in its construction: Pre-Alpine crystalline basement and Alpine volcanic-sedimentary cover. Crystalline basement complex (200 km x 40 km) is mainly constructed of Precambrian and Paleozoic crystalline schist, amphibolites, gneisses, migmatites and granitoids [1].

The variscan plutonic magmatism has played significant role in the formation of the Greater Caucasus crystalline basement complex. Our investigation indicate that granitoid melts are important component of these plutonic series, represented by different genetic types, and is characterized by a specific mechanism of magma generation processes. Four plutonic series of variscan generation have been distinguished (from the S to N): 1. Gabbro-plagiogranite, 2. Diorite-monzogranite, 3. Plagiogranite-granite, and 4. Granodiorite-alaskite.

Gabbro-plagiogranite series, which is exposed along the Main Trust of the Greater Caucasus in the form of lesser tectonic wedge, was formed at early stage of variscan orogen evolution (355±15 Ma; Rb-Sr; $I_{Sr}=0.70343$). The series should have been formed as the result of subducting oceanic crust partial melting ($P=8.2-8.7$ kb; $T=620-630^{\circ}$ C) and high water potential regime ($H_2O/CO_2=20.2$). Crystallization of plagiogranite melts occurred at 600° C temperature and 7.0-7.5 kb pressure condition. According all data gabbro-plagiogranite series corresponds to the subducting oceanic crust I type formation.

The diorite-adamellite series was formed at a late stage of the orogen evolution (320±12 Ma, U-Pb). Its protolith was located over the subducting oceanic crust and magma generation mechanism was tigel melting (mantle injection) and formed mantle-crust generation H type (hybrid) granitoid melts. In this series melts generation occurred at the temperature of 630-670⁰ C and 4.0-4.5 kb pressure condition.

Plagiogranite-granite series was formed at a late stage of the orogen evolution. Regional migmatization and ultrametamorphizm processes of this series is started at 720-750⁰ C temperature and under 3.7- 4.2 kb pressure. In the evolution processes of this series two stages are distinguished: syn-kinematic and post-kinematic. On the first stage of plagiogranite composition anatectic magma was genetated (318±7 Ma; Rb-Sr; $I_{Sr} = 0.70843$), which made mainly conforming bodies, and on the second stage the granite composition melts were formed, which mainly made cross-cutting bodies (315±5 Ma; Rb-Sr; $I_{Sr} = 0.71134$).

The granodiorite-alaskite series was formed at a late stage of the orogen evolution (295±10 Ma; Rb-Sr; $I_{Sr} = 0.71572$) and it ended the Greater Caucasus Variscan plutonic magmatizm. Magma in this series was generated as a result of remelting of Upper Caledonian granite-gneisses. The crystallization temperature ranges in the interval 710-735⁰ C, and pressure – in 3.2-3.5 kb. This series corresponds to syn-collisional remelting, leading to formation of a S type granite.



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[1] Okrostsvaridze A., Tormey D., 2011. J. of Nepal Geological Society, Special Issue, vol. 43, pp. 45-52.



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PT.014

Mineral Chemistry of Biotites and Amphiboles from Ediacaran High-K Calc-Alkaline Porphyritic Granites of the Rio Grande do Norte Domain, NE Brazil.

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Ediacaran high-K calc-alkaline granitic batholiths, plutons and small bodies are widespread throughout the Rio Grande do Norte Domain (RGND), northeastern Borborema Province. They comprise porphyritic biotite (\pm amphibole) monzogranites with K-feldspar megacrysts. This work presents a chemical characterization of the main mafic phases biotite and amphibole from many of these bodies along the RGND: Monte das Gameleiras and Barcelona plutons to the east, Acari Pluton to the center, and Tourão, Caraúbas and Catolé do Rocha plutons to the west. Biotite appears as euhedral to subhedral platy crystals with yellow-greenish to brownish pleochroic colors, being locally replaced by chlorite and muscovite. Based on their compositional variations, three distinct groups can be individualized: biotites with (I) average FeOt = 19.3 wt.%, MgO = 11.4% and TiO₂ = 1.8% (Acari and Monte das Gameleiras plutons); (II) FeOt = 25.2%, MgO = 7.2% and TiO₂ = 2.5% (Barcelona, Caraúbas and Tourão plutons); and (III) with FeOt = 32.9%, MgO = 1.7% and TiO₂ = 2.7% (Catolé do Rocha Pluton). The Fe/(Fe+Mg) ratio increases from \sim 0.5 in group (I) to \sim 0.7 in group (II) and \sim 0.9 in group (III), along with almost similar Al^{IV} contents increasing from 2.3 cpdf in group (I) to 2.5 in group (III). Therefore, group (I) biotite compositions are transitional between flogopite and annite, while group (II) and (III) correspond to annite. Moreover, group (I) compositions correspond to re-equilibrated primary biotites while groups (II) and (III) are transitional between primary and re-equilibrated primary biotites in the ternary diagram MgO–10*TiO₂–FeO+MnO. Of note, such post-magmatic re-equilibrium did not affect to a great extent the Al contents in the biotite (Al^{VI} = 0.3 – 0.5 cpdf in groups I and III and 0.1 – 0.7 in group II), which validates the use of magmatic association discriminant diagrams based on biotite chemistry. These diagrams define a transitional calc-alkaline to peraluminous affinity of groups (I) and (II), with Al₂O₃ = 14.8 and 14.9 wt%, respectively, and alkaline affinity of group (III), with Al₂O₃ = 14.8 %, which is compatible with the subalkaline/high-K calc-alkaline affinity of their host-granites. Amphibole often appears in contact with biotite as subhedral to anhedral crystals exhibiting greenish to brownish pleochroic color schemes and simple twinning. The observed compositional variations defined by the Mg/(Mg+Fe²⁺) ratio can be used to recognize the groups previously defined: the amphiboles from the Acari and Monte das Gamaleiras plutons (group I) have average values of 0.5, while lower values of 0.3 and 0.1 are typical of crystals from the Barcelona, Caraúbas e Tourão (group II) and Catolé do Rocha (group III) plutons, respectively. They correspond to calcic amphiboles with Ca_B contents higher than 1.8 cpdf and (Na+K)_A totals above 0.5 cpdf, being classified as ferro-edenite to edenite (group I), ferro-pargasite to hastingsite (group II) and hastingsite (group III). The results here presented correlate with the whole-rock geochemistry of the studied plutons and indicate that, although they all correspond to high-K calc-alkaline porphyritic granites, their chief mafics minerals exhibit significant chemical contrasts.



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PT.015

Timing of skarn-hosted W-Mo mineralization within a long-lived granitogenesis activity in the Seridó Belt, Northeastern Brazil: constraints from coupled Re-Os molybdenite and U-Pb zircon geochronology

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The Seridó belt is a Neoproterozoic medium- to high-grade metasedimentary sequence located in the Borborema Province, Northeastern Brazil, which hosts hundreds of deposits and minor occurrences of W-Mo mineralized skarns. The mineralization is usually associated with pyroxene, amphibole, ± garnet, ± plagioclase, and known as "primary" skarn. Some W-Mo deposits are also related to epidote, ± clinozoisite, ± vesuvianite, ± zeolites, ± opal that were formed under retrograde metamorphic conditions, being named "secondary" skarn. Some secondary skarns may also contain mineralization of Au(-Ag, Bi, Te) and a few contain just Au. The origin of these ore skarns has been attributed to metasomatic reactions after infiltration of hydrothermal fluids derived from igneous intrusions. The magmatic activity was broadly related to regional ductile deformation being dominantly represented by (1) porphyritic to coarse-grained, hornblende+biotite (*sensu lato*) granites and granodiorites (c. 595 to 577 Ma) often showing evidences of mingling with gabbroic to dioritic magmas, (2) medium- to fine-grained biotite-bearing leucogranites, and (3) pegmatitic granites and pegmatites (c. 515 to 509 Ma). In spite of the volumetric importance of the igneous activity, its timing and duration were until recently poorly constrained. Therefore, although the link between the magmatism and the W(-Au) mineralization has been admitted, the connections between the skarn mineralization and a specific magmatic suite were unknown. In this study we dated molybdenite by NTIMS on Re-Os from skarns of the three major deposits in the Seridó belt, and compared the results with U-Pb SHRIMP ages obtained for plutons representative of the biotite-bearing leucogranites. The Re-Os ages defined three distinct episodes for metal precipitation/remobilization, at 554 ± 2 Ma (Brejuí deposit), 524 ± 2 Ma (Bonfim deposit) and 510 ± 2 Ma (Bodó deposit). Because Re and the other PGEs record siderophile affinity, Re contents in molybdenite may be used as proxy to infer its crustal or mantelic origin. The high content of Re (> 110 ppm) of the Brejuí and Bonfim molybdenites is suggestive of a important mantle contribution for their Mo(W) mineralizations. However, the lower Re content (7.5 ppm) of the Bodó molybdenite, and that is associated with secondary skarns, shows a strong contribution of crust-derived fluids. Zircon U-Pb ages for the biotite leucogranites range from 576.8 ± 4.8 (Angicos), 548.6 ± 3.6 Ma (Picuí), 540.4 ± 1.5 Ma (Caramuru) and 526.6 ± 7.7 Ma (Cerro-Corá). These results show that the magmatic activity in the Seridó belt spanned by about 70 Ma (595 to 525 Ma), with metapelites recording HT/LP metamorphic conditions at c. 575 Ma. The molybdenite Re-Os ages in the Brejuí and Bonfim skarns and U-Pb ages allow to link the W-Mo mineralization to the latest magmatic episodes, particularly with the biotite leucogranites. The younger Bodó W(Mo) skarn, on the other hand, suggests local remobilization of W(Mo) fluids with the exhumation of the Seridó belt.



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PT.016

Na-Li-F-metasomatism related to a highly fractionated peraluminous I-type granite (La Pedriza, Spain, Iberian Variscan Belt)

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Na-rich metasomatism is usually related to carbonatite or alkaline complexes. In this work we study an outstanding outcrop of albitites on the basis of: (i) their genetic connection to a peraluminous I-type leucogranite, and (ii) the very unusual paragenesis of Li-Na-rich amphiboles occurring within it. These rocks were previously interpreted as tectonic-derived episyenites; nonetheless, new field, petrographical and geochemical studies make questionable this model.

Albitites outcrop as subvertical lense-shaped bodies of variable sizes, from 1 to 80 m in length, and width up to 6 m. La Pedriza albitites spread over an area of about 0.25 km², within a 1 km width band from the contact with the La Pedriza I-type leucogranite. The parent rocks of the albitites are porphyritic cordierite-bearing granite and biotite microgranite intrusions, whose main textural characteristics are preserved (isovolumetric metasomatism). Albitites are white coloured with dark-blue irregular mafic nodules. Contacts with host granitoids are sharp and irregular at cm-scale, and no zonation within the body is observed. Single outcrops differ from each other by mineralogical and geochemical features, defining a metasomatic family. Some aplite dikes crossing these bodies show similar metasomatic transformations.

The main mineral association of albitites consists of relict magmatic mineralogy enclosed by newly formed albite (70-85% modal), some K-feldspar, and interstitial nodules (10-20%) of quartz-pyroxene (aegirine-augite) and/or Li-Na-amphiboles. Accessories are titanite, magnetite, andradite, epidote, Mg-Li-rich mica (tainiolite), zircon, ilmenite, rutile, fluorite and apatite. The interstitial character of the main metasomatic assemblage suggests an infiltrational metasomatism.

La Pedriza albitites are classified as alkaline and metaluminous (close to peralkaline values). Compared to parental-rocks, albitites show enrichments in Na₂O, FeO, MgO, MnO, Li, F, Be, Zn, Sc and Sn, while SiO₂, K₂O, Rb, Cs and W are depleted. Their Na-Li-F-Be-rich chemistry is typical of metasomatic fluids derived from igneous intrusions. The lack of significant REE, Y, Nb, Ta, Th and U enrichment contrasts with Na-metasomatism associated with alkaline complexes. The gradual increase of Na₂O is negatively correlated with K₂O and Rb, and positively correlated with FeO, CaO, Y and REE. Identical Sr-Nd isotopic signatures between albitites and host granites suggest that magmatic fluids might be dominant in the metasomatic transformation.

Estimations based on oxygen thermometry yields a range of 520 to 635°C for albitite formation. Secondary aqueous fluid inclusion data indicate a minimum temperature of 397 ± 10°C for albitite formation, thus defining a mid-to-high-T hydrothermal metasomatism. The La Pedriza albitites are not related with fracturing and are not episyenites s.s., owing to the clear coprecipitation of quartz and alkaline mafics. We interpret this metasomatism as Na-Li-F-rich solutions linked with the fractionation of the nearby La Pedriza I-type granite. This massif is a cryptozoned pluton, reaching in this area the highest concentrations in Na, Rb, Nb, Ta, Y, HREE, F, Li, Sn, Mn and Cs, as a result of



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extensive fractional crystallization. This is an unusual Na-Li-F-rich contact metasomatism related to the fractionation of I-type peraluminous granitic melts.



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PT.017

New Geochronological data from Granites of Embu Terrane – Ribeira Belt – Southern Brazil
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The southeastern Ribeira Belt in the Mantiqueira Province, SE Brazil, consists of tectonic domains limited by significant shear zones, related to the Neoproterozoic Brasiliano Orogen. The northern Embu Supracrustal terrane is separated from the southern granite-gneissic migmatitic terrane by the Cubatão – Itariri Shear System. The Embu Terrane is a complex domain that hosts low to high metasedimentary successions and several granitic bodies of varied composition and size. It corresponds to an exotic block accreted to a continental mass -formed by the amalgamation between the São Francisco and Paranapanema cratons.

Petrographic and geochronological studies were carried out on granites of the Embu Terrane, southeast São Paulo state. Most of the small granitic bodies are undifferentiated as “syn-orogenic granites”, and this study provide new information of two small peraluminous granitic bodies, Juquiá and Sete Barras granites, hosted by high metamorphic supracrustal rocks.

The Juquiá granite, near the Cubatão shear zone is a megacrystic-deformed granite that yielded LA-ICP-MS U-Pb zircon ages of 809 Ma and the Sete Barras protomylonitic granite provided new U-Pb LA-ICP-MS zircon ages of ca 583 Ma.

These ages represent tectono-thermal events and record two important orogenic episodes (Brasiliano I and II) of the Brasiliano collage indicating the complexity of the Embu terrane that comprises several successive geological events and different kind of magmatism that took place over a ca. 200 million year time interval.



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PT.018

The complex patterning of granites and their feldspars in the deep crust

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During the post-orogenic stage of the Neoproterozoic coastal orogen in Brazil, inversely zoned plutons intruded a narrow mostly S-N tectonic corridor crosscutting all previous lithologies. Structural measurements, mapping of flow patterns, geochemical and isotopic data point towards contrasting compositional domains, which have been generated during a time span between 20 to 30 Ma during Cambro-Ordovician times (ca.520-490 Ma).

Mostly sub-vertical internal contacts between units suggest generation from large magma bodies of contrasting compositions, which mixed and hybridized at different proportions. They crystallized while crossing the lower to middle-crust (< 25 km depth from geobarometric studies). Accordingly mushroom- to funnel-like magma-chambers and/or conduits register snapshots of the interaction dynamics between granitic and basaltic magmas.

This work focuses on the pluton of Santa Angélica (SA), where mafic rocks predominate: two gabbroic twin cores are surrounded by hybrid regions in complex patterns of stretching and folding. Granite predominates only at the border region.

Mineralogical and whole-rock geochemical data point towards an expanded high-K calc-alkalic to alkalic suite. Rocks grade from biotite-hypersthene-augite monzogabbro, biotite-monzodiorite to allanite-biotite granite. Granitic to gabbroic rocks are metaluminous and both enriched in incompatible elements. This is more characteristic for the mafic to intermediary rocks. Anomalous K₂O, Ba, Sr, and LREE contents, as well as high contents in HFS elements such as Ti, Y, Nb, P, and Zr are typical. Low-silica rocks contain very high Ba and Sr values, over 5,000 and 1,500 ppm, respectively.

In comparison to the average nMORB mafic and hybrid rocks from SA are extremely enriched in Rb, Ba (up to 500X), K, La, Ce, P, Nd and Zr and show no depletion of compatible elements such as Tb and Y. On the other hand in comparison to average OIB magmas, mafic and hybrid rocks from SA are still enriched in Rb, Ba (up to 10X), similar in K, La, Ce, Nd and Zr and slightly depleted in Nb, Sr, Sm, P, Ti and Y.

As a consequence an abnormal mantle enrichment episode is thought to be the source for the enriched basic magma.

Magma mixing and fractional crystallization are recognized as main differentiation processes during the evolution of the different rocks.

Almost identical Sr–Nd isotopic ratios for both gabbrodiorite and granite point towards a highly homogenized mixed system, which is not consistent with the homogenization degree of the whole magmatic body at outcrop scale. A granitic magma contaminated a previously enriched mantle-derived basaltic magma in such a way to produce a hybrid monzogabbro with the same isotopic signature as the granite.

In this work we will discuss: 1) evidence for different mixing episodes, 2) whether the end-members are still to be found in the outcropping rocks, 3) differential mobility of major and trace elements and, 4) the role of late fluid-rock interaction in the system as depicted by the complex



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history of feldspars.



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PT.019

Mixing experiments with rhyolitic and basaltic melts: implications for the mingling issue

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Geochemical studies on glasses obtained from mixing experiments with melted products from natural rocks have highlighted the importance of fluid dynamics in producing heterogeneities (Perugini et al. 2008; De Campos et al. 2008.). Additional experimental studies with analogue and natural materials (e.g. De Campos et al. 2011; Morgavi et al. 2013) pointed out the controlling role played by chaotic mixing dynamics in generating the complexity of morphological patterns found in rocks. At high temperature, convection will bring together contrasting melt compositions as layers or filaments. This interaction is expected to produce large contact interfaces between contrasting melts. Along interfaces, chemical exchanges will be strongly enhanced. In a magmatic system (volcanic or plutonic) following the same dynamic and rheological laws, this process can propagate as fractals from the kilometer/meter to the micrometer length scale. Experiments and numerical modeling show that this process will lead to variable degrees of hybridization, which will be controlled by the different mobility of chemical elements (e.g. De Campos et al. 2011; Morgavi et al. 2013). In the petrologic literature, the term *magma mingling* has been used to indicate physical dispersion of magmas, with no chemical interaction being involved. On the other hand, magma mixing means that not only convection, but also diffusion, and therefore chemical exchanges, are operating in the system, generating hybrid compositions. Unless there is clear evidence for the absence of chemical exchange in the system, the term *magma mixing* should therefore be more appropriate. Recently, the coeval mobility of all elements present in a magmatic system during mixing has been measured from mixing experiments with phonolite/basalt and rhyolite/basalt (Perugini et al. 2013; Morgavi et al. 2013). According to these works, the main factors controlling element mobility are: (1) compositional and rheological variations within the system; (2) the appropriate thermodynamics for contrasting multicomponent melts; and (3) the complete strain history. In a natural scenario, these are unknown variables. An alternative way to normalize the effects of absolute diffusive and convective histories is to apply a parameter commonly used in the fluid dynamics literature to evaluate the degree of homogenization of fluid mixtures: the concentration variance (R^2). In this work, we compare and discuss results from mixing experiments using both Fe-free analogue (AnDi-haplogranite) and Fe-rich natural melts (basalt- rhyolite) and natural patterns. Our data point towards the conclusion that patterns normally interpreted as mingling are in reality the result of magma mixing at different hybridization degrees, both in volcanic and in plutonic environments.

References: Perugini et al. 2008 ChemGeol 256,146–157; Perugini et al. 2013 ChemGeol 335,8–23, De Campos et al. 2008 ChemGeol 256,146–157; De Campos et al. 2011 ContribMineralPetrol 161,863–881; Morgavi et al. 2013 ContribMineralPetrol 166,615-638



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PT.020

The Altamira Granite Unit, Eastern Cordillera of Colombian Andes: preliminary petrologic insights

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Granite magmatism is widespread in the Eastern Cordillera of Colombia, but there are no detailed studies up to now and such rocks are poorly known. In the Garzon area (the so-called “Garzon Massif”), a large number of granite and related dioritic intrusions built several granite units with Jurassic ages which intrude Permo-Carboniferous metamorphic sequences. A volcano-sedimentary sequence made up of tuffs, agglomerates, porphyritic rhyolitic lavas interlayered with siltstones and mudstones (Saldaña Formation), appears to be largely coeval with the granite magmatism. Most of these intrusions as well as the volcano-sedimentary rocks are fault-limited to the east with the Garzon Metamorphic Complex, made up of older Meso- to NeoProterozoic metamorphic and igneous rocks.

As a part of our ongoing research on the Eastern Cordillera granite magmatism, we present preliminary petrographic and geochemical data for the Altamira Granite Unit, one of the smallest intrusive units that crops out in the “Garzon Massif”. This unit covers a larger elongated area (ca. 35 vs. 8 km) with the major axis oriented SW-NE and is probably made up of discrete unmapped plutons.

Two main metaluminous granitic and one dioritic petrographic facies were recognized in the Altamira Granite Unit. The granitic facies are mainly made of massive equigranular to slightly inequigranular biotite monzogranites (largely predominant) and biotite-hornblende granodiorites, which contain apatite, zircon, titanite \pm allanite, magnetite \pm ilmenite as the main accessory phases. Porphyritic microgranites with plagioclase and quartz fenocrysts embedded in a granopyric-like quartz-feldspatic matrix occur as dikes and minor intrusions cross-cutting the granitic rocks. Massive equigranular dioritic rocks (mainly hornblende monzodiorites, with apatite, zircon, titanite and magnetite \pm ilmenite as accessory minerals) form small coeval occurrences. Younger basic dikes cross cut most plutonic rocks. A late hydrothermal alteration imprint is widespread in all the Altamira rocks and the younger dikes, given way to the development of hydrothermal mineral assemblages dominated by chlorite- and epidote-group minerals.

Available geochemical data points to a high-K calc-alkaline signature for the Altamira intrusive rocks. REE patterns depict a high fractionation degree among the LREE and of the LRRE over the HREE and moderate Eu negative anomalies. Multi element trace diagrams point to evidence significant relative enrichments in LILE (as K, Rb, Sr) and depletions in Ti and HFSE (as Nb and Ta), features usually supporting a subduction component in the source.

Our preliminary data suggest that the granites from the Altamira Granitic Unit could be generated and emplaced in a continental arc-like setting, and the parental magmas had contributions from both the mantle wedge and the overlying continental crust. Magmatic crystallization occurred in a moderate oxidizing environment.



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PT.021

Petrogenetic relationships among Variscan granitoids and Li ± F-rich aplite-pegmatites in the Central Iberian Zone (Spain and Portugal)

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Lithium (± F, Sn, Nb, Ta, P) mineralization is common in the Central Iberian Zone (CIZ) of the Iberian Massif (Spain and Portugal). The CIZ represents the westernmost segment of the European Variscan Belt. It is characterized by extensive syn- to late-D₂, S-type, granitic magmatism (330-290 Ma) and by the occurrence of high-grade metamorphic complexes with a regional extent. In this region the Li-rich rocks occur in a NNW-SSE striking belt, ≈500km long and ≈150 km wide. This mineralization mainly appears in aplite-pegmatite bodies, where the main Li-rich minerals are the silicates spodumene, petalite and Li-rich micas, and phosphates of the amblygonite-montebrazite series. Many of these Li-rich bodies show an aplitic texture, frequently with the development of line-rock units. Coarse crystals are also common, but usually smaller than 10cm long; and internal zoning of the pegmatites, if present, usually does not show the development of a core nor intermediate zones. The Li-richest bodies usually show an important overall enrichment in this element in the whole dyke, with no evidence of internal fractionation, often with values in Li₂O > 1% wt, and high Na, F and P contents.

A magmatic origin is the most accepted theory for the genesis of the pegmatitic melts. In the southern region of the CIZ, the Li-mineralization seems to be mainly related to highly fractionated leucogranitic facies of late- to post- tectonic, S-type, granitic units. However, in the northern part of the CIZ the affiliation of the Li-rich rocks is more difficult to establish. The late- to post-tectonic granites are less abundant, whereas pre- to syn-tectonic, anatectic granites are common, often occurring in high-grade metamorphic complexes, and frequently related to migmatites. A petrogenetic relationship among the Li-aplite-pegmatites and those syn-tectonic granites would imply a significant mobilization of Li during the Variscan magmatism in the CIZ, with the generation of quite similar Li-mineralization along most of the orogeny, that is, associated with granites of different ages/origin. Another possibility is that the Li-mineralization occurring in the northern parts of the CIZ is just spatially related to the syn-tectonic granitoids. In this case not-outcropping, late- to post-tectonic granites would be the parental melts. In both cases the parental granites would most probably be peraluminous, two mica, S-type leucogranites, usually P-rich and Ca-poor, originated by the partial melting of peraluminous metasedimentary rocks, including greywackes and shales. High degrees of fractional crystallization (up to 99%) of these granitic melts is the most plausible mechanism to explain the composition of the Li-richest bodies occurring in the CIZ. The distribution of the rare-element pegmatites in this region, often with the Li-F-richest facies occurring farthest from the parental granite, suggests a previous vertical chemical zonation of the melt within the source pluton, inherited by the pegmatitic melt before it intruded into the fractures where it crystallized. The higher enrichment in F, as well as H₂O and P, would reduce the viscosity of the most fractionated melts in a great extent, enhancing its mobility and, in turn, lowering the liquidus temperature.



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PT.022

Mapping the melt distribution in the lower continental crust by synchrotron micro-XRF analysis

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The enclaves from El Hoyazo (Southeastern Spain) represent the lower crustal remnants of the Alborán lower crust, preserving evidence of partial melting and melt segregation. The enclaves are restitic pelites that contain the primary melt as unaltered glass along grain boundaries and as melt inclusions. This work aims at reconstructing the melt segregation network at micrometric scale to understand the mechanism of crustal differentiation and the geophysical anisotropy of a partially molten crust.

The samples were investigated by micro-XRF technique at LNLS synchrotron radiation (Campinas, Brazil) on three mutually orthogonal sections. The combination of elemental maps evidenced the presence of a melt network. The melt network corresponds to sample regions of pure melts and to fine mixtures of melt and sillimanite (the so called mix). The amount of melt in the mix was determined to about 8-15% by image analysis.

The micro-XRF analysis revealed that the melt parths are mostly controlled by the distribution of biotite, garnet and plagioclase within the rock. Melt concentrates along grain boundaries and aligns according to the principal foliation. At the microscale, the melt network is controlled by the distribution of the reacting mineral. The high amount of residual melt in the sample is above the melt connectivity threshold, and supports the existence of a fully connected melt network.

The comparison of the melt topology at the microscale to that reported at the meso- and megascale in migmatites, suggest the existence of a fractal geometry in the pattern of melt migration. The structure of melt paths explains the actual seismic and electric anisotropies of the Alborán lower crust.



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PT.023

Insights into the petrogenesis of the peraluminous Aurumina Suite in the basement of the Brasília Fold Belt (Brazil)

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Peraluminous granites and tonalites that crop out in NE Goiás and SE Tocantins are grouped into the 2.12-2.18 Ga Aurumina Suite. These magmatic rocks intrude the amphibolite-facies paragneisses and schists of the Ticunzal Formation, and together both units constitute large portions of the Brasília Belt northern external zone basement in the Tocantins Province. In the past, features such as occurrence of magmatic muscovite and garnet, presence of either enclaves or lamellae of high-crystallinity graphitic material and negative values of $\epsilon_{Nd}(T)$ led to suspect a S-type character for the suite. However, the presence of peraluminous tonalites closely related both in space and time to the granitic rocks always proved to be a challenge when attempting to assess a genetic model for the suite, as tonalitic and granodioritic compositions are commonly thought to result from partial melting of basaltic sources rather than metasedimentary ones. Up to now, no such mafic rocks of similar age or older have been described in the studied area. The least silica-rich rocks found in the basement of this region belong to a unit known as the Nova Roma quartz diorite, which consists of I-type-like, hornblende-bearing magmatic rocks of restricted occurrence that intrude both a tonalite and the Ticunzal Formation, and yield U-Pb zircon ages that lie within the same interval of 2.12-2.18 Ga that characterizes the crystallization age of the Aurumina Suite.

In this work, reassessing of previous geochemical data as well as new analyses show that several tonalite and granite samples of the Aurumina Suite display relatively high FeO+MgO+TiO₂ sums that result, when plotted in appropriate variation diagrams, in the samples being arranged along lines that represent theoretical hybridization paths between metasedimentary and basaltic reservoirs at pressures lower than 5 kbar. Interestingly, samples of the Nova Roma quartz diorite also display this geochemical pattern, plotting at the most mafic end of the trend. $\epsilon_{Nd}(T)$ values of samples from the Aurumina Suite vary between 0.6 and -5, with the tonalites and some of the granitic rocks having such radiogenic isotope compositions that define shallow-dipping time-evolution paths yielding the least negative $\epsilon_{Nd}(0)$ values for the suite.

Based on these data, we conclude that the peraluminous Aurumina Suite does not fully represent a classic S-type suite since it appears that a source of likely basaltic composition played a role in its genesis. In fact, the Nova Roma quartz diorite, which was always regarded as unrelated to the Aurumina Suite, might have stemmed from the same magmatic event that gave origin to the latter and would represent the most mafic-component-rich member of the "supersuite" that both units seem to constitute. Future studies based on petrologic modeling should clarify the relations between these units in detail. The tectonic setting in which this magmatism took place is still poorly constrained and shall be addressed by subsequent work.



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PT.024

Cryptic evidence of fluid-present partial melting of Archean banded gneisses in the Southern São Francisco craton (Brazil): implications for the evolution of the continental crust

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In the Southern São Francisco Craton (Brazil), mafic-intermediate amphibolite boudins and lenses are hosted within banded orthogneisses. These meter-scale blocks represent disrupted pre-metamorphic mafic intrusions (i.e. dikes) that were rotated into parallelism with the banding in the hosting gneisses and disrupted during ductile deformation of the basement. In the Bação Complex, in the western part of the Southern São Francisco Craton, one mafic boudin was found showing clear field and petrographic evidence for partial melting. The occurrence of coarse-grained euhedral clinopyroxene porphyroblasts within the leucosome of the boudins together with the lack of garnet and orthopyroxene in the rock-assemblage is consistent with anatexis via incongruent fluid-present melting reactions consuming hornblende, plagioclase and quartz to form clinopyroxene and melt. Pseudosection modelling constrains the peak assemblage for this rock at ca. 700 °C and 0.5 GPa. Zircon crystals collected from the leucosome yield a LA-ICP-MS U-Pb age of 2728 ± 4 Ma. This age matches the age of metamorphic overgrowths on the zircon crystals in the banded gneisses. Oscillatory-zoned zircon cores from the gneiss gave a Concordia age of 2778 ± 2 Ma. These data indicate that upper-amphibolite facies metamorphism and deformation of the basement took place in the Neoproterozoic, ca. 30 Ma after the formation of the gneiss.

Clear field evidence suggesting partial melting of the gneiss is missing. However, microstructural evidence such as the occurrence of a thin film of melt between grain boundaries suggests that the gneiss underwent partial melting through water present congruent reactions consuming quartz, plagioclase and alkali-feldspar. Experiments show that fluid-present melting of metagranites can produce up to 30% melt at a temperature as low as 690°C. The volume of melt preserved in the gneiss appears to be very low (ca. 1%), but the rock contains up to ca. 15 vol% of felsic dikes oriented parallel to the banding. Melt that escaped from the gneiss might have been efficiently segregated during deformation, contributing to the formation of the felsic dikes and possibly to the genesis of silica-rich biotite-bearing granites whose emplacement age matches with the age of metamorphism.

We suggest that fluid-present melting of Archean gneisses in the Southern São Francisco Craton (Brazil) played a role in shaping the composition of the continental crust. Evidence for such a process can be elusive because the melting reaction is congruent and the composition of the melt is similar to the composition of the source rock. Finally, it is worth remarking that the chemical composition of the partially molten orthogneiss differs from the composition of the source rock, with the chemical diversity between the two rocks scaling with the amount of melt escaped. Thus, failing to discern the restitic nature of some orthogneisses has serious consequences on the interpretation of their chemical composition.



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PT.025

Strain partitioning into dry and wet zones and the formation of Ca-rich myrmekite in syntectonic syenites: a case for melt-assisted dissolution-replacement creep under granulite facies conditions

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Myrmekite is a fine intergrowth of (generally Na-rich) plagioclase and vermicular quartz developed on K-feldspar. The myrmekite-forming reaction is intimately related to both deformation and access of fluids, as it results in volume decrease and finer grain size, thus enhancing plastic behaviour and permeability. The role of fluids in controlling deformation mechanisms is well known in upper and mid-crustal level. On the other hand, in spite of the essentially anhydrous character of granulite facies conditions, the crystallization of magmas in these environments may lead to local fluid concentration which may in turn have an effect on deformation mechanisms. The formation of Ca-rich myrmekites is described in a Neoproterozoic syntectonic syenite (642 Ma) from Encruzilhada do Sul, southern Brazil, which is intrusive in a granulite facies collisional thrust pile (peak metamorphism at 650 Ma). The Arroio das Palmas Syenite is mainly porphyritic, and subordinately fine-grained equigranular, with biotite and clinopyroxene as main mafic phases and with minor quantities of hornblende and quartz. It exhibits high- and low-strain zones. Within low-strain zones, well-developed magmatic foliation and lineation are marked by shape alignment of K-feldspar and mafic minerals. Subgrains and recrystallized grains (*ca.* 0.5 mm) are developed to different degrees at the border of K-feldspar megacrysts, and interstitial quartz presents chessboard subgrain pattern. Heterogeneously distributed fluid-rich, late-magmatic liquids were responsible for strain partitioning into dry and wet high-strain zones at outcrop scale, where contrasting deformation mechanisms are reported and different end-products are formed from a single syenite protolith. In dry high-strain zones K-feldspar and clinopyroxene are recrystallized under high-T conditions. In wet high-strain zones, the de-stabilization of clinopyroxene and pervasive replacement of relatively undeformed K-feldspar porphyroclasts by myrmekite and subordinate graphic-like intergrowths indicate melt-assisted dissolution-replacement creep as the main deformation mechanism. The recrystallization of these intergrowths is observed and is considered to contribute significantly to the development of the mylonitic foliation and banding. A model is proposed for strain partitioning relating a positive feedback between myrmekite-forming reaction, strain softening, continuous inflow of late-magmatic liquids and dissolution-replacement creep in the wet zone at the expenses of the original mineralogy, which is preserved in the dry zones. Regarding the constraints of the model, melt-assisted dissolution-replacement creep in syntectonic environments under granulite-facies conditions may extend the field of operation of dissolution-replacement creep to the lower continental crust.



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PT.026

The origin of the Moacyr monazite standard – elemental and isotopic constraints

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Over the past 20 years, high spatial resolution U/Pb geochronology and isotope geochemistry has revolutionized the study of felsic magmatic rocks by establishing crystallization and inheritance ages in zoned minerals, and by isotopically fingerprinting source regions, constraining the extent of magma mixing and/or crustal recycling in granite genesis.

These techniques require well-calibrated standards. LA-ICP-MS has shown the greatest increase both in application to geochronology and isotope geochemistry compared to ID-TIMS or SIMS. One widely distributed monazite U/Pb standard comes from the Itambé pegmatite district of Bahia State (E Brazil), and is known as either “Moacyr” or “Moacir” monazite in the literature. This pegmatite district forms the northern extent of the Eastern Brazilian Pegmatite Belt, which continues southwards into the 630-480 Ma Araçuaí Orogen. “Moacyr” monazite was originally collected by a Bahia State Geological Survey geotechnician and was subsequently distributed to several research groups by Prof. Moacyr Marinho. However, the exact sampling locality was not recorded and the Itambé pegmatite district contains three different large pegmatites (the Bananeira, Coqueiro and Paraíso pegmatites), all of which contain large quantities of monazite. An initial ID-TIMS U/Pb age determination on one “Moacyr” aliquot gave a concordant ca. 474 Ma age. Subsequent ID-TIMS age determinations have suggested that the “Moacyr” monazite is reversely discordant, with best estimate crystallization (²⁰⁷Pb/²³⁵U) ages in the range ca. 504-508 Ma. These estimates do not entirely overlap within error, and it is unclear whether this is an inter-laboratory analytical effect, or results from geological factors e.g. samples taken from different localities.

The main goal of this study is to identify the origin of a ca. 50g crystal fragment of “Moacyr” monazite. This fragment is termed “Itambé” to distinguish it from other Moacyr monazite aliquots. The origin of the “Itambé” sample was investigated by comparing new data on its age, Nd-isotope composition and chemical composition with those of monazite directly sampled by the authors from the three pegmatite bodies that comprise the Itambé pegmatite district.

The U-Pb LA-ICP-MS results showed that the samples have, within error, the same ages (ca. 508 Ma), so other means must be used to distinguish between them. In regard to chemical composition, on the basis of MREE/HREE fractionation (ie, (La/Gd)_N and (Gd/Lu)_N values), Eu/Eu* and the chondrite-normalized REE patterns of the “Itambé” monazite is very similar to that from the Coqueiro pegmatite, and both are distinctly different from the Bananeira and Paraíso monazites. This distinction also is apparent in their Nd-isotope compositions.

The combination of elemental and Nd-isotopic compositions suggests that the “Itambé” monazite aliquot is from the Coqueiro pegmatite. Moreover, the εNd values of the “Itambé” monazite fragment (εNd_t = -4.2) and that from all the Itambé district pegmatites, are distinct from other standards (eg, Managountry; εNd_t = -22.3) as well as gem-quality monazite from ca. 490-520 Ma pegmatites from the Araçuaí Orogen, further to the south, which are much more isotopically evolved (εNd_t = -17 to -14). We acknowledge support from FAPEMIG (apoio a participação em eventos) and the CNPq (Brazil).



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PT.027

Early Mesozoic rejuvenation and reworking of continental crust in South China

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Ancient continents are generally modified by structural, magmatic and metamorphic processes after their formation to form new structural fabrics and juvenile crust (i.e., reworking and rejuvenation), which is the key process in continental crustal evolution. South China has experienced collision with Indochina and North China blocks and subduction of the Paleo-Pacific Ocean plate since Mesozoic, with multiple stages of magmatism. The large scale of igneous rocks provide powerful evidence and important information regarding rejuvenation and reworking of continental crust. Here we present new zircon U-Pb-Hf-O data and whole rock geochemistry and Sr-Nd-Hf isotopes of Early Mesozoic granite, syenite and gabbro in the south Jiangxi Province to trace their ages, magmatic source and petrogenesis, and to further constrain the Early Mesozoic rejuvenation and reworking of continental crust of South China.

The intrusive rocks in the south Jiangxi Province mainly consist of biotite granites with small stocks of Kf granite, syenite and gabbro. Zircon U-Pb dating gives the emplace age of 247-241 Ma for biotite granites, 198-195 Ma for syenites, 190 Ma for Kf granites and 188 Ma for gabbros, respectively. The Triassic biotite granites are metaluminous to weakly peraluminous, with SiO₂ contents of 63.9-73.9 wt.%, low P₂O₅ contents. They have high (⁸⁷Sr/⁸⁶Sr)_i ratios (0.7086-0.7225) and negative ε_{Nd}(t) (-12 to -14.5) and ε_{Hf}(t) (-9.9 to -12) values for whole rocks, and ε_{Hf}(t) values of -8.5 to -17.2 and δ¹⁸O values of 8.6-10 ‰ for zircons, implying that the Triassic biotite granites are fractionated I-type granites that were derived from partial melting of ancient metabasaltic rocks, coupled with crystal fractionation and wallrock contamination. The Early Jurassic syenites have low (⁸⁷Sr/⁸⁶Sr)_i ratios (0.7023-0.7056) and positive ε_{Nd}(t) (0.3 to 5.3) and ε_{Hf}(t) (3.3 to 12) values at SiO₂ contents of 61.4-72.3 wt.%. Zircons have ε_{Hf}(t) values of 8.8-15 and δ¹⁸O values of 4.5-5.3 ‰. They were possibly derived from an enriched mantle source with widely crystal fractionation. The Early Jurassic Kf granites have typical geochemical features of peraluminous A-type granites, with high Ga/Al ratios, and Zr, Hf, Nb and total alkali contents. They have ε_{Nd}(t) (-0.5 to -4.2) and ε_{Hf}(t) (0.9 to 4.9) values for whole rocks, and ε_{Hf}(t) values of -3.0-8.7 and δ¹⁸O values of 4.0-7.3 ‰ for zircons, indicating a young crustal source. The Early Jurassic gabbros have ε_{Nd}(t) (-1.5 to 0.6) and ε_{Hf}(t) (-1.6 to 5.7) values for whole rocks and ε_{Hf}(t) values of 3.9-6.4 and δ¹⁸O values of 4.9-5.9 ‰ for zircons, suggesting that they resulted from crustal assimilation of enriched lithospheric mantle-derived melts. The distinct sources of the Early Mesozoic igneous rocks indicate that the continental crust of South China was reworked and rejuvenated by mafic magma underplating and intracrustal melting possibly related to tectonic transition from Tethys orogenic regime to Paleo-Pacific regime during Early Mesozoic.



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PT.028

Semi-pelite anatexis: generation of tonalite-trondhjemite melts in metamorphic system

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Semi-pelite, or wacke, is an important component in continental crust, which under amphibolite facies metamorphism originates biotite schist with variable amounts of plagioclase and aluminum-rich minerals, as garnet, staurolite and Al₂SiO₅ polymorphs. The Santo Antônio unit is part of the Andrelândia *Nappe* System, Southern Brasília Orogen, MG, Brazil, and it groups a transition from kyanite-garnet-muscovite-biotite-plagioclase schist to metatexite with incipient to moderate partial melting. The investigation of its metamorphism and anatexis is accomplished using field data, mineral chemistry and calculating pseudosections with THERMOCALC. The metatexite presents leucosome veins mainly composed of quartz and plagioclase, with some mica, rare garnet and almost no high-stability phases, as zircon, rutile, ilmenite and monazite, and, although deformed, igneous textures, as euhedral plagioclase with concentric zoning and thin quartz films trapped in intergranular boundaries, are recognized. New biotite occurs either as melanosome, the main peritectic phase formed during incongruent partial melt reaction of muscovite, or as schlieren. Despite its origin as the main residual phase, it is difficult to distinguish whether biotite is peritectic or retrometamorphic, as most neosome remains unsegregated, even in the outcrops with higher leucosome content, up to 30% in volume in the unit structural top. From schist to metatexite a compositional banding is developed due to different amounts of leucosome lenses that are parallel or locally discordant to main foliation in matrix (palaeosome + unsegregated neosome). Pseudosection modeling in NCKFMASHTO system was calculated for two textural homogeneous samples from each main example, schist and metatexite, showing wide tri- to pentavariant and small uni-, di-, hexa-, or heptavariant fields. In both examples, metamorphic peak assemblage is quartz, biotite, plagioclase, garnet, ilmenite, rutile and melt, formed at expenses of Na-rich muscovite, plagioclase and kyanite; no K-feldspar is observed. The compositional variations observed in mica (Na_{0.07-0.15}, Fe_{0.10-0.12} apfu), plagioclase (An₁₆₋₄₀ matrix, An₁₂₋₃₅ leucosome, An₁₆₋₄₈ garnet inclusions) and garnet (X_{Mg}_{0.09-0.28}, variable core-rim zoning) are in accordance with calculated compositional isopleths and combined indicate heating at high-pressure, reaching metamorphic peak at ~ 750 °C above 10 kbar, followed by cooling-decompression stage, in agreement with optimized thermobarometry and Zr-in-rutile temperatures. Modeling indicates melt composition is sodium and silica-rich that is in consonance with leucosome composition, rich in quartz and Na-rich plagioclase: moderate temperature and high-pressure partial melting via plagioclase-muscovite breakdown will produce tonalite-trondhjemite melt before addition of K-feldspar in the system, which occurs only in high *P-T* conditions, above 10 kbar and 850 °C. The increase in leucosome volume toward the unit structural top is also compatible with calculated higher *P-T* conditions, and implies an inverted metamorphic gradient for the area. The characterization of this process highlights the importance of Na-rich muscovite and plagioclase in the generation of tonalite-trondhjemite melts over granite ones, from semi-pelite protoliths, when proper *P-T* are achieved.



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PT.029

WATER-PRESENT ECLOGITE MELTING – THE EFFECTS OF PHENGITE AND WATER IN THE PARTIAL MELTING OF ARCHEAN BASALTIC ROCKS AND POTASSIC MELT GENERATION.

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The tonalite-thronthjemite-granodiorite (TTGs) suite of granitoid rocks were dominant during the formation of the felsic continental crust in the Archean. TTGs are granitoids characterised by high contents of silica (typically higher than 68 wt% SiO₂) and sodium, with low potassium-sodium ratios (Na₂O ~4.65 wt%; K₂O/Na₂O ~0.4), low La/Yb ratios (~48) and low Yb concentration (~0.6 ppm). It was demonstrated in 2012 that it is possible to generate melts with compositions very similar to the average Archean thronthjemite, through partial melting of water saturated eclogitic rocks, under PT conditions consistent with Archean subduction. Within the Barberton greenstone belt, TTG magmatism occurred at ca 3.55, 3.42 and 3.23 Ga. It has been documented some potassic and peraluminous granites which occur as clasts within a conglomerate of the greenstone belt to have ages of 3550±45 Ma, 3460±34 Ma and 3270±36 Ma. These granites differ from typical S-type granites for their very low CaO (0.30 wt% in average), despite having reasonable Sr (12–330 ppm). It has been demonstrated that these granites formed by anatexis of sedimentary rocks subducted with oceanic crust as an explanation of the coeval production of peraluminous granite and TTG magmas. This study has experimentally investigated the possibility that the TTG and S-type granite magmas are produced by the same source as a consequence of high pressure melting. The experiments have used the composition of an Archean oceanic crust, in conjunction with PT conditions consistent with ancient subduction zone thermal structure.

Experiments were conducted at 2,5 GPa, with temperature varying between 600 to 850°C. It was demonstrated that at relatively low temperature (800°C to 850°C at 25 kbar) the mafic source produces peraluminous granitic melts with low CaO contents (0.88 wt% in average). The modeling of equilibria phases and their stability also support the results found experimentally, suggesting that such a melt is produced by breaking all the minerals holding potassium first, enriching the produced melt in potassium and, only after, generate the TTG-like granitoids.



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PT.030

Long-lived subduction-related granitoid magmatism in the neoproterozoic Mara Rosa Magmatic Arc, central Brazil: LA- ICPMS and ID-TIMS U-Pb geochronology

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The Mara Rosa Magmatic Arc is an important component of the neoproterozoic Brasília Belt, in central Brazil, underlying extensive areas in the western part of the orogen. Preliminary geochronological data have indicated that this juvenile terrain formed between ca. 860 and 630 Ma, representing the closure of a wide oceanic basin, the Goiás-Pharusian ocean, between the São Francisco-Congo, Amazonian and West African paleocontinents. It is formed by: (i) supracrustal sequences (Santa Terezinha and Mara Rosa sequences) comprising feldspar-bearing schist, felsic and mafic metavolcanic rocks and minor quartzite, and (ii) plutonic/metaplutonic suites comprising pre- to post-tectonic intrusive bodies, ranging in composition from gabbro to granite, with an important tonalitic component. New LA-ICPMS U–Pb zircon data discussed here indicate a complex magmatic and metamorphic evolution of the arc during continental convergence.

The Mara Rosa Sequence is interpreted in this study as representative of a primitive neoproterozoic island arc. It contains the oldest (ca. 915 Ma) metavolcanic rock known in the arc. The detrital zircon grains range in age from from 950 to 780 Ma indicating that the original sources are within the Mara Rosa Arc itself. The metaplutonic suites comprise at least three broad groups of plutons: (i) the oldest include typically juvenile, primitive rocks, possibly formed in island arcs with ages ranging from ca. 874 to 852 Ma, (ii) the second, emplaced between ca. 812 and 800 Ma, exhibit crustal isotopic signature and many inherited zircon grains and (iii) the youngest is formed by a cryogenian bimodal suite of gabbrodiorites and granodiorites crystallized between ca. 650 Ma and 611 Ma. Granites of this phase are generally leucocratic and slightly peraluminous presenting conspicuous inheritance of paleo- and mesoproterozoic material.

Ages of metamorphism determined on metamorphic zircon and monazite are of ca. 630-620 Ma indicating that this is the timing of final closure of the Goiás-Pharusian ocean. The new data suggests a complex evolution scenario for the Goiás Magmatic Arc, and for the Brasília Belt itself. Any tectonic model should, therefore, take into consideration several paleosubduction zones and successive events of accretion of magmatic arcs along the western margin of the orogen.

In Brazil, this system of arcs is covered by the Parnaíba Paleo- Mesozoic sedimentary basin and re-appears in NE Brazil (Ceará), and in Africa, in the Hoggar-Pharusian region, where juvenile arcs such as the Tilemsi and Amalaoulaou are recognized. This implies that this semi-continuous arc system extended for several thousands of kilometers, from central Brazil and NW Africa, developed in a tectonic setting possibly similar to the arcs of the Western Pacific Ocean.



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PT.031

Peritectic assemblage entrainment and the composition of S-type granites: a thermodynamically constrained evaluation

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Granitoid magma compositions may be controlled by processes that operate in the source. One of these processes is the peritectic assemblage entrainment (PAE), which states that S-type granites are formed by the entrainment to the melt of a fraction of the peritectic mineral assemblage (PMA: garnet/cordierite/orthopyroxene, Ca-rich plagioclase, K-feldspar and/or ilmenite) produced during incongruent melting of muscovite- and biotite-bearing rocks during partial melting of metasedimentary rocks, and co-segregation of the melt and this fraction of PMA. This process seems to explain satisfactorily the observed tight correlation between several elements like Ti, Si or Ca and maficity (Fe+Mg on an element basis). Consequently, the addition of the PMA reduces the Si and K content and increases the Ca and Ti content and maficity of granitoid magmas as the melt is enriched mainly in Si, Na and K, the peritectic mineral assemblage in Ca, Ti, Fe and Mg and the entrainment of the PMA dilutes those elements present mainly in the melt and enriches the magma in those elements present mainly in the mineral assemblage. Phase equilibria modelling is especially suitable to test the PAE process as the composition and amount of the melt and the peritectic minerals are thermodynamically constrained, and the composition of theoretical magmas formed by the peritectic assemblage entrainment process can easily be compared with natural S-type granitoids. The study presented here is the first attempt in such comparison. To reach this goal, the composition of a schist believed to be the source rock of the S-type Peninsula pluton, South Africa, was used to calculate the composition of the magmas. Several melting processes have been tested at 0.8 GPa from 650 °C, below the solidus, to 900 °C. These models included equilibrium batch melting (EBM), equilibrium fractional melting (EFM) and disequilibrium fractional melting (DFM), all of them with no entrained PMA, to test the composition of pure melts. In EFM and DFM, melt was segregated after every 1°C, closely resembling fractional melting, whilst in DFM the disequilibrium behaviour of plagioclase during partial melting was considered. Neither of the melts matched the composition of the granites of the Peninsula pluton except for the leucogranites as the melts were too felsic. Two more models with entrained peritectic mineral assemblage were calculated (EFM+PAE and DFM+PAE), where the magma was segregated after the melt fraction reached 5 wt%, and the composition of magmas consisting of 100 wt% melt, 80 wt% melt + 20 wt% PMA and 60 wt% melt + 40 wt% PMA was calculated. The entrained mineral fraction keeps the stoichiometric proportions of the produced peritectic phases. The compositional trends formed by both EFM+PAE and DFM+PAE are roughly parallel to the trends of the granites but DFM+PAE magmas produce a better fit in most of the elements and element ratios studied. This thermodynamic study demonstrates that peritectic assemblage entrainment is a viable process to explain the composition of S-type granites and remarks the importance of entrained peritectic plagioclase and the stoichiometric proportions of the entrained peritectic phases in the granite chemistry.



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PT.032

Two granulite-facies anatexis episodes in the Carlos Chagas Batholith (Brazil)

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The Carlos Chagas batholith (CCB) is a large body (exposed area = 14,000 km²) of peraluminous granitoid rocks formed during the syn-collisional period (585-560 Ma) of the Araçuaí orogeny (Brazil). A dominant feature of this batholith is its garnet-rich and biotite-poor character. No previous studies have investigated the origin of the mineralogy of the CCB in detail. In this study, we present new petrographic and mineral chemical evidence which documents garnet growth during two separate partial melting episodes. *In situ* U-Pb monazite and zircon dating, allow the timing of the partial melting events to be accurately constrained.

Three different domains within CCB can be differentiated based on the occurrence of the mineral assemblages: (1) Qz+Pl+Kfs+Bt+Grt+Ilm±Rt, (2) Qz+Pl+Kfs+Bt+Grt+Ilm+Sil±Crd, (3) Qz+Pl+Kfs+Bt+Grt+Ilm+Sil+Spl. In all three domains garnet occurs as large poikiloblastic crystals which include rounded biotite crystals with higher TiO₂ contents than the matrix biotite. In domains 2 and 3 a sillimanite fabric wraps around the large garnet crystals and a second generation of garnet occurs as smaller euhedral crystals that overgrow both the sillimanite fabric and the large garnet crystals. This 2nd generation of garnet contains sillimanite inclusions. Both generations of garnet are unzoned in terms of major element (Alm₇₀₋₈₀Py₁₅₋₂₃Sps₂₋₄Grs₂₋₆ and Alm₇₁₋₈₃Py₁₂₋₂₃Sps₂₋₄Gr₀₂₋₆ respectively) and HREE (Gd_N/Lu_N=0.08-0.60 and 0.51-1.60 respectively).

Textural evidence for the presence of melt at the peak of metamorphism is recognized in all domains on all scales, from the formation of garnet-bearing neosome to melt inclusions within garnet. Phase equilibria modelling using melt-depleted bulk compositions allows that P-T conditions of the last melting event to be constrained in each domain. Domain 1 records the conditions of the 1st metamorphic event to be 807-905 °C and 12.4-12.8 kbar, whilst Domains 2 and 3 record the conditions of equilibration during the 2nd metamorphic event to be: 765-835 °C and 5.1-9.5 kbar; and 765-819 °C and 5.0-10.2 kbar respectively.

The CCB crystallized as a K-feldspar megacrystic biotite granite at 587-572 Ma and the 1st granulite facies event occurred at 560-552 Ma, producing poikiloblastic garnet (1-15%) in neosomes around phenocrysts via biotite fluid-absent melting. The Nova Venécia complex, which forms the country rocks around the CCB, records conditions of 750-850 °C and 5.3-7.5 Kbar at this time.

Reheating related to asthenosphere ascent during the extensional thinning and gravitational collapse of the orogen promoted sufficient heat to allow for a 2nd anatexis event in the CCB, where rehydration had allowed for the formation of retrograde muscovite. This 2nd granulite event is recorded in the zircon and monazite geochronology of all domains at 528-515 Ma, but a new generation of garnet is only identified in the rocks of Domains 2 and 3. In these rocks sillimanite is produced by muscovite dehydration melting followed by biotite melting in the sillimanite-bearing rocks and generation of the 2nd generation of garnet. Juxtaposition of the CCB with the Nova Venécia complex was probably accomplished during this extensional episode.



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The late Neoproterozoic Uruana syenite: evidences for ultrapotassic magmatism in the central Brasilia Belt

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The Brasilia belt is part of a large Neoproterozoic (Brasiliano/Pan African) orogen developed between the Amazon, São Francisco and Paranapanema cratons. It represents a well preserved complex orogen formed by (i) the Neoproterozoic Goiás magmatic arc, constituted by igneous and volcano-sedimentary rocks, (ii) Archean-Paleoproterozoic terrains and (iii) thick Meso-Neoproterozoic metasedimentary sequences. The Uruana syenite is located in the central part of the Brasilia belt just to the north of the Anapolis-Itaçu granulitic complex intruding orthogneisses of unknown age, supracrustal rocks of the Neoproterozoic Rio do Peixe volcano-sedimentary sequence and metasediments of the Araxá Group and Serra Dourada Sequence. The Uruana syenite, with an age of 620 Ma, represents a body of approximately 60x20 km elongated in W-E direction with important milonitic deformation probably related to the Pireneus transcurrent lineament that represent a regional scale tectonic features separating the northern and southern portions of the Brasilia belt. The Uruana syenite has a typical green schist mineralogical association represented by actinolite, epidote, biotite titanite and plagioclase. It exhibits a homogenous porphyritic texture with cm-size K-feldspar porphyroclasts and locally presents abundant microgranular mafic enclaves (MME). The geochemical composition of the syenite and the MMIs shows wide variation in SiO₂ (45-67 wt %), high K₂O content (5.40–8.62 wt.%), high LILE (Ba=390–2053 ppm, Sr=294–1771ppm), HFSE and LREE content. Most of the lithologies show ultrapotassic signature with the most basic MME sample having lamproitic affinity. The petrographical and geochemical data suggest that the MMEs could be classified as minettes representing a calc-alkaline ultrapotassic magma. The source of this magma could be represented by a lithospheric mantle metasomatized between 900 and 600 Ma during the formation of the Goiás Magmatic Arc. The partial melting of the metasomatized mantle in the region could be triggered by a lithospheric delamination process occurred after the peak of granulitic metamorphism at approximately 650 Ma.



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New mapping, 40Ar/39Ar ages and thermobarometric constraints for the Late Triassic Central Patagonian Batholith, North Patagonian Massif, Argentina

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This contribution reports a reassessment of the units of the Late Triassic Central Patagonian Batholith (CPB, North-Patagonian Massif, Argentinean Argentina) based on a detailed field mapping and petrographic studies complemented by new 40Ar/39Ar biotite ages. This batholith bears magmatic to solid-state foliations, and its emplacement was interpreted as due to the activity of a major transcurrent fault during the Early Mesozoic. The CPB consists of the Gastre and the Lipetrén superunits. The Gastre Superunit is composed of four units, where the oldest one is the Equigranular Hornblende-Biotite Granodiorites. This unit is characterized by medium to coarse-grained grey equigranular granodiorites and monzogranites with a modal composition given by plagioclase (40-60%), quartz (15-35%), K-feldspar (15-20%), hornblende (5-8%), biotite (2-5%), titanite, apatite and opaque minerals (1-5%). This unit is in transitional contact with the Porphyritic Biotite-Hornblende Monzogranites, which are a suite of monzogranites and granodiorites composed of euhedral K-feldspar megacrysts immersed in a medium-grained groundmass with hypidiomorphic texture. A third unit, the Equigranular Biotitic Monzogranites, forms stocks of light pink, medium-to coarse-grained equigranular monzogranites which intrude the previously mentioned units. The stocks are constituted by plagioclase (30%), microcline (35-20%), quartz (35-25%), biotite (10%), hornblende (5% or absent) and titanite, apatite and titanomagnetite (5%). The Gastre Superunit of the CPB is finally composed of the The Hornblende Quartz-Diorites, a unit characterized by three stocks of dioritic to quartz-monzodioritic composition and by many dioritic to quartz-dioritic dikes. The stocks intrude and are, in turn, locally intruded by the other units (intrusion-reintrusion phenomena). The dikes intrude all the other units of the Gastre Superunit. Data of mineral chemistry from a granodiorite belonging to the Porphyritic Biotite-Hornblende Monzogranites and from a tonalite belonging to a stock of the Hornblende Quartz-Diorites allowed us to constrain emplacement depth and crystallization temperature in these units. Emplacement depth is bracketed between 6 and 11 kilometers (1.8 to 3 kbar using the calibration of Schmidt 1992), with maximum recorded temperatures of emplacement comprised between 760 and 800^oC (Holland and Blundy 1994 geothermometer). The Porphyritic Biotite-Hornblende Monzogranites yield a 40Ar/39Ar age in biotite of 213±5 Ma.

The Lipetrén Superunit is constituted by fine-grained biotite monzo- and syenogranites which intrude all the units of the Gastre Superunit. The monzogranites yielded a 40Ar/39Ar age in biotite of 206 ± 4 Ma. The fine-grained and even granophyric textures in the Lipetrén Superunit suggest a rapid cooling in a subvolcanic environment; therefore its biotite 40Ar/39Ar age would be close to its real emplacement crystallization age. The new 40Ar/39Ar ages, together with previously reported Rb/Sr ages, indicate that a time span ≥7 Ma elapsed between the intrusion of the Gastre and the Lipetrén superunits. Unlike the Gastre Superunit, the Lipetrén Superunit does not bear magma hybridization textures.

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PT.035

Petrogenesis of the 2.09 Ga Laouni migmatitic granite Basement (central Hoggar, southern Algeria) : in-situ zircon U-Pb age and Nd-Hf isotopic constraints.

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Located within the Laouni terrane, in the LATEA metacraton, near Tessalit and Bahouinet, the rare migmatitic granite Basement occurring in the huge Pan-African granites offers an opportunity to investigate its age, nature and origin. This rock unit is characterized by a significant tectonic foliation defined by micas as well as local banding formed by variable quartz and feldspars that interacted with micas. Two types of granites are recognized : one is fine-grained, strongly foliated, the second one is medium to coarse grained. Despite their textural diversity in terms of grain size and presence/absence of K-feldspar megacrysts, all samples show similar mineralogical assemblages consisting of variable proportion of quartz, K-feldspar, plagioclase, biotite, \pm muscovite, zircon, apatite, monazite and ilmenite. Quartz is generally anhedral with undulose extinction. Microperthitic K-feldspar is often megacrystals (1-2 cm), interstitial or graphically intergrown with quartz. Plagioclase is generally weakly zoned (An₃₁₋₃₆). Fe-rich biotite is typically much more abundant than muscovite. The most distinctive feature of the muscovite analyses is the high TiO₂ (up to 1.64 wt%). Euhedral zircon, apatite and monazite occur mainly as inclusions in biotite and rarely in plagioclase and quartz. Migmatitic granites have peraluminous syenogranitic compositions (SiO₂= 60-70 wt%, A/CNK: 0.97 to 1.12 and normative corundum contents ranging from 0.91 to 3.48. They are characterized by K₂O more abundant than Na₂O and they are ferroan and alkalic to alkali-calcic in composition. Rare earth element (REE) patterns are relatively uniform, with steep slopes (La/Yb_N = 15-88) that result from enrichment in light REE (LREE). Eu anomalies are very apparent with a high negative anomaly in every sample. U-Pb data on zircons gave an age of crystallization of 2087 Ma. Sm-Nd data are variable (ϵ Nd (t) = -7.32 to 1.57, T_{DM}= 2.96-2.30 Ga) and ϵ Hf (t) values are also variable (-2.9 to +1.66 with T_{DM} = 2.76 Ga). The positive and negative isotopic ϵ Nd and ϵ Hf data suggest that the migmatitic granite probably resulted from a crustal material with addition of a minor contribution from the mantle by magma mixing in the crustal magma chamber. The Nd and Hf model ages indicate that this Paleoproterozoic granite was derived from a Neoproterozoic source.



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Effects of granitic magmas at high-grade metamorphism: illustrative examples from South Marginal Zone of the Limpopo Complex, South Africa

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During metamorphism and subsequent exhumation, Precambrian high-grade complexes become injected by various granitoid magmas that originated from deeper crustal levels (Morfin et al., 2013, *Lithos*, 168-169, 200-218). The effect of these magmas on the country rocks becomes apparent through transportation of entrapped granulites, formation of local zones of HT-UHT metamorphism and partial melting, assimilation of granulites, and production of large volumes of exotic fluids that interacted with granulites. We present petrological, fluid inclusion and thermobarometric studies exemplifying these complex effects from rocks associated with high-grade shear zones (Petronella, Matok) in the Southern Marginal Zone (SMZ) of the Limpopo Complex (South Africa). During exhumation onto the Kaapvaal craton during the time period 2.72 – 2.66 Ga, the SMZ has been invaded by trondhjemite-granodiorite melts (Belyanin et al., 2014, *Prec. Res.*, 254, 169-193; Safonov et al., 2014, *Prec. Res.*, 253, 114-145), which are, probably, closely associated with the large diorite-granodiorite-quartz syenite Matok pluton (Laurent et al., 2014, *Lithos*, 196-197, 131-149). These hot ($T \sim 1000^\circ\text{C}$) magmas entrapped and heated metapelites at $P \sim 7.5\text{-}8.5$ kbar (23-25 km depth) and dragged them to a depth of 18-20 km (6.3-6.5 kbar) (Safonov et al., 2014, *Prec. Res.*, 253, 114-145). Heating of the country orthopyroxene-cordierite-biotite metagraywakes resulted in localized dehydration melting of the rocks at temperatures up to 950°C . The peritectic melting reactions produced new generations of garnet, orthopyroxene and sillimanite in the rocks and finally resulted in formation of spectacular K-feldspar-rich garnet-orthopyroxene enclaves. In turn, the heterogeneous assimilation of the trondhjemitic melts by the metagraywake material is also reflected in several distinct garnet generations. Various mineral assemblages from the garnet-bearing trondhjemites, garnet-orthopyroxene enclaves and surrounding rocks allowed tracing the sub-isobaric cooling of the magma-rock system from $T \sim 900^\circ\text{C}$ to $\sim 600^\circ\text{C}$ at 6.3 - 6.5 kbar. Fluid inclusions trapped in garnet and quartz in the trondhjemite show that the magma transported a CO_2 fluid coexisting with aqueous-salt fluid bearing NaCl, KCl and CaCl_2 . Reduction of the CO_2 fluid during the assimilation of the sulfide-rich metagraywake material locally produced graphite-bearing varieties of trondhjemites. Similar CO_2 and aqueous-chloride fluids were detected in quartz of granodiorite and porphyritic quartz syenite of the Matok complex. The aqueous fluids with water activities 0.5-0.3, being exsolved from the granitoid magmas during sub-isobaric cooling and solidification, provoked formation of various assemblages after cordierite and orthopyroxene in the surrounding rocks. They include late garnet, Na_2O -rich gedrite (locally coexisting with anthophyllite), biotite, sillimanite (kyanite), staurolite, sodic plagioclase. Our data show that granitoid melts played a critical role in the exhumation of the Limpopo granulites onto the adjacent granite-greenstone craton, transference of heat in the crust, and transportation of large volumes of external H_2O - CO_2 -salt fluids that subsequently participated in the rehydration of a significant portion of the SMZ (van Reenen et al., 2014, *Prec. Res.*, 253, 63-80).

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PT.037

Generation of granitic magmas during amphibolite- to granulite-facies anatexis: the perspective of melt inclusions

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Crustal anatexis, accompanied by melt extraction and ascent of magma to upper crustal levels, constitutes the most important mechanism of geochemical differentiation of the continental crust. Being trapped by growing peritectic phases at suprasolidus conditions, melt inclusions (MI) in anatectic enclaves, migmatites and granulites represent a window into the pre-peak anatectic history of partially melted rocks (Acosta-Vigil et al., 2010, JP, 51:785-821; Bartoli et al., 2013, Geology, 41:115-118; Bartoli et al., 2014, EPSL, 395:281-290), and may provide a wealth of microstructural and compositional information on crustal anatexis (Cesare et al., 2011, JVE, 38:1-21; Acosta-Vigil et al., 2012, JP, 53:1319-1356). The crustal footwall of the Ronda peridotites (S Spain) consists of an inverted metamorphic sequence with migmatites and mylonites at the top. Mylonites represent strongly deformed former diatexites. To shed light on the nature and mechanisms of melting, a microstructural and geochemical study has been conducted on primary MI hosted in peritectic garnet of i) metatexites at the bottom of the migmatitic sequence and ii) mylonites close to the contact with the mantle rocks. Both rock types have compositions corresponding to peraluminous greywackes. Phase equilibria modeling shows that metatexites and mylonites underwent anatexis under amphibolite- and granulite-facies conditions, respectively (660–700 °C, 4.5–5 kbar and 820-830 °C, 5.5-6.0 kbar). Clusters of MI in the metatexites are rounded and preferentially located at the core of small garnet crystals, whereas these clusters may have a sigmoidal- to spiral-like shape in garnets of mylonites. MI are small (2-10 µm) and show variable degrees of crystallization, from totally glassy to fully crystallized (i.e., nanogranites). The latter consist of Qtz+Pl+Kfs+Bt+Ms aggregates (often modal Kfs > Pl in mylonites). Piston cylinder remelting experiments led to the complete rehomogenization of nanogranites in metatexites at the conditions inferred for anatexis: 700 °C and 5 kbar. Rehomogenized nanogranites in metatexites and glassy MI in mylonites are all leucogranitic and peraluminous and differ from those of coexisting leucosomes and from melts calculated by phase equilibria modeling at the inferred P–T conditions of entrapment. Systematic compositional variations have been observed between MI in metatexites and mylonites. MI produced under amphibolite-facies conditions show higher H₂O and Na₂O/K₂O, lower FeO and higher concentrations of the trace elements controlled by feldspars: Sr and Ba. MI formed under granulite-facies conditions have higher concentrations of trace elements controlled by biotite (Cs, Rb and FRTE e.g. Zn, Sc) and accessory minerals (HFSE e.g. Zr, U, Th). The calculated Zrn saturation temperatures for the MI in the mylonite are 50-100 °C lower than temperatures obtained from phase equilibria modelling, suggesting that MI are likely undersaturated in the accessory phases. Compared with coexisting MI, leucosomes show anomalously higher contents of Ca, Sr and Ba which suggests the presence of residual feldspars. The MI in metatexites and mylonites are interpreted to record the composition of the anatectic melts produced from a peraluminous greywacke 1) on, and immediately after crossing, the fluid-saturated solidus of this metasedimentary rock, and 2) during syn-kinematic anatexis via biotite dehydration melting at increasing temperature, respectively.



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PT.038

Source-inherited compositional diversity in post-collisional granitoids: geochemical evidence in the late Variscan Serre Batholith (Calabria, Italy)

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The c. 13 km-thick Serre Batholith makes up the middle portion of a continuous and nearly complete section of late Paleozoic continental crust exposed in central Calabria (southern Italy). Despite its limited extension of c. 1200 km², the batholith displays a wide compositional variety, with rock types ranging from quartz diorite-tonalite to granodiorite and monzogranite, with minor syenogranites and rare gabbros. Major, trace element and Sr-Nd isotopic data point to the generation of the batholith through the assembly of a number of magma batches with distinct initial compositions, produced by partial melting of different crustal sources. Compositional diversity of the granitoid rocks appears primarily source-inherited, reflecting the intrinsic chemical variability of both metaigneous and metasedimentary magma sources. Metabasaltic source rocks are suggested for the quartz diorites-tonalites, whereas metagreywackes with various pelitic and mafic contents are the most likely sources of weakly peraluminous biotite±amphibole granodiorites and two-mica granodiorites and granites. Strongly peraluminous K-feldspar megacrystic leucogranites produced by partial melting of mafic pelitic sources appear to represent the only pure crustal melts. The other granitoids are too silica-poor and MgO+FeO rich to represent pure melts, so they must represent mixtures of granite melt and other components, such as solid restitic/peritectic material entrained from the magma source, or more mafic magma injected in the granite melt after its ascent or emplacement. Mixing processes appear to have acted only locally, reinforcing the greater relative importance of source- or near source-related processes in generating the main geochemical diversity of the Serre Batholith granitoids. En-route to magma chamber processes such as crystal fractionation and, especially for some quartz diorites-tonalites, contamination by metapelitic country rocks, have then contributed to generate a significant second-order compositional variability. Major element-based geochemical parameters point to a strong affinity of the central Calabrian granitoid rocks with Cordilleran granitoids, inherited from the compositions of the source rocks rather than reflecting the real tectonic environment of the magmas. The magnesian “arc” signature is indeed here considered as resulting from partial melting of crustal material of magmatic arc derivation, such as magnesian igneous rocks and sediments derived from their rapid erosion. No firm evidence for a direct contribution from the mantle to the geochemical variability of the Serre Batholith granitoids has been found in this study, suggesting that the magmatism was not strictly associated with the generation of new continental crust. The late-Variscan granitoids of Serre Batholith appear to represent recycled and reworked crustal material, supporting the idea that post-collisional granitoid magmatism is mostly an agent of intracrustal differentiation, rather than crustal accretion.



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Coupling between deformation and magmatism in the Sarandí del Yí Shear Zone, Uruguay
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In orogenic belts, the temporal and spatial association of magmatism and crustal-scale shear zones suggests a causal relationship. This feedback can result from magmatism migration and emplacement controlled by shear zones, shear zone nucleation due to magma emplacement or mutual interaction between both shear zones and magmatism. However, it is also argued that there is no coupling between these processes.

The Sarandí del Yí Shear Zone is a crustal-scale shear zone that constitutes the eastern boundary of the Paleoproterozoic Río de la Plata Craton. The Sarandí del Yí Shear Zone was defined as a structural lineament, which was also interpreted as a terrane boundary. Afterwards, it was considered a pre-Brasiliano dextral shear zone that was sinistrally reactivated during the late Neoproterozoic. On the basis of structural, microstructural and kinematic data, deformation in the Sarandí del Yí Shear Zone was constrained to occur under middle/upper amphibolite facies conditions with dextral shearing during juxtaposition of the Río de la Plata Craton and the Nico Pérez Terrane. Subsequent lower amphibolite-upper greenschist facies metamorphism was related to pure-shear dominated sinistral shearing, which was followed by a late cataclasis that reworked the easternmost border of the shear zone.

Several magmatic units were emplaced along the Sarandí del Yí Shear Zone. The Solís de Mataojo Granitic Complex was syntectonically emplaced during sinistral strike-slip at 584 ± 13 Ma (single-phase Pb-Pb stepwise leaching titanite) and presents calc-alkaline geochemical signature. The emplacement of the alkaline Sierra de las Ánimas Complex (579 ± 1.5 Ma, Ar-Ar hornblende; 574.5 ± 8.1 Ma and 581.8 ± 3.4 Ma, U-Pb SHRIMP zircon) was also structurally controlled by the Sarandí del Yí Shear Zone. This alkaline complex only underwent minor low-temperature deformation and therefore constrains the end of the ductile deformation along the shear zone.

The recorded transition from calc-alkaline to alkaline magmatism took place in a post-collisional setting. As the Sarandí del Yí Shear Zone represents a former terrane boundary, it provided an effective channel for magma migration from the lithospheric mantle and emplacement in upper crustal levels. On the other hand, heat provided by these intrusions could also induce strain softening, thus favoring further shearing to some extent.



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PT.040

Nepheline syenites to granitic rocks from the Itatiaia Alkaline Massif, southern Brazil: new geological and petrological insights

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The Itatiaia Alkaline Massif is one of the biggest alkaline Mezo-Cenozoic occurrences of Brazil (~220 km²; 22°18'/22°28' S; 44°34'/44°49' W). It has an elongated NW-SE shape with a ~10 km diameter ring structure at the central region. Recent geological mapping has shown a much more complex geological and lithological context, than previously described. Over twenty petrographic facies were identified, which could represent different magmatic pulses or stages of magmatic evolution. The geomorphology (with elevations ranging from 540 to 2792 m) heavily emphasizes the relations between these facies and suggests different intrusions divided in three areas with distinct characteristics: SE, Central and NW.

The SE area does not show remarkable structural features and is composed exclusively by miaskitic to agpaitic nepheline syenites. The most silica-undersaturated facies is on the edge, in contact with basement, and is locality peraluminous with modal hercynite and corundum. There are dykes of aphyric, porphyritic (some of them with pseudoleucite) and breccoid phonolites, besides a nephelinite.

The Central area is shaped as a ring structure that intrudes partially the SE area. It shows an external C-shape ring made up by miaskitic to agpaitic nepheline syenites and phonolites. The moon-shaped inner facies migrates to NW, suggesting successive intrusions. They are composed by different units of pulaskites, nordmarkites and quartz alkali feldspar syenites, which trends to increase the silica saturations to the center. A small intrusive body of alaskite occurs next to the center. Dykes of phonolite occurs in the outer regions, whereas in the inner part dykes of trachyte and rhyolite occur. The transition to the NW area occurs by a 'neck' formed by quartz syenite glomeroporphyritic with anti-rapakivi, enclaves and others textures that attest instability. There are also irregular bodies of breccoid to porphyritic trachyte with aphanitic matrix and the fragments are almost entirely angular with fine to aphanitic granulation. The NW area also shows some moon-shaped structures where nepheline syenites predominate with nordmarkites on the northern boundary. Locality, cumulatic melagabro and biotite monzonite occur. In the center of the area there is a volcanic neck formed by porphyritic to breccoid trachyte that stands out in the landscape.

Besides these structural and petrographic differences, the three areas also differ in geochemical behavior. The SE area shows different or opposite trace-elements patterns with other two areas, displaying little or no relation to the evolution of the rest of the massif. The Central area shows well-defined trends with silica enrichment, while the NW area shows a little spread trend, however mostly agreeing with the Central area. Zircon SHRIMP U-Pb ages also agree with these differences. The SE area shows an age of 71 Ma, the Central area varies around 69 Ma and NW area show an age of 67.5 Ma. These ages may represent three magmatic events to form the massif over at least 4 million years.

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PT.041

The origin of mangerites from granulites partial melting in the Socorro-Guaxupé Nappe, MG, Brazil

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In southeastern Brazil, an important rock association including granulites, migmatites and granite-charnockite bodies constitute the Socorro-Guaxupé Nappe, an allochthonous terrane, which represents the root of a Neoproterozoic magmatic arc, part of the Brasília Orogen. Three important anhydrous igneous suites are recognized within the whole pile of the nappe: São Pedro de Caldas, Divinolândia and Paraguaçu, being the last one with the poorest characterization, so far. Charnockite rocks constitute the three suites, mainly mangerite in composition, isotropic or foliated, medium- to coarse-grained, grey to light green, which have tabular shape and it is intrusive in metatexite and diatexite. Zircon saturation thermometry yielded temperatures of 900 °C for crystallization of the magma, which occurred at 625 Ma, the same age of the metamorphism. For the Paraguaçu Suite, mangerite presents high Ba/Rb ratios indicating a source previously depleted in Rb and enriched in Ba, which may be linked to the generation and extraction of granitic melts due to biotite breakdown and production of K-feldspar. LREE patterns present enrichment relative to chondrite, about 100 to 300 times, whereas HREE are 10 to 40 times richer than chondrite, and positive or no Eu anomalies are observed. Felsic garnet granulite is depleted in all REE in relation to mangerite, although presents enrichment in LREE in relation to chondrite, 70 times, and no Eu anomaly. Peak mineral assemblage for the felsic garnet granulite is orthopyroxene, clinopyroxene, garnet, plagioclase, orthoclase and quartz; all hornblende and biotite are retro-metamorphic. Thermobarometry and pseudosection modeling of basal portion of Socorro-Guaxupé Nappe provides metamorphic peak conditions of *ca.* 950 °C at 11.5 kbar, characterizing it as an ultra high-temperature metamorphism. The *P-T* conditions match with the ones required to produce the mangerite magma and the observed dry suites. The residue of these suites, the felsic garnet granulite, is poor in radiogenic elements, such as Rb, Cs, U, Th and also in HREE. The partial melting in ultra high-temperatures was able to melt zircon and apatite, producing a residue HREE -poor, even if it is rich in garnet.



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Petrogenesis of granite-charnockite association in Madurai Block, Southern Granulite Terrain, India: Constraints from Sr-Nd isotope and elemental geochemistry

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Granites in metamorphic terrains are important to understand the processes of crust-mantle interaction, crustal-melting, melt-extraction and emplacement leading to progressive differentiation and evolution of continental crust. We report new elemental and radiogenic isotope results from the granites and associated charnockite (orthopyroxene bearing granite) in the north-eastern part of the Madurai Block.

Madurai Block, in the Southern Granulite Terrain (SGT), India, has been shown to have experienced Ultra High Temperature (UHT) metamorphism, probably twice, in the Mid- and Late-Neoproterozoic. However, the causes and effects of this UHT metamorphism are yet to be understood.

Charnockite occurs in three different associations in the Pudukottai region of the eastern Madurai Block: 1) patches within the biotite gneiss, 2) foliation parallel bands and irregularly distributed patches within the garnet bearing pink granite and 3) massive charnockite within the granitic gneiss. Whole-rock elemental chemistry indicates that the charnockite and associated pink granite are meta-aluminous, alkali-calcic to alkali ferroan granite typical of A-type granites, while charnockite and the host biotite gneiss are calc-alkali to alkali-calcic magnesian granite. The patterns of multi-trace-element plots of pink granite are similar to the associated charnockite and same is true for the biotite gneiss and associated charnockite. Pink granite samples yield REE patterns varying from LREE enriched with negative or positive Eu anomaly to HREE enriched and LREE depleted pattern. These patterns are interpreted to reflect involvement of garnet to different extent.

Four whole-rock samples of pink granite yield Rb-Sr isochron age of 870 ± 37 Ma (MSWD 0.91) while the Nd depleted mantle model ages (T_{DM}) of the pink granite range between 2.3 to 2.9 Ga and the charnockite hosted in these granites have T_{DM} ages between 2.2 to 3.3 Ga. For gneisses T_{DM} are between 3.2 Ga to 3.4 Ga while the charnockite patch within these gneisses has T_{DM} age of 3.7 Ga. The age corrected Sr and Nd isotope ratios of pink granite are similar to their associated charnockite which are different from that of the biotite gneiss and its associated charnockite. However, all these granitoids are mainly derived from the crustal melting.

These model ages, together with the field, petrographic and geochemical evidences suggest that the biotite gneiss and its associated charnockite are result of an earlier episode of melting and melt extraction from the lower, probably mafic crust. The A-type pink granite and associated charnockite show ample evidences of 'binary mixing'. These evidences, however, could also be interpreted as different extent of 'un-mixing' of restite and melt as suggested earlier to explain the variation in the south Australian and New Hampshire granites. Some of the garnet grains in the pink-granite show textural evidences of being entrained in the melt from the restite. We during the present study explore the hypothesis of melting of lower/middle crust during the UHT metamorphism to generate the granite, and more importantly the role of residual source (restite) in the formation of orthopyroxene bearing charnockite within the granite which has been earlier interpreted as 'incipient charnockite'.



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Ultrahigh-temperature metamorphism in granulites with no “classic diagnostic” mineral assemblage, from the Socorro-Guaxupé Nappe, MG, Brasil

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In most known granulite terrains recognized as underwent ultrahigh-temperature metamorphism, a series of diagnostic mineral assemblages is commonly recognized, *e.g.* sapphirine + quartz, aluminum-rich orthopyroxene + sillimanite + quartz, among others. In southern Minas Gerais, the Socorro-Guaxupé Nappe is part of the Brasília Orogen, a neoproterozoic fold belt related to a magmatic arc develop in the active margin among São Francisco and Paranapanema Plates. At the base of this nappe, a felsic garnet granulite dominates the geology, bearing a few lenses of mafic garnet granulite, leucosome veins with garnet and orthopyroxene, and rare layers of pelite diatexite. With samples collected in Guaxupé, UHT conditions were calculated for this unit. Samples collected south of Varginha, in outcrops in the Verde River, at the base of this nappe, are used here. The felsic garnet granulite is composed of quartz, two feldspars, garnet, orthopyroxene, clinopyroxene, and ilmenite, which are the metamorphic peak assemblage; apatite and zircon are the main accessory phases. Around garnet consecutive corona of clinopyroxene, and rare orthopyroxene, is followed by hornblende and biotite, both also occurring as replacement of pyroxene porphyroblasts. Garnet composition has almost no chemical zoning along the grains, with average composition of $alm_{0.50}prp_{0.30}grs_{0.18}sp_{0.02}$. Orthopyroxene presents X_{Mg} of 0.60 with core slightly richer in aluminum when compared to rims, varying from 0.14 to 0.11 a.p.f.u. Plagioclase varies from An_{41} , in core, to An_{39} , at rims. In clinopyroxene aluminum varies from 0.21 to 0.15 a.p.f.u., with core richer in this element, which is balanced by Mg, with X_{Mg} varying from 0.66 to 0.71. *P-T* calculation is done for two samples using three different methods, THERMOCALC average *P-T*, RCLC and pseudosection. Average *P-T* method using the anhydrous mineral assemblage yielded, for VAB-01, 938 ± 47 °C and $11.4 \pm 0,6$ kbar, and, for VAB-19, 927 ± 87 °C and $11.6 \pm 0,4$ kbar. The results produced with the RCLC method are better for sample VAB-01, as smaller adjustments were necessary and yields 1004 °C and 13.45 kbar. Although, similar temperature results are calculated for VAB-19, 1035 °C, much higher pressures are obtained, 15.4 kbar, and major adjustments are required, as it is also noted with THERMOCALC calculations that yielded larger uncertainties. Pseudosection calculation in the NCKFMASHTO chemical system indicates the anhydrous mineral assemblage is only stable, for this bulk composition, at temperatures higher than 880 °C and with pressures between 9.2 and 12.7 kbar. This is in agreement with most calculation done, but rolled out the RCLC higher-pressure calculations. Rare lenses of diatexite lenses of pelite protolith, inside this unit, is formed by 80 to 90% of granite composition leucosome and 10 to 20 % of round aggregates of garnet, sillimanite, rutile, green spinel, and smaller amounts of quartz, which demonstrate that fertile compositions underwent extreme partial melting, in agreement with such extreme calculated *P-T* conditions. Although no diagnostic mineral assemblage is recognized, so far, within rocks of the Socorro-Guaxupé Nappe, its character of ultrahigh-temperature metamorphism is here reinforced.



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PT.044

Remelting and Remobilization in a Magmatic Arc: the St Peter Suite, South Australia

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Thermo-mechanical models of magmatic arcs suggest that intermittent intrusion of magma batches should lead to remelting and remobilization of earlier intrusive rocks as a result of fluctuations in temperature and water content. However, examples of remelting and remobilization of earlier intrusive rocks, formed during arc-building, are surprisingly rare. We investigate the evolution of magmatic rocks of the Palaeoproterozoic St Peter Suite, in the Gawler Craton, South Australia. This suite records multiple intrusions, magma hybridization, and the remelting and remobilization of these intrusions to form migmatites and newly-formed leucocratic magmas.

In this poster, we detail first how multiple magma batches interact with one another as liquids and mushes during syn-magmatic deformation phases, and then detail the nature of migmatites resulting from anatexis of these same magmatic rocks and the resulting channel ways that allowed for magma remobilization. LA-ICP/MS U/Pb zircon dating yielded crystallization ages of 1647 ± 12 Ma for an early diorite-to-granite suite, and 1604 ± 12 Ma for a later magmatic suite of broadly similar composition. Both these suites underwent anatexis events. Titanite from late-formed leucosomes found within D₂ shear zones in the older suite, yielded SHRIMP U/Pb age of 1605 ± 7 Ma, within error of the age of the younger suite. We therefore infer that intrusion, crystallization and remelting/remobilization of this younger suite of rocks occurred within 10-15 M.yr. Thus, the St Peter Suite exposures record many of the key processes expected in arcs, including the prediction that early intrusive arc rocks remelt to form younger more fractionated magmas.



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PT.045

Restite mobilisation versus melt segregation: source controls on granitic magma chemistry in the Sierra de Quilmes, NW Argentina

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The compositional variability of crustal-derived granites has been attributed to a multitude of processes. Magma mixing and fractional crystallisation have previously been given a great deal of attention, and used to account for the wide variation in granite compositions. We focus instead on restite unmixing as the dominant process influencing chemical variability in granitic rocks. We describe the relationship between granulite facies migmatites and granites in the Sierra de Quilmes. The north-south trending mountains that define the region, known as the Sierras Pampeanas, are characterised by variably metamorphosed turbidites of the Neoproterozoic–Cambrian Puncoviscana Formation. Early Ordovician subduction on the western margin of Gondwana produced widespread high-T, low-P metamorphism of pelites and greywackes during the 470 Ma Famatinian Orogeny, resulting in extensive anatexis and granite plutonism. The Sierra de Quilmes is a tilted metamorphic complex in the northern Sierras Pampeanas, and provides exposure of the near-complete metamorphic sequence from granulite-facies magma source rocks in the southwest to granite emplacement levels in amphibolite and greenschist facies rocks in the northeast. Anatexis is associated with the fluid-absent incongruent breakdown of biotite, evidenced by the presence of peritectic Grt±Crd±Opx in restitic assemblages. In the southwest Sierra de Quilmes, the Ovejeria Complex is dominated by gradational contacts between diatexite migmatites and granites. This corresponds with greater heterogeneity in the form of schollen and Bt-schlieren within granites. In contrast, in the northeast Sierra de Quilmes, the Laguna Complex has common melt segregation structures in metatexites from which cleaner and more leucocratic and homogeneous granites are extracted feeding the leucocratic Cafayate pluton. Bulk rock geochemistry of migmatites and granites reveals two contrasting trends between the two complexes. The diatexites and granites from the Ovejeria Complex are compositionally similar to the Puncoviscana Formation, suggesting mobilisation of residuum to produce the heterogeneous granites. In contrast, such rocks in the Laguna Complex define geochemical trends indicative of melt-residuum separation, with residual compositions enriched in FeO_T, MgO and TiO₂, and a complementary fractionated assemblage with elevated SiO₂ and K₂O related to the homogeneous leucocratic plutons. The difference in geochemical trends between the two complexes, combined with distinct field relationships, indicates how the process of magma segregation and extraction from the source impacts on their geochemistry. Here we have two complexes side by side, one that records restite unmixing trends and the other that is dominated by segregation of melt from the source and subsequent fractionation.



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Early Cretaceous subvolcanic calc-alkaline granitoid magmatism in Shyok Suture Zone, Ladakh Himalaya, India: Evidence from phase petrology and U-Pb SHRIMP zircon geochronology

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Lithounits constituting Ladakh Himalaya are exposed along Indus and Shyok Sutures Zones of northwest Himalaya. Shyok Suture Zone (SSZ) represents tectonized remainder of a marginal (back-arc) basin while experiencing crustal shortening and is mainly composed of volcano-sedimentary formations. Nubra-Shyok valley is mainly comprised of calc-alkaline granitoids exposed in Tirit region, referred herein Tirit granitoids, which are intrusive into dacite and andesite of Khardung Formation. In this region marginal parts of Ladakh granitoids are also exposed intruding the Shyok Formation. Field relationships, biotite chemistry, Al-in-hornblende barometers, U-Pb SHRIMP zircon geochronology have been carried out in order to infer the nature of magmatism, depth of emplacement and timing of Tirit granitoid magma. Dacitic and andesitic xenoliths in Tirit granitoids suggest assimilation, stopping and collapse of overlying volcanic materials while intrusion of Tirit granitoid melts at epizonal-subvolcanic levels. Composition of biotite suggests metaluminous (I-type) calc-alkaline nature of Tirit granitoid melt formed in subduction setting. Al-in-hornblende barometers (~1.08-2.1 kbar) further corroborate solidification of Tirit granitoid melt at subvolcanic level equivalent to a minimum of *ca* 4 km or to a maximum of *ca* 8 km thick overburden of volcanics. On the other hand, tectonically separated marginal parts of Ladakh granitoids contain less frequent xenoliths of shale and metabasics of Shyok Formation, which suggest winty intrusive nature. Both Ladakh and Tirit granitoids contain mafic to hybrid microgranular enclaves, which suggest mixing and mingling of mafic-felsic magmas in plutonic environment, a typical feature observed in calc-alkaline I-type granitoid complex.

Three granitoid samples, one each from assimilated and unassimilated Tirit granitoids and one sample from Ladakh granitoids close to the contact with country-rocks, were chosen for U-Pb SHRIMP zircon chronology. Zircons from unassimilated Tirit granitoid have yielded mean age of 109.4±1.1 Ma corresponding to Early Cretaceous. It is noteworthy that inherited cores of some zircons have provided older age groups (278-393 Ma, 519-713 Ma and 1933 Ma), which suggest involvement of heterogeneous Carboniferous, Cambrian-Neoproterozoic and Paleoproterozoic crustal sources in the generation of Tirit granitoids. It is likely that sediments derived from ancient continental crust were mixed with juvenile crust before the onset of subduction of oceanic crust below the Asian plate. Zircons from assimilative Tirit granitoid yields an age of 105.30±0.80 Ma. Two inherited zircon core yield ages of 476 Ma and 952 Ma again pointing involvement of Gondwanian components in the genesis of Tirit granitoids. Zircons from Ladakh granitoids have yielded age of 67.32±0.66 Ma, and remarkably these zircons are devoid of inherited cores. Tirit granitoids (110-105 Ma) must have formed during Early Cretaceous, and the dacite and andesite must have erupted prior to 105 Ma. Earlier suggested ages (~68-74 Ma) for Tirit granitoids elsewhere correlate well with the ages of Ladakh granitoids. We conclude that the Tirit granitoids in SSZ represent Early Cretaceous calc-alkaline magmatism formed in subduction environment, which



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intruded the dacite and andesite (>105 Ma) layers at subvolcanic levels.



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PT.047

Petrogenesis of arc-related Paleoproterozoic tonalites, granodiorites and coeval mafic rocks from southernmost Brazil, based on elemental and isotopic geochemistry

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In southern Brazil, three associations of tonalites and granodiorites that are geochemically similar to tonalite-trondhjemitic-granodiorite (TTG) associations have been identified as originating from the Arroio dos Ratos Complex (ARC) Paleoproterozoic magmatism. The metatonalites of Association 1 (A1; 2,148±33 Ma) have a fabric that is compatible with strong solid-state deformation. The tonalites and granodiorites of Association 2 (A2; 2,150±28 Ma) are intrusive in A1 and have a similar composition, but are less deformed and their primary structures are partly preserved. Both associations display contemporary relations with basic to intermediate magmas. Association 3 (A3; 2,077±13 Ma) is represented by tonalitic to granodioritic gneisses, without any associated basic to intermediate magmatism, and its main characteristic is the banding that resulted from strong solid-state deformation. Partial melting features are locally present in A3. The geochemical compositions of the three associations are similar and indicate sources related to a continental magmatic arc environment. The $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ ratios (0.701-0.703), $\epsilon\text{Nd}_{(t)}$ values (+1.45 to +5.19) and T_{DM} ages close to the crystallization ages indicate juvenile sources for the A1 and A2. The A3 rocks have $^{87}\text{Sr}/^{86}\text{Sr}_{(i)}$ ratio of 0.715, $\epsilon\text{Nd}_{(t)}$ value of +0.47 and T_{DM} age that is close to the crystallization age, indicating a source composition different to that of the other associations, whose origin remains under discussion. The Pb isotopic ratios of A1 and A2 are similar and compatible with the evolution of the mantle and orogen ($^{208}\text{Pb}/^{204}\text{Pb} = 37.3-37.6$; $^{207}\text{Pb}/^{204}\text{Pb} = 15.62-15.65$; $^{206}\text{Pb}/^{204}\text{Pb} = 18.0-18.2$). The Pb isotopic ratios of A3 differ from A1 and A2, indicating a source that was poorer in Th ($^{208}\text{Pb}/^{204}\text{Pb} = 37.1$; $^{207}\text{Pb}/^{204}\text{Pb} = 15.64$; $^{206}\text{Pb}/^{204}\text{Pb} = 18.5$). The geochemistry of A1 and A2 suggest a juvenile source with contamination by crustal material. However, the Sr-Nd-Pb isotopic signature of this crustal material is similar to the source material that originates these associations and that may be the crust generated in the magmatic arc, which is compatible with the geochronological results. The dataset points to the occurrence of self-cannibalism processes in the generation of the ARC rocks. Although subduction plate melting processes are commonly accepted mechanisms for the generation of TTG associations, the major and trace element geochemical data and the isotopic data obtained in this study suggest that melting of metasomatized mantle (E-MORB type) as the source for the generation of the ARC rocks. In this case, the generation of rock associations with typical TTG characteristics (*i.e.*, the depletion of HREE) may have arisen from the melting of a garnet-lherzolite-type mantle, which is also indicated by the contemporary relationships with basic to intermediate magmas. The three associations display microstructures that indicate two episodes of recrystallization, one of a higher (Paleoproterozoic metamorphic event?) temperature and one of a lower temperature. The last is compatible with the temperature conditions observed in the host rocks of the Neoproterozoic post-collisional granitoids that have been emplaced along the Southern Brazilian Shear Belt (SBSB). Zircon crystals with Paleoproterozoic igneous core exhibit a metamorphic overgrowth at 635±6 Ma, compatible with the crystallization ages of the SBSB granitoids.



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In situ U-Pb dating and Hf isotope geochemistry of zircons from granites of the Costeiro Domain, SE Brazil: timing and source contrasts with neighboring terranes of the Ribeira Belt
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New in situ U-Pb (Shrimp and LA-ICPMS) zircon age determinations carried out in the Ubatuba Charnockite (582.4±4.8 Ma), Ilhabela Granite (573.5±3.6 Ma) and Alcatrazes Granite (568.8±3.4 Ma) are within the range of the main period of high-K calc-alkaline granitic magmatism in the Costeiro Domain of the Ribeira Belt, SE Brazil. This is also the timespan when some large batholiths were emplaced in this domain; examples are the Natividade da Serra Batholith (dominated by peraluminous leucogranites; 587±7 Ma; Janasi et al. 2003, *Geologia USP* 3:13-24) and the Pico do Papagaio Batholith (579±2 Ma; Meira et al, 2014, IX South American Symposium on Isotope Geology, Brazil). Therefore, a large amount and variety of granite magmas was generated in the Costeiro Domain during the “Rio Doce orogeny” (590-565 Ma; Campos Neto & Figueiredo 1995, *J South Amer Earth Sci* 8:143-162). This time range is slightly younger than observed for peak granitic magmatism in the Ribeira Belt immediately to the NW (the Embu Terrane and São Roque Domain; ~605-580 Ma).

Shrimp U-Pb zircon ages of the Santos and Guarujá stocks (respectively, 497.3±7.0 Ma and 496.9±6.6 Ma) indicate that they are related to the extensive belt of Cambrian bimodal (granite-diorite) magmatism that developed throughout the Atlantic coast of east Brazil. This event occurred at least 60 Ma later than post-orogenic magmatism in the northwestern domains of the Southern Ribeira Belt (the 590-560 Ma Itu Granitic Province, Janasi et al. 2009, *Can Min* 47:1505-1526). Zircon εHf(t) varies between 0 and -11 in the dated samples, with the two younger granites showing the lowest range of values; the data also suggest a SE-NW shift (perpendicular to the main structural trend) with decreasing εHf(t) from Alcatrazes (0 to -4) to Santos (-5 to -11). These slightly negative zircon εHf(t) indicate that all studied granites have sources with shorter crust residence times when compared to neighboring terranes (e.g., Hf T_{DM} = 1.5-2.1 Ga versus 2.1-3.0 Ga in São Roque and Embu). Our new data, taken together with the Nd isotope signatures of other granites from the Costeiro Domain, and with information from detrital zircons of supracrustal sequences (both indicative of the predominance of mesoproterozoic crust residence ages), confirms correlation with the Oriental Terrane (Heilbron et al.2004. *J Virtual Explorer* 17, Paper 4). Therefore, the Costeiro Domain is interpreted as an accretion margin terrain which began to develop at least since 790 Ma, and marks the closure of an oceanic space between the Neoproterozoic São Francisco and Congo-Angola paleoplates.

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Low- $\delta^{18}\text{O}$ shallow-level Neoproterozoic A-type granites from the Florianópolis Batholith, south Brazil

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Large portions of the extensive Florianópolis Batholith in south Brazil are dominated by post-orogenic ~590 Ma A-type granites emplaced at shallow crustal levels. Several distinct granite units (e.g., Ilha, Vila da Penha, Serra do Tabuleiro, Cambirela) are recognized from their mineralogical and textural features, but all share some key geochemical characteristics, in particular a strongly fractionated character, as indicated by very high SiO_2 (75-78%), low MgO (<0.10%), Sr (usually < 50 ppm) and high Rb/Sr (3-9, but up to 180). Such high-silica compositions require the operation of low-pressure evolution processes, either fractionation in shallow magma chambers or partial melting at upper crust. Absence or rarity of enclaves is another remarkable feature common to many of these granitic suites.

A pioneering study of in situ oxygen isotope determinations by SIMS in zircons from representative samples of the main A-type granite suites from the batholith reveals a wide range of $\delta^{18}\text{O}_{\text{VSMOW}}$ (+7.3 to +3.4‰). Intra-sample variations are often wider than typical uncertainties in individual analyses ($\pm 0.2\%$), revealing the presence of zircon crystals and/or zones crystallized from distinct melts, i.e., reflecting open-system processes as magma mixing or contamination. An extreme case is an ignimbrite sample from the Cambirela suite at the Matadeiro Beach in Florianópolis, with a bimodal population of low (+3.4 \pm 0.4‰) and high (+6.9 \pm 0.2‰) $\delta^{18}\text{O}$ zircon crystals, suggestive of co-eruption of two acidic melts.

Of particular significance for the petrogenesis of the batholith is the identification of granites with low $\delta^{18}\text{O}$ zircon (e.g., Ilha Granite sample REF-04U: +3.5‰). Such sub-mantle values are interpreted in the literature as indicative of shallow-level remelting of hydrothermally altered crustal material, for example in the Yellowstone rhyolites.

Taken together with other evidence (e.g., similar weakly negative $\epsilon\text{Nd}(t)$; major and trace-element modeling), our results indicate that the Florianópolis A-type granites are products of shallow-level melting of recently crystallized, in part hydrothermally altered, calc-alkaline granites that may form the bulk of the deeper portions of the batholith.



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Contrasting sources of basaltic pre-collisional syn-sedimentary igneous activity in the Kaoko Belt of NW Namibia

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Pre-collisional (now metamorphosed) sedimentary rocks of the Kaoko Belt in NW Namibia contain bodies of two temporally and compositionally distinct metavolcanic suites.

The **older suite** (c. 800 Ma) comes from the Coastal Terrane, i.e. the westernmost exposed unit of the Kaoko Belt. It is bimodal (basalt–rhyolite; SiO₂ = 46.2–76.4 wt. %) and characterized by (normal-K) calc-alkaline chemistry. The NMORB-normalized spiderplots (Sun & McDonough, 1989) are characterized by strong enrichment of LILE over HFSE, with deep troughs for Ta, Nb and Ti (“TNT anomaly”), thus resembling patterns of subduction-related magmas. The ϵ^{Nd}_{800} values are positive (mafic: +6.0 to +4.1, felsic: +4.3 to +2.7), resulting in low single-stage depleted-mantle Nd model ages (Liew & Hofmann, 1988; T^{Nd}_{DM}) of 0.97–1.18 Ga.

The **younger suite** (c. 740–710 Ma) of tholeiitic basalts (SiO₂ = 46.5–51.8 wt. %) forms a part of an original sedimentary sequence deposited on the Congo Craton crystalline basement. The NMORB-normalized spiderplots show a degree of LILE enrichment comparable to the older suite but lack the TNT-type depletions. The ϵ^{Nd}_{740} values are also exclusively positive (+6.6 to +0.7; T^{Nd}_{DM} = 0.92–1.76 Ga), showing a strong positive correlation with Zr/Nb in addition.

The older suite present in the Coastal Terrane is interpreted as having originated from subduction-modified mantle-wedge. As the geological evidence points to general rift-related setting at the time of intrusion, the subduction modification probably had taken place before, albeit the maximal age of this event could have not been greater than c. 1.0–1.2 Ga as indicated by the Nd model ages. This is an age of the Namaqua Metamorphic Complex (NMC) exposed along the western edge of the Kalahari Craton in southern Namibia and interpreted by Becker et al. (2006) as a part of the late Mesoproterozoic active margin. We speculate that the Coastal Terrane may have developed as a rift structure floored by the northerly continuation of the NMC along the western edge of the Congo Craton.

On the other hand, the younger suite within the sedimentary cover of the stable Congo Craton (THS) is clearly rift-related, and its chemistry most likely reflects the generation from a heterogeneous mantle that contained variable proportions of strongly depleted and bulk-Earth like domains, the latter most likely forming a part of the local subcontinental cratonic lithosphere.

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Remobilization and localized thermal overturn of a stratified, partly crystallized magma chamber – the story of the reversely zoned Říčany intrusion (Bohemian Massif)

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Many circular to elliptical granitic plutons exhibit remarkable concentric compositional and textural zoning. Of particular interest are those with reverse zoning, with the more felsic/ evolved facies occurring along pluton margins and mafic/less evolved rocks in the centre. It has been demonstrated that these plutons may record complex histories of deeper horizontally stratified, multiply replenished magma chambers (e.g., Fridrich & Mahood, 1984). The early Carboniferous (c. 337 Ma) Říčany Pluton (Central Bohemian Plutonic Complex), consists of two coeval, nested Bt (–Mu) granite facies: outer, strongly porphyritic (SPm) and inner, weakly porphyritic one (WPc). Gravity data indicate that the nested pluton is only a small outcrop of a large anvil-like body at depth with a feeder channel reaching > 14 km below the present-day surface. The two main granite facies share nearly identical modal composition and are both geochemically evolved. Their contact is concealed but probably gradational over several hundreds of metres. Mafic microgranular enclaves, commonly associated with K-feldspar phenocryst patches, are abundant in the pluton centre (WPc), suggesting repeated input of enriched mantle-derived melts ($\epsilon^{Nd}_{337} < -8.5$, $^{87}Sr/^{86}Sr_{337} \sim 0.710$) as well as their multistage interaction with granitic magmas and nearly solidified cumulates. The pluton is interesting in that it is doubly reversely zoned. On the pluton scale, the outer SPm is geochemically more evolved than the inner WPc. On the scale of individual units, outward whole-rock geochemical variations within each facies are compatible with fractional crystallization dominated by K-feldspar. Both types of zoning are cryptic, manifested by variations in the trace- and minor-element compositions (inward increase in Ba, Sr, Zr, Th, Ti and P) rather than in major elements or gross petrography. The proposed genetic model invokes vertical overturn of a deeper, horizontally stratified anvil-shaped magma chamber, and helical flow of magma to higher crustal levels. The energy for melt remobilization and extraction from the Kfs-rich crystal mush and for its subsequent ascent is thought to have been provided by a long-lived thermal anomaly above the pluton feeding zone, enhanced by multiple injections of hot basic magmas. In general, it is concluded that the 3D shape of the granitic bodies exerts first-order control on their cooling histories and thus also on their physico-chemical evolution. Thicker and longer lived portions of magma chambers are sites for extensive fractionation and potentially vigorous interaction with basic magmas. These hot domains are then prone to rejuvenation and subsequent extraction of mobile magma leading potentially to volcanic eruptions.

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Metasedimentary melting in the formation of charnockite: the Darongshan S-type granitic complex in southern China

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Charnockites are Opx-bearing igneous rocks commonly found in high-grade metamorphic terranes. However, their association with typical S-type cordierite-bearing granites is less well-known. The Darongshan S-type granitic complex (DSGC) in South China contains granites varying in mafic silicate mineral assemblages from Bt + Crd (Darongshan suite) to Opx + Grt + Bt + Crd (Jiuzhou suite) and Opx + Crd ± Bt (Taima suite), corresponding to a geochemical transition from magnesian calc-alkalic to ferroan calc-alkalic. However, the genesis and emplacement ages of these granites within the DSGC remains highly contentious. In order to understand genesis of the Jiuzhou and Taima charnockites and their genetic relationship with Darongshan S-type granite, here we firstly determined zircon and monazite U-(Th-)Pb ages of each suite using Cameca 1280 SIMS. Both zircon and monazite U-(Th-)Pb ages show that all suites of the complex were emplaced contemporaneously at ca. 249 Ma. Further in-situ zircon Hf-O isotope analyses reveal that the granitic complex was dominantly derived from metasedimentary rocks (zircon $\delta^{18}\text{O} \approx 11\%$, $\epsilon_{\text{Hf}}(t) \approx -10$), with rare material input from the mantle, consistent with their reduced nature ($\Delta \log \text{FMQ} \leq 0$; Mn-in-apatite oxybarometer). The variation in zircon $\delta^{18}\text{O}$ (7.8 to 12.9‰) is more likely a result of hybridization, whereas that in zircon $\epsilon_{\text{Hf}}(t)$ (-31.9 to -1.8) is a result of both hybridization and disequilibrium melting. The DSGC generally exhibits higher zircon saturation temperature than the coeval I- and S-type granites in South China. Heat input from mantle through basaltic intrusion/underplating is considered to contribute high-temperature (>850 °C) melting at mid-crustal levels (i.e. the Crd stable field) for generation of the granitic complex. We interpret that the DSGC S-type granites and charnockites were intruded in a back-arc setting, and basaltic magmatism was directly associated with slab tearing and roll-back during the latest Permian and early Triassic time.



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**BIMODAL MAGMATISM OF THE TUCUMÃ AREA, CARAJÁS PROVINCE:
AGE, CLASSIFICATION AND PROCESSES**

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Geological mapping of the Tucumã area has enabled the identification of dike swarms intruded into an Archean basement. The disposition of these dikes is consistent with the regional NW-SE trend, and can reach up to 20 kilometers in length. They were divided into three main groups: (i) felsic dikes (70% of the dikes), composed exclusively of porphyritic rhyolites with euhedral phenocrysts of quartz and feldspars immersed in an aphyric felsite matrix; (ii) mafic dikes, with restricted occurrence, composed primarily of basaltic andesites and secondarily of basalts, with a mineralogical assembly consisting of plagioclase, clinopyroxene, orthopyroxene and olivine; and (iii) intermediate rocks, represented by andesites and dacites. Dacitic rocks are found in outcrops associated with felsic dikes, showing different degrees of hybridization or a mixture of mafic and felsic magmas. This is evidenced by a large number of mafic enclaves in the felsic dikes and the frequent presence of embayment textures. SHRIMP U-Pb zircon dating of felsic dikes yielded an age of 1888 ± 3.3 Ma. The felsic dikes are peraluminous to slightly metaluminous and characterized as akin to A2, ferrous and reduced granites. The intermediate and mafic dikes are metaluminous and belong to the tholeiitic series. Geochemical modeling showed that mafic rocks evolved by pyroxene and plagioclase crystallization, while K-feldspar and biotite are the fractionate phases in felsic magma. A simple binary mixture model was used to determine the origin of intermediate rocks, demonstrating that mixing 60% rhyolite and 40% basaltic andesite melts generated the dacitic composition, while the andesite liquid could be produced by mixing 60% and 40% basaltic andesite and rhyolite melts, respectively. The results suggested that mixing of basaltic and andesitic magmas occurred during ascent and storage in the crust, where andesitic dikes are likely produced by a more homogeneous mixture at high depths in the continental crust (mixing), while dacite dikes can be generated in the upper crust at a lower temperature, providing a less efficient mixing process (mingling). The affinities observed between the felsic dikes and the A-type granites of the Rio Maria and São Felix do Xingu regions demonstrate that bimodal magmatism in the Tucumã area is clear evidence that the Paleoproterozoic magmatism of the Carajás Province was formed by processes involving thermal perturbations in the upper mantle, mafic underplating, and associated crustal extension or transtension.

Keywords: Dikes, Bimodal magmatism, Paleoproterozoic, Carajás Province.



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Magmatic garnets in Cordilleran-type granitoids: evidence for crystallization in the lower crust.

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The Galiléia batholith (ca. 30000 km²), located in the westernmost part of the Araçuaí Orogen (Brazil), is a Neoproterozoic (600 – 575 Ma) weakly to moderately foliated calc-alkaline metaluminous (ASI 0.97 – 1.07) granite characterized by the widespread occurrence of both garnet and epidote. Garnets form 1 to 6 mm diameter skeletal and euhedral crystals, and although absent in some rocks, they are widespread in the host granite reaching up to 5 %. Occasionally they occur in the mafic enclaves as well. The lack of a pervasive well-defined foliation in the rock, the occurrence of garnet inclusions hosted within cm-sized alkali-feldspar in porphyric phases of the batholith, as well as the fact that mineral inclusions in garnet constitutes the same assemblage that occurs in the matrix of the granite, supports a magmatic origin for these crystals. In addition, a variety of resorption textures indicates that garnet crystals experienced periods of disequilibrium with the granitic melt. Garnets are exceptionally high in grossular (24 - 43 mol %) and spessartine (9 - 19 mol %), very low in pyrope (< 7 mol %), and are unzoned. Moreover, grossular content does not vary with respect to CaO, Y_N and (La/Yb)_N whole rock variability. Other minerals are reabsorbed epidotes usually rimming allanites, and having low (9 – 23 mol %) Ps ([Pistacite: Fe³⁺/(Fe³⁺+Al)*100]) content, rare zoisite (FeO_{tot} < 2 wt %) inclusions in garnets and white micas, chemically similar to low Si-phengites (Si ≈ 3.2 a.f.u.). As revealed by the experiments on metaluminous systems, the presence of garnet+epidote/zoisite+white mica supports granite crystallization above 0.8 GPa. Considering this high-pressure mineralogical assemblage, combined with pressure estimates for the metamorphism of the intruded metasedimentary rock (medium amphibolite-facies, ca. 0.6 GPa), we propose a “two-stage crystallization model” for the Galiléia granitoids. Firstly, they started crystallizing in the lower crust, in an already thickened continental crust, at possibly 0.8 – 1.0 GPa (ca. 24 - 30 km), according to white mica geobarometry. Then, in agreement with resorbed garnets and pressure estimates from the country rocks, the granite reach the depth of final emplacement at 0.6 – 0.7 GPa. Furthermore, since epidotes are a last-stage phase and their resorbed textures are similar to experiments for epidote dissolution kinetics in granitic magmas, this may suggest that this last step was fast (< 10³ years), enough also for garnet preservation. Where garnets lack, different and plausible slow intrusion rates are supposedly involved. Finally, the most striking characteristic of the Galiléia garnets is their high-grossular content. Geochemically, they are similar if not identical to other magmatic garnets reported from small metaluminous granitic bodies in Alaska and China. Here, we have the great and quite rare possibility to study these high-grossular magmatic garnets and in turn, their metaluminous granitoid hosts, that until now have never been studied in detail.

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The Hf features of the Southern São Francisco Craton basement: a detrital zircon record view
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The basement of the Archaean southern São Francisco Craton (SSFC) is characterized by large granite gneiss domes. The tectonomagmatic evolution of these domes is suggested to involve three phases of magmatism: 1) the Santa Bárbara event (SB; 3.22 to 3.2 Ga); 2) Rio das Velhas I (RVI; 2.93 to 2.9 Ga); and Rio das Velhas II (RVII; 2.8 to 2.77 Ga) events [1]. The domes are mostly TTG gneisses and were intruded by later granitoids, the Mamona event [3], that resulted in the thermal stabilization of the crust [2]. The basement is in direct contact with the Rio das Velhas greenstone belt, the final sequence of which is a clastic deposit described as a flysch to malasse basin deposit called the Maquiné Group [4]. As the last sequence of the greenstone belt, it is very likely that the Maquiné Group rocks contain the whole zircon record of the underlying crystalline complexes and volcanic rocks. Thus, the Maquiné Group becomes the key to understanding the history of the southern São Francisco Craton.

U-Pb and Lu-Hf isotope analysis of zircons from the Maquine Group provide evidence of the three main periods of magmatism described above as well as older, now eroded crust. The range of zircon ages goes from 2.7 to 3.9 Ga. This interval suggests a protracted evolution of crustal development and highlights the importance of the Maquiné basin for preserving this long record of crustal evolution. Moreover, the verification of the magmatic events in the detrital spectra suggests that the Palaeoarchaean TTG crust has been continuously reworked and eroded through time.

Zircons older than 3.0 Ga yield mainly subchondritic ϵ_{Hf} values between -4.1 and +3.0 and model ages (T_{DM}) between 4.03 and 3.08 Ga. Neoarchaean zircons formed between 3.0 and 2.7 Ga and yield a larger range of ϵ_{Hf} values (-7.6 and +3.0) and smaller range of T_{DM} ages (between 3.51 and 2.87 Ga). Thus, the dispersion of ϵ_{Hf} values increases, becoming more negative the younger the zircons are. Positive values for ϵ_{Hf} , reaching up to +3.0 support the idea that magmas were partially juvenile and incorporated a significant amount of reworked material. The values corresponding to RV I and II events are substantially more negative than older magmatic events such as the Santa Barbara, suggesting that crustal reworking magmatism was already present in the Paleoproterozoic and increased towards the Neoarchaean. These Hf features are in agreement with the reworking process of continental crust models [5, 6] and illustrate a crust and mantle mixing process. Our U-Pb-Hf dataset supports the interpretation of a long-lived evolution for the southern Sao Francisco Craton through a succession of magmatic arcs in the Archaean.

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[6] Cawood *et al.*, 2013. *Geo. Soc. Ame.Bul.* **125** p14-32



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Petrogenesis of the Liangcheng S-type granites in the eastern part of the Khondalite Belt, North China Craton

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Restite unmixing, peritectic assemblage entrainment, and magma mixing are dominant mechanisms to be proposed to account for the chemical variation of the S-type granites [1]. A large volume of garnet granites are parautochthonous S-type granites developed within granulite-facies metasedimentary rocks in the Liangcheng area, eastern part of the Khondalite Belt, North China Craton. Small coeval gabbroic intrusions are widely distributed in the metasedimentary rocks and S-type granites, and are thought to have not only provided heat for the crustal anatexis and local ultra-high temperature metamorphism, but also added material to the S-type granites [2]. The close relationship with granulite-facies metasedimentary rocks and mafic rocks makes the Liangcheng S-type granites a favorable case to scrutinize the operation of these possible processes.

The Liangcheng S-type granites consist mainly of garnet, orthopyroxene, biotite, plagioclase, K-feldspar, and quartz. Garnets constitute 5-20% of the S-type granites, and locally occur as aggregates. The presence of orthopyroxene implies that the Liangcheng S-type granites are high temperature granites, which is also supported by low Al_2O_3/TiO_2 ratios and high calculated Zr saturation temperature (ca. 825-901 °C). Thus, they were suggested to be formed by fluid-absent biotite melting of metasedimentary rocks.

The Liangcheng S-type granites are strongly peraluminous with $A/CNK=1.1-1.6$. They are characterized by large variations in major and trace element compositions with SiO_2 of 58-70 wt%, $FeO+MgO$ of 5.6-14.4 wt%, and REE of 270-554 ppm. Major element modelling suggests that addition of 20-40% garnetites (restite) and gabbro to anatectic melts was responsible for the large chemical variations of the S-type granites. Based on the petrographic and trace element characteristics, most garnets in the S-type granites were inferred to be of peritectic origin, indicating peritectic garnet entrainment during the formation of the S-type granites. Interaction with mafic rocks is suggested by mafic microgranular enclaves (MME), synplutonic dykes, and garnet-biotite rinds around the MME in the S-type granites. Garnet-biotite rinds have been formed by the chemical reaction between mafic enclaves and granitic magma, and then may have been flushed away by magmatic flow, thereby contributing ferromagnesian component to the granitic magma. This scenario is also supported by garnetites formed between gabbroic sills and metapelites.

Field, petrographic and geochemical evidence from the Liangcheng S-type granites suggests that restite unmixing, magma mixing, chemical reaction between MME and anatectic melts probably operated together to produce the S-type granites.

[1] Clemens & Stevens (2012) *Lithos* **134-135**, 317-329

[2] Peng *et al* (2012) *PR* **222-223**, 107-123



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PT.057

Mantle metasomatism by deeply-subducted continental crust: Evidence from zircon hafnium and oxygen isotopes of alkaline rocks

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Mantle metasomatism commonly induces enrichment of the subcontinental lithospheric mantle (SCLM) in incompatible trace elements, and changes its isotopic compositions, which is the main cause of SCLM heterogeneity. Metasomatism of subducted oceanic crust is interpreted as the petrogenesis of island arc volcanic rocks, and is well studied. However, it is little known about the metasomatism of SCLM by recycled continental crust. Alkaline rock is generally derived from small-degree partial melting of the SCLM at high pressures, which is a window to probe into the effect of metasomatism in the SCLM. Hafnium and oxygen isotopes of zircon have been proven to be a powerful tool for elucidating the magma source and petrogenetic process. Here we report zircon U-Pb ages and Hf-O isotopic compositions, as well as whole rock geochemical data, of Triassic alkaline rocks in the eastern North China Craton (NCC), to trace the nature of metasomatic agents and constrain geodynamic evolution of the eastern NCC during Early Mesozoic. Early Mesozoic alkaline rocks are widespread in the northern NCC. The Saima alkaline complex and Hekanzi pluton are located in the Liaodong Peninsula and western Liaoning province, separated by the Tan-Lu Fault Zone. The Saima complex mainly consists of nepheline syenite and quartz-bearing syenites, with alkaline volcanic rocks, whereas the Hekanzi pluton is mainly composed of nepheline syenites. Detailed zircon U-Pb dating shows the ages of Saima alkaline rocks are 230-224 Ma, consist with that of the Hekanzi pluton (224-226 Ma). Geochemical characteristics show that the alkaline rocks were mainly derived from small degree partial melting of an ancient, refractory lithospheric mantle that had been re-enriched by metasomatism prior to Triassic. However, the Hekanzi alkaline rocks have zircon $\epsilon_{\text{Hf}}(t)$ values of -2.5 to +0.6 and $\delta^{18}\text{O}$ values of +3.1‰ to +5.3‰, distinct from the Saima alkaline rocks that have extremely negative zircon $\epsilon_{\text{Hf}}(t)$ values of -11 to -13 and elevated $\delta^{18}\text{O}$ values of +6‰ to +8‰. Coupled with the fast homogenization of oxygen isotopes at high temperatures in the mantle environments, these data reflect that the SCLM beneath the two regions had experienced different metasomatism a short time prior to Triassic. Given the SCLM with $\epsilon_{\text{Hf}}(t)$ values of about -5 and $\delta^{18}\text{O}$ values of +5.3‰ before metasomatism and coupled with the major tectonic processes in the eastern China during Late Paleozoic to Early Mesozoic, our data suggest that the source of the Hekanzi rocks had been metasomatized by fluids/melts originated from high-temperature altered subducted Paleo-Asian oceanic plate, whereas the source of the Saima alkaline rocks had experienced metasomatism by recycled continental crust-derived melts/fluids. Importantly, the identification of recycled continental crustal materials in the SCLM shows that the mantle beneath this region was metasomatized by deeply-subducted Yangtze continental crust during Early Triassic.



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The shape of the Nahuelbuta Batholith in an active continental margin (Central Chile)

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The Nahuelbuta Batholith is part of Coastal Batholith that invaded the Metamorphic Complex of the Eastern Series by the Upper Carboniferous (Pennsylvanian) during the Gondwanan Cycle. The Eastern and the Western Series are turbiditic sequences deposited during the Mississippian and belong to the same tectonic cycle. Regional metamorphism at 400°C in the Eastern Series was followed by contact metamorphism. The intrusion depth was 0.45 GPa and the sillimanite without K-feldspar in the metapelitic contact aureole indicate that the temperature was lower than 720°C. The Nahuelbuta batholith has a major N-S extension and covers a 4800 km² surface. The intrusive rocks are tonalites to monzogranites, with minor diorites and gabbros. Plagioclase, quartz, biotite, amphibole and alkaline feldspar are the main rock forming-minerals. Accessory minerals include magmatic epidote, allanite, zircon, apatite and locally garnet and muscovite. Magnetite is notably absent. The felsic igneous rocks are predominantly coarse grained and equigranular. The microstructures indicate that most of the igneous rocks were deformed by magmatic flow with a minor high-temperature solid-state overprint deformation like myrmekites. In the northern parts of the contact aureole develops a N-S striking mylonites zone with a steep to moderate inclination towards the east. A within dip stretching lineation indicates reverse sense of shear. The magmatic foliation shows an overprint of high to low temperature solid-state fabrics. Anisotropy of magnetic susceptibility was applied for the foliations and lineations and parameters in the igneous rocks. The bulk magnetic susceptibility (κ) of less than $610 \cdot 10^{-6}$ SI denotes that the igneous rocks are paramagnetic, controlled by biotite, epidote and amphibole that are more frequent in the diorites and tonalites which appear at the margin. Those values are unrelated to the outcrop shape of the batholith which is an indication that it is a plutonic complex. The degree in corrected anisotropy (P') varies between 1.00 and 1.08. The shape parameter of the susceptibility ellipsoid (T) shows dominantly oblate values. The rather steep magmatic foliation is an indication that the igneous rocks have a wedge shape. This intrusion shape is more common at active margins with a steep shear zone. For the volume we applied the formula that was given by Petford et al. (2000) for a flat-shaped intrusion. The result indicates that the igneous complex has a 5 km thickness, which is the minimum value for a wedge shaped intrusion. The average rate of pluton construction is in the range of 10^{-1} to 10^{-4} km³/yr (Saint Blanquat et al. 2011). In the Nahuelbuta case, the age dating indicates that this batholith was emplaced in ~10 Ma, which results in a construction rate of $2.4 \cdot 10^{-3}$ km³/yr. This rate is independent from the tectonic regime.

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PT.059

Geochemistry and setting of the Stavely Arc, western Victoria, Australia

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Several belts of poorly-exposed, Cambrian igneous rocks occur in the Grampians-Stavely Zone of western Victoria, close to the interpreted east Gondwana continental margin. Although the Cambrian igneous rocks outcrop sporadically, most belts are covered by recent sediments and are only visible in regional magnetic data. Deep seismic reflection data suggest that the igneous belts are part of a largely intact magmatic arc edifice, referred to as the Stavely Arc, with the exposed rocks interpreted as thrust slices of the underlying arc system. The setting for these rocks has variously been interpreted as an evolved island arc, Andean-style continental arc, or post-orogenic rift-related magmatism. Stratigraphic drilling was undertaken in 2014 to better delineate and understand the nature and extent of this arc, its temporal and geochemical evolution, and to identify potential associated mineral systems.

Volcanic rocks are dominantly intermediate to felsic, and exhibit geochemical features typical of those found in magmatic arcs. The majority of samples are low- to medium-K, with SiO₂ contents of 55-77% (typically 57-66%), 0.38-0.97% TiO₂, and Mg# typically ~35-64. A second group of low- to medium-K rocks (53-65% SiO₂) is characterised by lower TiO₂ (<0.33%) and higher MgO (>5.3%) and Mg# (~54-67). A third group with higher SiO₂ contents (66-71%) is dominantly medium-K, and is notable as being considerably more enriched than the other groups. SHRIMP U-Pb zircon ages are only available for the first group, and cluster around 505-500 Ma, with evidence for some inheritance of ~570 Ma zircons.

Intrusive rocks are volumetrically subordinate to the volcanics, and range from diorite to granite. In general, intrusive rocks show geochemical similarities with the volcanic rocks, suggesting a shared origin. Available geochronological data show that these intrusives are dominantly syn- to immediately post-volcanism (~505-498 Ma). The earliest dated intrusives (511 Ma) occur along thrust slices against the volcanics, are siliceous (~78% SiO₂), yet have elevated MgO, Mg# (75-80), and Ni. A number of dacitic porphyries are known in the southern Stavely Arc, some of which are mineralised. SHRIMP U-Pb zircon ages for these porphyries define an age range of between 506-501 Ma. These porphyries show some geochemical similarities with felsic post-tectonic granodiorite. The porphyries are low-K and have elevated Al₂O₃, Mg#, Ni and Sr, and lower total FeO at equivalent SiO₂ levels relative to the volcanic rocks.

The available data indicate that the volcanic rocks become relatively more enriched in incompatible elements to the west, progressively inboard of the interpreted volcanic front. This is similar to the *K-h* relationship observed in many modern arcs, and helps to constrain the original geometry of the Stavely Arc system and a west-dipping subduction polarity between at least ~511-500 Ma. Overall geochemical systematics suggest that the Stavely Arc has affinities with modern island arcs with some continental influence. Despite its proximity to Proterozoic crust and evidence for older inherited zircons, the effect of continental crust on the geochemistry of the Stavely Arc appears to be limited, suggesting that models invoking a purely Andean-style margin are too simplistic.



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PT.060

Unraveling granitic magma generation in time and space within a confined orogenic setting (Araçuaí orogen, SE Brazil)

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The Araçuaí orogen (SE Brazil) and the West Congo belt (SW Africa) are counterparts of a confined orogenic system evolved within an embayment (an inland–sea basin) carved into the São Francisco–Congo paleocontinent in Neoproterozoic time. In apparent disagreement with such a peculiar geotectonic setting (that, at first sight, would suggest an exclusively ensialic evolution), the Araçuaí orogen includes ophiolite slivers and a calc-alkaline volcanic arc, as well as a huge amount of collisional and post-collisional granites. Based on robust analytical and field databases, we address the 150 Ma-long, multistage, granite generation history recorded by the Araçuaí orogen, discussing possible heat sources related to the distinct episodes of granite production. During the subduction stage of oceanic lithosphere, a succession of mostly medium- to high-K calc-alkaline plutons (G1 supersuite) formed the Rio Doce magmatic on the eastern (upper) continental plate margin of the orogen. The Rio Doce arc seems to record three evolution phases: i) eastward migration of the arc front (630–605 Ma), ii) widespread non-zoned magma production through the whole arc (605–585 Ma) and, iii) late I-type plutonism marking the pre-collision to collision transition (585–575 Ma). These phases may be explained by usual processes of volcanic arc generation and growth, like subduction of oceanic lithosphere under a continental margin, followed by asthenosphere ascent related to slab retreating and break-off. The oldest S-type granites started to form in the pre-collision to collision transition. The main fertile sources that generated the collisional S-type granites (G2 supersuite) are Al-rich paragneisses, most of them found in the eastern and northeastern sectors of the Araçuaí orogen. Progressive anatexis and melt accumulation attained the climax from ca. 575 Ma to ca. 560 Ma, leading to the development of giant batholiths composed of peraluminous granites. The youngest collisional granites have been dated around 545 Ma. The regional thermal anomaly lasted longer than the main compressional stresses, causing a late re-melting episode on G2 granites and triggering the formation of new peraluminous magma batches (the G3 leucogranites, ca. 545-520 Ma). After this period, the compressional (tangential) stresses stopped, giving place to the post-collisional stage related to the gravitational collapse of the orogen, when a myriad of balloon-shaped plutons intruded the regional rocks along major crustal discontinuities (the S-type G4, and the I-type to A2-type G5 supersuites). G5 plutons (525-480 Ma) show clear evidence of magma mixing processes, involving mantle magmas and crustal melts. This long lasting history of generation of collisional and post-collisional granites requires distinct heat sources, such as the late subduction of an ocean ridge segment, thrust stacking of the hot arc onto the back-arc, radiogenic heat release from the collisional thickened crust and, finally, asthenosphere upwelling during the gravitational collapse of the Araçuaí orogen.



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PT.061

Magnetic susceptibility and strain mechanisms of the albite-enriched facies of Madeira A-type Granite, Pitinga Mineral Province, Amazon Craton, Brazil.

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The albite-enriched granite is the latter facies of the A-type Madeira granite, which is a special Orosirian pulse of the anorogenic magmatic event with alkaline affinity and its crustal emplacement has been briefly discussed. The objective of this study is to determine the model of accommodation of the albite-enriched granite combining anisotropy of magnetic susceptibility (AMS), shaped preferred orientation (SPO), optical microtextural and strain mechanisms analyses. The main compositional feature of the albite-enriched granite facies with a porphyritic texture is constant proportions of K-feldspar, albite and quartz. Feldspars have undergone deformation mainly by crystal plastic dynamic recrystallization, bulging limits, and mechanic twins respectively. Some elongate crystals of quartz have 3:1 axial ratio and solid-state deformation by undulose extinct, subgrain rotation and SPO with trend SW-NE. This facies is subdivided in two subfacies, the core albite granite (CAG) with cryolite, zircon, polyolithionite, annite, and riebeckite like minerals accessory, and the border albite granite (BAG) characterized by pervasive propylitic alteration process, fluorite and chlorite growth. The rock magnetism analyses revealed magnetic susceptibility $> 5\text{mSI}$ in the CAG, the saturation of isothermal magnetic remanence, occurred in 280 (10^{-3} Tesla). The thermomagnetic cycle is characterized by Morin transition (-160°C) and total saturation at Curie point (580°C). This magnetic parameters result of clusters of euhedral magnetite crystals, with homogeneous internal texture related with primary K-feldspar and fine albite crystals. Therefore, the magnetic petrofabric represents the early plutonic crystallization process during its emplacement in the crust. Nevertheless, low changes in the thermomagnetic curves and locally magnetite hosted in cleavage of annite crystals suggest mineralogical changes derived of metasomatic albitization in the albite-enriched granite. Whereas the rock magnetism data in the BAG showed paramagnetic susceptibility (0,51 mSI), the isothermal remanence and thermomagnetic loop noticed the presence of hematite. Microscopy study showed subhedral disperse crystals of hematite associated with fluorite and chlorite. Negative correlation of modal content between oxides, total mafic minerals and using the characteristic of Fe-oxides, suggest that magnetic fabric in this facies was influenced by late magmatic events. Thereby, the low anisotropy degree in the albite-enriched granite (1.02 to 1.04), the oblate-prolate shape of the AMS ellipsoids related with subvertical lineation and magnetic foliation (mass transport SW-NE) in BAG and CAG, characterize the magnetic fabric of those plutons that is compatible with the orientation of the mafic and quartz silicates (SPO). On this results, we suggest the following model for emplacement of the albite-enriched granite: i) the magnetic fabric was registered during crystallization processes in the CAG; ii) hydrothermal alteration is responsible by the hematization of magnetite and oxidation of the albite-rich granite observed in the lowest magnetic susceptibility magnitudes in the BAG, iii) the strain mechanisms of silicates are related with ductile regime revealed by the SPO; iv) despite the petrofabric was resulted of discrete magmatic pulses, the strain conditions non varied during the magmatism; v) the plutonic emplacement was controlled by non coaxial regional stress field.



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PT.062

Generating granites and rhyolites in the mid-Atlantic: Insights from elemental, isotopic, and geochronologic studies of Iceland's zircon

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Iceland's size and thick crust (to >30 km), as well as atypically abundant silicic magma ($\geq 10\%$ of erupted products), make it unique among oceanic islands. These characteristics have led to proposals that it provides an example of early stages of formation of permanent, low-density crust, perhaps mimicking initiation of the first such Hadean crust. To better understand Iceland's geological evolution, and silicic magma genesis in particular, we have undertaken a comprehensive study of zircon in >80 samples including modern stream sediments and eruption products and ancient volcanic, intrusive, and sedimentary rocks spanning the history of the island. We have determined trace element compositions of almost 2000 zircon grains and ages (*in situ* U-Pb & U-Th disequilibria) and oxygen and Hf isotopic compositions of ~1000 grains. Context for these studies is provided through petrographic and elemental and Nd-Hf-Pb isotopic studies of host rocks.

Findings to date include (e.g., Carley et al 2011 (Mineralogy & Petrology), 2014 (EPSL); Padilla et al 2013 (IAVCEI abst), 2014 (GSA abst)); Banik et al 2013 (IAVCEI abst), 2014 (AGU abst)):

- Ti concentrations in Icelandic zircons are high, typically ≥ 10 ppm, suggesting high-T crystallization; this is consistent with high Zr in whole-rocks and glasses and zircon saturation Ts that exceed 800-850°C
- Zircons are typically richer in middle and heavy REE (and Ti) and poorer in Hf than those from convergent margins, and higher in U than those from mid-ocean spreading centers. They are similar to zircons from incipient spreading centers that encroach onto continents (Afar region; uppermost Gulf of California)
- Very low $\delta^{18}\text{O}$, mostly 0-5 ‰ (mean 3 ‰), demonstrates that almost all magmas were derived in part from crust altered by high-T meteoric water; extreme values to <-10 ‰ for zircon from small intrusive phases suggest pure melting of intensely altered crust
- Despite cooling of Iceland's climate and resulting drop in $\delta^{18}\text{O}$ of meteoric waters, there is no secular trend toward lighter oxygen in silicic magmas
- U-Th ages of zircon from historic eruptions indicate storage and growth times that are measurable (thousands to tens of kyr) but shorter than those for arc volcanoes; U-Pb dating reveals sparse antecrysts at some centers hundreds of kyrs older than eruption ages
- Duration of silicic activity at individual central volcanoes can exceed two million years, longer than previously estimated
- Data for the 11-12 Ma Króksfjörður central volcano support suggestions that it erupted both typical Icelandic tholeiitic and calc-alkaline magma (e.g. Jónasson et al



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J Pet 1992, Willbold et al EPSL 2009); calc-alkaline lavas, much cooler and wetter than others in Iceland, were remarkably similar to those produced at modern subduction zones

- Variability in isotopic compositions of zircons and whole rocks indicates that silicic magmas are polygenetic, commonly with components from both coeval basalt and altered pre-existing crust
- Icelandic zircons differ dramatically in elemental and oxygen isotopic compositions from Hadean zircon, which are the only tangible record of that eon, and hence there is no evidence for a connection between magmatic processes in modern Iceland and those on earliest Earth



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PT.063

EARLY PALEOGENE MAGMATISM FROM THE NORTHERN ANDES: A RECORD OF SLAB MELTING AND INTRAPLATE MAGMATISM IN COLOMBIA?

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The Northern Andes has been related to complex processes of subduction-collision associate with the Caribbean Plate since the end of the Mesozoic, this scenario made possible the formation of a late Cretaceous-Paleogene magmatic arc along the Colombian Andes. Contemporary Late Paleocene-Early Eocene sedimentary sequences from Eastern Colombia record the presence of detrital and volcanic zircon populations with Paleogene ages, suggesting intraplate volcanic activity at 400 km from the collisional margin.

New U-Pb zircon ages from representative Paleogene plutonic rocks (tonalites and granodiorites) of the Western and Central Cordilleras of the Colombian Andes and from sedimentary successions of eastern Colombia shows that the entire magmatism was active from ~65 to 50 Ma.

Whole rock geochemistry of the intrusive rocks is typical of a volcanic arc setting with Nb and Ti negative anomalies and a high LREE/HREE ratio. Eu anomalies are absent, and the parameters used to identify adakites are present such as: Sr/Y >40, K₂O/Na₂O ~0.4, SiO₂ >56%, Al₂O₃ >15%, MgO <3%, Na₂O >3.5% and mg# ~50.

Initial Hf signatures from the plutonic rocks range from +1 to +7, whereas those from the Late Paleocene-Early Eocene sediments show two contrasting signatures: one is similar to the Paleogene plutons from the Central Cordillera (ϵ_{Hf_i} = +1.5 to +8), which suggests an input from western sources to the distal foreland basin by that time (Paleo-Eastern Cordillera). The second population records a highly negative Hf signature (ϵ_{Hf_i} = -0.6 to -14) which contrasts with the previous one, suggesting the presence of a new and *in-situ* intraplate magmatic focus possibly eroded and deposited within of the foreland basin, which was in a distal position of the continental margin.

Magmatism of this period is related to the flat subduction of an oceanic plateau-like crust under NW South America, which can cause partial melting of the downgoing oceanic slab due to an unusual high heat flow. Further interaction of these melts with peridotite during their ascent through the mantle wedge will form the adakite magmatism.

Intraplate magmatism is associated to adiabatic melting due to lithospheric extension or to a mantle plume, but none of these scenarios have been recognized during the Paleogene in eastern Colombia. Alternatively, we suggest that this intraplate magmatism is related to a distortion of the mantle isotherms due to a lithosphere folding. Melts produced by this process will be mingled with the lower crust as indicated by the crustal signature reflected in the Hf isotopes. The rise to the surface of these magmas and further emplacement could be throughout faults reactivated during the Cenozoic.



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Post-collisional rhyolitic systems associated with the Neoproterozoic Pelotas Batholith, Southern Brazil

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Neoproterozoic rhyolitic volcanic and subvolcanic systems in southernmost Brazil are correlated with intense acid magmatism linked to different petrotectonic associations of the Sul-Rio-Grandense Shield. A portion of this volcanism in the Dom Feliciano Belt is associated with the Pelotas Batholith, which resulted from magmatic episodes associated with the Ediacaran post-collisional evolution of southern Brazil. The rhyolitic systems are commonly associated with the most differentiated granite suite phases during the final stages of emplacement of the Pelotas Batholith. They are geographically associated with three domains of the batholith, which are typically parallel to NE-SW structures: the southwest, central and northeast domains. The southwest domain (Cerro Chato region) includes effusive and pyroclastic deposits that can be considered unique volcanic strictu sensu records in the Pelotas Batholith. The central domain contains several swarm of meter-to decameter-thick acid dykes with the dominant orientation to NW and NS (Piratini Dykes Swarm). The northeast domain presents acid subvolcanic rocks formally named as Ana Dias Rhyolite (ADR) and it consists of hypabyssal rocks that compose a shallow body and metric-thick dykes (NNE-SSW). LA-MC-ICP-MS data obtained from zircon indicate crystallization age of 581.9 ± 1.9 Ma for the Ana Dias Rhyolite, 557 ± 3 Ma for the Cerro Chato volcanic rocks and 550 Ma for the Piratini dykes. The geochemical data of all rhyolites exhibit characteristics that are similar to those of the granitic rocks of the Dom Feliciano Suite, which is considered the most differentiated granite suite phases during the final stages of emplacement of the Pelotas Batholith. These characteristics are point out by elevated SiO₂ and alkali concentrations, high FeO_t/FeO_t+MgO ratios and agpaite index; and low Al₂O₃, CaO, and MgO contents, which suggest the rhyolites as belonging to the alkaline to subalkaline series and a metaluminous to peralkaline character. The moderate contents of Zr, Rb, Y, Nb, and Ga and the relatively low Ba and Sr values are common in the acid magmas with alkaline affinity. The enrichment in more incompatible elements, in addition to the negative anomaly of Ba, the slight enrichment in Ce relative to adjacent elements, as well as the enrichment in K₂O and Rb relative to Nb, suggesting magmas derived from mantle sources enriched in incompatible elements with some crustal contamination. The volcanic and subvolcanic rhyolitic systems present geochemical characteristics that are consistent with those of A-type granitic magmas associated with the Late Neoproterozoic post-collision magmatism in the Sul-Rio-Grandense Shield, southernmost Brazil.



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Emplacement mechanisms and crystallization conditions of synkinematic Archean (2.75 Ga) granites from the Carajás Mineral Province, northern Brazil

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Tectono-thermal evolution of the Carajás Mineral Province is marked by the intrusion of 2.75 Ga synkinematic granites chemically comparable to the A-type and high-K calc-alkaline granites. These intrusions are named Estrela, Serra do Rabo and Igarapé Gelado. Other coeval massifs (eg. Planalto granite) studied by other colleagues belong to the same granitogenesis episode. These granites crosscut metabasites and banded iron formation previously metamorphosed under greenschist (chlorite zone). Along the contacts, metabasites present strong vertical foliation and amphibole-bearing veins in response to regional compressive stresses plus inflating (ballooning) of the magma chambers. Contact metamorphism of hornblende to pyroxene hornfels conditions would have increased the plastic behavior of the inner aureole creating a ductile envelope. Banded iron formations occurs as steep-dipping decameter-wide and kilometer-long that lenses that are concordant to the regional structures. The host rocks structures suggest that the emplacement of these synkinematic granites contributed to the development of a dome and keel architecture. Barometry based on chlorite of metabasites indicates emplacement pressures around 3 kbar. Estrela, Serra do Rabo and Igarapé Gelado granites have E-W elongated shape parallel to the regional structures. Igneous layering, subsolidus magmatic foliation and syn-emplacement mylonites are present in most these massifs. The presence of ferropargasite, ferrotschermakite, hastingsite, annite and ilmenite suggest low oxygen fugacity conditions during the crystallization of the 2.75 Ga granites from the Carajás Mineral Province. Sphene-bearing simplectites formed by the corrosion of amphibole and biotite point to flattening in the presence of residual melt. Some granites having graphic textures display sieve-textured amphibole. Granites are crosscut by quartzofeldspathic pegmatite veins having tube-shaped amphibole megacrysts. Both sieve-texture and tube-shaped amphibole megacrysts reflect high-level emplacement, volatiles releasing and undercooling crystallization conditions.



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PT.066

Geochronology (U-Pb, Ar/Ar) and tectonic setting of the peralkaline-shoshonitic magmatism of the Teixeira-Terra Nova Domain (Central Borborema Province, NE Brazil)

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Peralkaline and shoshonitic plutons and dikes form a distinct magmatic event intrusive in the Teixeira-Terra Nova structural domain of the Central Borborema Province (NE Brazil). The plutons vary from syenogranite to syenite (Teixeira, Triunfo) and include, in the peralkaline types, aegirine-augite and/or richterite as the main mafic silicates. Quartz-monzonite to monzogranite, sometimes with clinopyroxene (Uri pluton) but usually with biotite and Fe-hastingsite, form the main occurrences of the shoshonitic magmatism. Mafic stocks of gabbro-norite (Taperoá) with Ti-rich biotite occur locally. The dikes show compositions that vary from peralkaline to ultrapotassic. They cut the Proterozoic basement and its metapelitic cover, as well as an older granitic magmatism (Tavares, West Salgueiro). The magmatic fabrics investigated by AMS indicate that the peralkaline plutons precede the development of the major shear zones, such as the Patos Lineament, but cut an older regional foliation recorded in the host rocks of the Manaira peralkaline dikes. Fabrics (lineation, foliation) in the Uri pluton display a steep to vertical inclinations in agreement with the upward movement of magma in an extensional setting. The peralkaline and shoshonitic plutons and dikes, including the mafic stock of Taperoá, provide zircon U-Pb (SHRIMP) ages ranging between 590 Ma and 598 Ma. Ar/Ar ages of amphibole from the Manaira dikes yielded plateau-ages in the range of 595-600 Ma in agreement with the zircon U-Pb age of the Triunfo syenite at 595 Ma. The combined structural and geochronological data indicate that relatively shallow plutons and dikes succeeded an earlier magmatism, mostly calc-alkaline in composition between 610-620 Ma, but preceded the development of the regional shear zones that in some places controlled the emplacement of porphyritic K-rich granites, diorites and leucogranites dated between 580 and 530 Ma. The Teixeira-Terra Nova peralkaline-shoshonitic magmatism records therefore a transition in the tectonic regime, from a compressional phase related to convergence and collision of magmatic arcs and cratons to a post-collisional setting dominated by extension and transcurrent movements.



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Differentiation of water-bearing silicic magma: An experimental test of in-situ crystallization

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Fractionation of water-bearing silicic magmas can be accomplished by the formation of a water saturation front propagating from the walls inwards in a cooling magma chamber. The crystallization of magmatic anhydrous phases involves enrichment in water in the liquid. As the crystallization proceeds in response to the imposed thermal gradient, the water content of the remaining liquid is increased up to reaching water saturation. The consequent formation of bubbles generates local overpressure leading to a process of gas driven filter-pressing, which is responsible for the expulsion of a differentiated liquid towards less-crystalline zones ahead the solidification front. Part of this differentiated liquid is retained filling the terminal porosity of the crystal mush.. With the aim to probe these inferences, crystallization experiments in a thermal gradient (ca. 50 °C per mm in 10 mm length capsules) have been carried out in a horizontally-arranged piston-cylinder apparatus, in order to inhibit gravity effects.. An andesitic composition (AGV-2 standard) with added water was selected as starting material. Different cooling rates (9.6 and 0.6 °C/hour) and run temperatures ranging from 1200 to 950 °C were applied at 5 kbar. The results support the spontaneous differentiation of the hydrous silicic magma by the fluxing of a fractionated liquid expelled from the mush zone, at the colder end of the experimental capsules. Bulk compositions become more differentiated as the residual liquid fraction increases. Bulk laser ablation (LA-ICP-MS) analyses of quenched runs in sectors across the thermal gradient yield that fractionation is more efficient for trace elements at conditions of rapid cooling, in which disequilibrium results in nearly zero values of partitioning coefficients for all incompatible elements. These results constitute a qualitative approach that may help to understand granitic magma fractionation in zoned plutons and the formation of enriched fractionated reservoirs in granite cupolas, which are favoured in shallow magma chambers where thermal contrast is maximum between magma and host leading to high cooling rates and disequilibrium fractionation.



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Tectonic record, magmatic history and hydrothermal alteration in the Guérande Carboniferous leucogranite, Armorican Massif, France: implications on the genesis of U mineralization.

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Most uranium (U) deposits in the Hercynian belt are related to Late Carboniferous peraluminous granites (Cuney et al., 1990). In the French Armorican Massif, three distinct U districts are spatially associated with the leucogranites of Pontivy, Mortagne and Guérande, respectively. The Guérande leucogranite, which constitutes the object of this study, was emplaced in an extensional deformation zone in the southern part of the Armorican Massif (Gapais et al., 2015). The apical zone of the intrusion is structurally located below the U deposit of Pen Ar Ran, a perigranitic vein-type deposit where the mineralization occurs at the contact between black-shales and Ordovician acid metavolcanics. One of the questions debated is the origin of the U. The REE spectra of the Pen Ar Ran U oxides argue for a volcanic origin of the U (Bonhoure et al., 2007). On the other hand, the U content of the metavolcanics is rather low (< 5 ppm). Another possibility is that the U was leached from the surrounding leucogranite (Tartèse et al., 2013) that has moderate U content (< 8 ppm). To shed some light on the role of the Guérande granite in the genesis of the Pen Ar Ran deposit, a structural, petro-geochemical, geochronological and thermochronological study was undertaken on the intrusion and was combined with U oxide dating by Secondary Ion Mass Spectrometry (SIMS) on the U mineralization itself (Ballouard et al., 2015, this study). The Guérande granite was emplaced at 309.7 ± 1.3 Ma. Its magmatic evolution was controlled by fractional crystallization and the apical zone of the intrusion was subjected to a pervasive hydrothermal alteration. At 302.5 ± 1.6 Ma, the emplacement of late leucogranitic dykes was contemporaneous with deformation and hydrothermal circulation. Whole rock geochemical analyses suggest U leaching in the most evolved facies from the apical zone of the granite, and oxygen isotope data show that the deformed facies from the roof experienced a sub-solidus hydrothermal alteration with surface-derived fluids. We propose that the U leached out by these oxidizing fluids could have then been precipitated in the reducing environment made up of the surrounding black-shales to form U deposits. U-Pb dating on U oxides from the Pen Ar Ran deposit (*) favors this model as the emplacement of a first generation of U oxide is dated at 296.4 ± 2.6 Ma, i.e. sub-contemporaneously with hydrothermal circulation and the late magmatic activity recorded within the Guérande granite.

(*) U oxides provided by Areva.



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Petrology and U-Pb (SHRIMP) geochronology of the Lagoa do Roçado Granodiorite, Sergipano Orogenic System, NE-Brazil

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The Northern area of the *Sergipano* Orogenic System has abundant granitic intrusions, with a diversity of compositional types. The *Lagoa do Roçado* Granodioritic Stock (LRGS, ~ 12 km²) is an elongated body that intrudes the metasediments of the Macururé Domain. These are gray, predominantly equigranular rocks. Mafic microgranular enclaves are common across the LRGS. The observed textures - in field as in the microscope - show no evidence of deformation. Petrographic studies allowed to identify the stock as essentially composed of granodiorites, in which biotite, hornblende and diopside are essential phases and titanite, allanite, pistacita, zircon, apatite and opaque minerals occur in accessory amounts. The geochemical data shows that these are intermediate, subalkaline and high-K calc-alkaline rocks, therefore the microgranular mafic enclaves have shoshonitic affinity. The good linear correlation identified in Harker's diagrams between felsic and mafic rock types suggests that magma mixing. REE patterns show enrichment of the light REE relative to the heavy REE and a weak negative anomaly in Eu, indicating fractionation of plagioclase. Negative anomalies of Ti and Nb, associated to the enrichment of Ba and high LILE / HFSE ratios, may be related to magmas generated in orogenic environments. The values observed for Rb, Ta and Y and their distribution in ambience tectonic diagrams indicate that these rocks may be correlated to volcanic arc granites and that they classify as post-collisional granites.

Geochronological analysis for zircons from a biotite-hornblende-granodiorite sample (187A), were obtained by SHRIMP II and define a concordant age of 618 ± 4 Ma (MSWD = 0.7). This age is here as interpreted to be the crystallization age of LRGS. This stock belongs to a group of granites regionally called "Gloria Type", which are considered late to post tectonic regarding the Brazilian Orogeny. Other granitic bodies of the Gloria typology also have similar ages as the stocks of Coronel João Sá (625 ± 2 Ma) and Camará (628 ± 12 Ma). This new age obtained for the LRGS suggests that an important magmatic event occurred on Sergipano Orogenic System between 618 and 630 Ma. Its remarkable that, although it has an age close to the ages of other bodies present in Macururé domain, the LRGS was not significantly affected by tectonic events.[Acknowledgments: CNPq/ FAPITEC /PRONEX e FAPDF]



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U-Pb AGES OF THE EARLY POST-COLLISIONAL SHOSHONITIC MAGMATISM FROM SOUTHERN BRAZIL

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In southern Brazil shoshonitic granitic rocks are associated with the Neoproterozoic post-collisional setting of the Brasiliano/Pan-African Orogenic Cycle. In the eastern portion of these shield areas post-collisional magmatic activity is represented mainly by the Pelotas Batholith, a large volume of Neoproterozoic granitoids exposed along a NE-striking belt formed by several strike-slip shear zones. This major feature is the Southern Brazilian Shear Belt (SBSB) extending from Santa Catarina, in the north, to Uruguay, in the south, and its development is thought to have initiated after the main collision (*ca.* 650 Ma). Magmatic activity within the SBSB is dominated by medium- to high-K subalkaline magmatism in the early phase (630 - 620 Ma), followed by shoshonitic associations (~600 Ma) and alkaline associations (~590 Ma). Peraluminous syntectonic granitoids crystallized between 630 and 605 Ma. Rocks of shoshonitic affinity may be found in the SBSB as the Estaleiro Granodiorite (EG) (602 Ma); the Solís de Mataojo granitoids (584 Ma); the Cruzeiro do Sul Granodiorite (CSG) and late granodiorite to monzonite dikes (LD). Outside the SBSB, they are represented by the Lavras do Sul Shoshonitic Association (LSSA) (587 to 601 Ma) and the Las Flores basalts. The CSG and LD are exposed within a ENE-WSW regional strike-slip shear zone (Quitéria-Serra do Erval Shear Zone - QSESZ). The CSG is a porphyritic hornblende-biotite granodiorite with magmatic foliation and a solid-state mylonitic structure. Mafic microgranular enclaves elongated parallel to the main foliation are widespread. The LD are compositionally similar to the CSG, although somewhat more differentiated. They present either discordant intrusive relations with CSG or are concordant with the main foliation of the host rocks. Their mylonitic foliation is slightly discordant with the one in the host rock, but deformational features are less evident. The shoshonitic characteristics of both rock groups are indicated by their high Sr contents and regular rare earth element (REE) chondrite-normalized patterns. These rocks are metaluminous to slightly peraluminous with medium to high K content, which is interpreted as an indication of crustal contamination. Compared to rocks of shoshonitic affinity, such as those of the LSSA and of the EG, the CSG exhibits similar patterns in multi-element and REE diagrams, which may indicate similar types of mantle sources. New geochronological data, based on zircon U-Pb analyses of two CSG and one LD sample, indicate ages of 635 ± 1.5 Ma and 636.3 ± 4.1 Ma for the CGS magmatic crystallization, with inheritance ages around 660 and 790 Ma. Some Pb loss is observed, probably due to the intrusion of LD. The LD crystallized at 609.2 ± 2.1 Ma with two Paleoproterozoic zircon grains. The age values between 635 and 609 Ma define the minimum period of activity of the QSESZ, as well as a new time span for the shoshonitic magmatism in southern Brazil and the activation of early mantle sources in the BP. The structural and compositional features of the CSG and LD are consistent with their post-collisional character and with the earliest shoshonitic magmatism in the SBSB.



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WHOLE ROCK AND MINERAL CHEMISTRY OF HOST-ENCLAVE PAIRS FROM TIMBAÚBA COMPLEX, BORBOREMA PROVINCE, NE BRAZIL

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The Timbaúba complex comprises an area of about 350 km², in the Transversal Zone Domain of the Borborema Province. It consists of three E-W elongated plutons, intruded along the eastern portion of the E-W trending, dextral sense Coxixola - Timbaúba shear zone. They intrude Neoproterozoic metavolcanic - metasedimentary sequence, which includes garnet-bearing biotite gneiss intercalated with mafic metavolcanic rocks, and marbles. This study focuses on its largest pluton, which have U-Pb zircon SHRIMP age of 616 ± 5 Ma. This pluton has composition ranging from monzogranite to granodiorite enclosing mafic microgranular enclaves, partially melted, of dioritic, tonalitic and amphibolitic composition. The granitoids are metaluminous, high-K, to normal calc-alkaline and magnesian, while the enclaves are ferroan. Amphibole is the dominant mafic phase, followed by biotite. Titanite occurs as euhedral crystals, reaching up to 1.5 cm long within the migmatized portions, as well as anhedral secondary crystals, resulted from biotite and amphibole destabilization. The multi-element chondrite normalized patterns clearly differentiated between the enclaves and their host granitoids. The enclaves have a much lower concentration of all trace elements, except Ti, resulting in a less fractionated pattern compared to the host. Zoned allanite with high levels of total REE in the core and very low on the edge was recorded in some enclaves. The Al-content in amphiboles from the magmatic enclaves and their host granitoids and using the Anderson and Smith's calibration (1995), defined solidification pressures of the ~ 3.6 Kb and ~ 5.5 Kb respectively. The temperatures of plagioclase - amphibole equilibrium range from $\sim 700^\circ\text{C}$ in the host granitoids and $650-800^\circ\text{C}$ for the enclaves. The calculated viscosity revealed that enclave and their host had a difference of two orders of magnitude during cooling. Amphiboles are calcic, and have composition of tschermakite to Mg-hornblende and Fe-Mg-Pargasite to hastingsite for the enclaves, Fe-Mg-hornblende and tschermakite for the host rocks. The $f\text{O}_2$ conditions, based on amphibole composition, for both enclaves and their host, range from intermediate to high. Biotite composition is similar to biotite of calc-alkaline granitoids with $\text{Fe}/(\text{Fe}+\text{Mg})$ ratios ranging from 0.43 to 0.52. The narrow variation in the $\text{Fe}/(\text{Fe}+\text{Mg})$ ratios recorded in the biotites and, the amphibole chemistry suggest the studied granitoids crystallized under near constant temperature and oxygen fugacity conditions. The plagioclases have a composition ranging from andesine to oligoclase. Correlation between host granitoids and enclaves, using major elements from whole rock as well as mineral chemistry, revealed that the enclaves-host pairs do not follow a shared evolutionary pattern. Thus, the enclaves and the host rocks have distinct sources.



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Tonalite intrusion into marble: complex physical and chemical interaction

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The interaction of granitoids and marbles, and the intense reactions that lead to skarns, have long been a subject of economic and scientific interest. Here, we report on a number of unexpected features related to the intrusion of Neoproterozoic tonalites into the Matarazzo marble in the Eastern Domain of Dom Feliciano Belt, southern Brazil. The marbles are dominantly calcitic (only 0.5 % of MgO) with diopside, opaque and quartz, in a coarse granoblastic polygonal texture, suggesting a high metamorphic grade. The tonalite intrudes the marble as dykes that carry blocks of migmatitic amphibolite, with peritectic hornblende, and leucosomes that are continuous with the surrounding tonalite, suggesting a genetic relationship. The tonalite dykes are highly irregular, with lobate-cusped contacts with the marble and commonly surrounded by skarn. The tonalite itself, close to the contact, becomes a syenite with no quartz, and rich in Pl, Hbl, and centimetric Ttn grains, ideal for dating intrusion and metasomatism. The nature of the contacts is reminiscent of those developed during magma mingling, including structures similar to back-veining, and none of these structures have previously been reported in the literature. They suggest two possibilities: either the marble melted at the contact with the tonalite, as has been demonstrated for the Bergel pluton, or the intrusion strongly dissolved the marble. After intrusion and cooling, the rock mass has been disaggregated during intense deformation that lead to isoclinal folding of the marble and extreme stretching, while the silicic intrusions were disaggregated and broken into blocks, down to grain size, explaining the presence of blocks disaggregated down to individual, isolated quartz grains in the marble.



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Feldspar megacrysts of the Santa Angelica composite pluton – revealing the formation/transformation path with the use of a combined CL and LA ICP MS dataset.

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The complexity of the collapse of the Araçuaí-Ribeira orogen in Brazil is well reflected in the rock textures and composition of the Santa Angelica (513 ± 8 Ma) composite pluton. Its evolution has been shaped during a post-collisional tectonic phase. It consists of an elliptically shaped intrusion composed of several roughly concentric lens-shaped granitic layers, elongated lenses of monzo-gabbroic to monzo-dioritic rocks, and tightly packed heterogeneous mafic enclave swarms. A main stage with the coeval intrusion of mafic and granitic magmas (granite I) has been accompanied by mutual interaction, partial hybridization and partial homogenization. Less voluminous reintrusion episodes such as dykes and small plugs of contrasting composition lasted until 492 ± 15 Ma when a later fine-grained granite II intruded the northeast region of the pluton.

Thus, individual parts of the Santa Angelica pluton are characterized by contrasting compositions. Numerous studies have been conducted on the pluton, including rock geochemistry, geochronology, and fractal analysis. These point towards magma mixing and not only mingling. Magma interactions are also perfectly replicated in the complex intergrowth textures and geochemical compositions of single mineral phases. The studied feldspar megacrysts of hybrid rocks reveal complex growth morphology and geochemical patterns. Both show signs of multi-stage domain crystallization, dissolution, recrystallization, and mutual replacement by other phases. The assemblage better characterizes the timing and geochemical nature of magma entry into the pluton. Early stages of megacryst formation may be related to high-temperature crystallization events (Na:K appropriate for sanidine/sodium sanidine). The crystal is zoned. The zoning is primarily reflected in major (Na-K) and trace element distributions (Ba, Rb, Sr). The zone morphology cannot be attributed to melt self-organization. Some newly crystallized plagioclases have been added to the growing megacryst. Megacrysts of early-stage plagioclase are also found outside of the alkali feldspar megacryst. Subsequent alkali feldspar megacryst introduction into diverse dynamic and geochemical environments has resulted in partial crystal fragmentation and dissolution. With the introduction of megacrysts from different magma sources and with re-equilibration, megacryst cracks were sealed via new feldspar generation. The overgrown ternary feldspar dissolved the megacryst margin, fulfilling embayment requirements. Growth/regrowth stages are reflected in slight variations of the Strontium isotope ratio. All domains formed due to crystallization/recrystallization processes are characterized by different trace element patterns. In these domains, correlations between pairs of LIL elements are not linear, which may suggest chaotic element delivery into the growing crystal. Finally, the megacryst is strongly affected by interactions with fluids. These interactions transformed the primordial K-Na feldspar into a nearly pure K-feldspar and contributed with various trace elements to the domains. Fluid megacryst interactions resulted in carbonate crystallization. The hybrid rock formation emerged from interactions between two different geochemical



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environments, which are reflected in the rock fabrics. Despite the importance of fabric analyses, such methods do not reconstruct paths of magma/fluid interaction with the degree of precision attainable through single crystal analyses. A multi-tool approach is required to reveal the effects of all processes. These effects frequently overlap, and single effect identification is difficult to achieve. A minimum of two complementary datasets is recommended in cases of multi-stage process reconstruction: acquired via LA ICP MS and cathodoluminescence.



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The effects of the magma injection rate in textural and compositional variations in plutons: The contrasting cases of La Gloria and San Gabriel neighboring plutons, Central Chile

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La Gloria and San Gabriel plutons are both upper Miocene granitic bodies located 40 km eastward of Santiago, Central Chile, separated by 20km in N-S direction. Both plutons have similar ages (9-13 Ma), isotopic and geochemical composition and minerals (mostly quartz-monzodiorite and quartz-monzonite with amphibole, biotite and accessory phases), but exhibit contrasting macroscopic textural record.

La Gloria pluton records a gradual concentric mineralogical, geochemical and magnetic zonation pattern where a relatively more mafic magma domain is preserved at the center, without showing significant granulometric differences along the pluton's edges. It also contains xenoliths concentrated close to the margins and at the lower central part as well as leucogranite dikes widely distributed in the pluton. In contrast, San Gabriel pluton records an abrupt change towards marginal facies of different grain size and lithology. Xenolith-rich horizontal layers distributed at different depths and widely distributed leucogranite dikes are found within this pluton.

New zircon U-Pb zircon ages, together with geochemical and textural data obtained in the two plutons were combined to physicochemical modeling, to interpret the observed contrasting macroscopic textures as consequence of lateral and vertical magma transport at different rates. A high magma pulse emplacement rate of La Gloria pluton gives rise to pluton-scale convection, compositional homogenization (i.e self-mixing) and lateral magma migration. In contrast, a lower emplacement rate of San Gabriel pluton gives rise to an assemblage of multiple magma pulses and roof collapse. These results imply that magma injection rate is a critical parameter to understand the geochemical and mineralogical evolution of magma reservoirs; high magma injection rates would give rise to homogenous reservoir and late leucocratic dike extraction while low magma injection rates would produce a broader lithological and textural diversity, with well-defined internal contacts, yielded by a limited self-mixing process.



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First occurrence of nepheline in the Gran Paradiso Permian pluton, Internal Western Alps

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The Gran Paradiso massif (GP) main rock type is a Permian porphyritic granite (271 +/- 8 Ma, from 10 zircon U-Pb ages [Bertrand *et al.*, 2005, Schw. Min. Pet. Mitt., 85:15-29]) emplaced into an older metamorphic series. Some parts of the massif display peculiar, Mg-rich rocks highly depleted in Ca, Na and Si and commonly referred to as 'whiteschists' [Ferrando, 2012, Terra Nova, 24:423-436]. In the western part of the massif (Evettes refuge), fairly continuous outcrops show close associations of whiteschists with albitic, locally K-feldspar porphyritic syenites, within the GP porphyritic granite. In such albitic syenites, nepheline was found associated with paragonite, in an albite groundmass where subordinate quartz drops are mantled by aegirine and sodic amphibole. The rock is a highly alkaline syenite (9.4-9.9 wt.% Na₂O), though not Si-undersaturated according to CIPW norm. First detection of nepheline was permitted by EDS chemical mapping, confirmed by electron microprobe analysis (WDS), Raman microspectroscopy, and X-ray diffraction. Optical detection of nepheline is reputedly a risky business, and its imaging by EDS-mapping is not straightforward either: a long scan time is required before a clear-cut difference is evidenced with the enclosing albite, because of the relatively low atomic numbers of Na and Al.

All those rocks contain abundant, euhedral zircon crystals with Th/U ratios in the 0.1-0.7 range, i.e. typical of magmatic zircon. LA-ICP-MS isotope measurements were performed on zircons from one whiteschist and one nepheline syenite. Altogether, they yielded two U-Pb age groups at 246 +/- 3 Ma and 257 +/- 3 Ma, significantly younger than the host GP pluton. By contrast, allanite crystals extracted from the same syenite yielded LA-ICP-MS U-Pb ages at 34 +/- 3 Ma, which reflects the Alpine metamorphic imprint that affected the whole massif and reached eclogite-facies conditions. Jadeite was actually found in another variety of syenite, more leucocratic and K-feldspar porphyritic, from the same outcrop.

Nepheline chemistry, with a Na/(Na+K) ratio in the 0.8-0.9 range and Si near 8.1 a.p.f.u. (for 32 O, based on 104 WDS measurements) does not depart significantly from classical compositions [Barth, 1963, Schw. Min. Pet. Mitt., 43:153-164; Balassone *et al.*, 2014, Min. Petr., 108:71-90]. Although nepheline and quartz were not observed in direct contact, their close association suggests that the equilibrium was not achieved, at the thin section scale. Hence, it is suggested that nepheline was generated during the late, post-eclogitic stage of the Alpine metamorphism, through destabilization of jadeite giving albite + nepheline, known to occur experimentally below 0.5 GPa [Newton & Kennedy, 1968, Am. J. Sc., 266, 728-735].

Highly albitic modal compositions were classically noticed in the GP by Michel [1953, thesis Clermont-Ferrand] as well as in the Monte Rosa, another Internal Crystalline Massif of the Alps by Bearth [1952, Beitr. Geol. Kart. Schw., 96], those authors defending a primordial sodic metasomatism vs. a late-Alpine albitization, respectively. The evidence presented here of late magmatic, highly alkalic pulses, Late Permian to Early Triassic in age, while sodic minerals are of Alpine (re?)generation, might renew this old debate.



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PT.076

PETROGENESIS, DEFORMATION AND U-Pb AND Ar-Ar GEOCHRONOLOGY OF THE SANTA HELENA BATHOLITH: IMPLICATIONS FOR THE TECTONIC EVOLUTION OF THE SW AMAZONIAN CRATON

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The Rondonian-San Ignacio Province (1.56-1.30 Ga) in the SW Amazonian Craton records intense Calimian granitic magmatism represented by the Pindaituba Intrusive Suite and Santa Helena Batholith, which are attributed to the Santa Helena Orogeny. This work presents a collection of geologic-structural, petrographic, geochemical, geochronological (U-Pb) and isotopic (Sm-Nd) data of the Santa Helena Batholith in order to discuss its petrogenesis as well as the tectonic setting responsible for the magma generation. This unit is an N-S trending elongated intrusion hosted by Paleoproterozoic supracrustal and infracrustal rocks. The Santa Helena Batholith comprises monzonogranitic rocks strongly foliated, equi-inequigranular to porphyritic, coarse to fine-grained, leucocratic, grey to reddish-pink; biotite is the major mafic mineral, and hornblende and garnet are subordinate. The batholith records at least three phases of ductile deformation. The F₁ deformation phase developed an E-W trending penetrative foliation S₁, perpendicular to the length of the intrusion, and steeply dipping towards the center and gently dipping towards the northern border of the intrusion. F₂ phase caused S₁ folding and, on the eastern and western borders of the intrusion, is responsible for its complete transposition into a NNW orientation, with steep dips. F₃ phase is observed on the W and NE borders of the batholith as a result of normal-sense shear zones, Piratininga and Indaiavai-Lucialva. The rocks of the Santa Helena Batholith shows compositional and textural diversity, allowing to recognize four petrographic facies, all of them with similar characteristics of I-type granitoids. SiO₂ values vary widely from 65.7 to 79.4 %, classifying them into acid and highly evolved rocks. Negative linear relationship between this index and Al₂O₃, Fe₂O₃, CaO, MgO, TiO₂, MnO, Zr, Ba and Sr indicates differentiation marked by increase in modal quartz; fractionation of plagioclase and primary mafic minerals (hornblende, biotite, ilmenite-magnetite, titanite and zircon), as well as an impoverishment of anorthite molecule in plagioclase. This magmatism can be classified as subalkaline, high-K calc-alkaline to shoshonitic, metaluminous to peraluminous, showing HREE fractionation relative to LREE, having the former a near-flat pattern and Eu negative anomalies; also compositionally similar to Phanerozoic granitoids formed in tardi to post-collisional settings. U-Pb ages (TIMS and SHRIMP) from zircons indicate magma crystallization from 1.45 to 1.42 Ga while εNd(t) values are between +3 and +4,3 and TDM ages of 1.62 and 1.43 Ga. Ar-Ar analyses carried out on the center and border of the intrusion indicate an interval of regional cooling from 0.930 to 0.915 Ga for the batholith.



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Generation and evolution of A-type granitic magmas: an study based on zircon dating and geochemistry in the Itu Batholith, SP, Brazil

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The 580-560 Ma A-type Itu Batholith is a main constituent of the post-orogenic Itu Granitic Province in SE Brazil, intruding Neoproterozoic high-grade metamorphic rocks of the Socorro-Guaxupé Nappe. It is made up of four main plutons, each resulting from the interaction between several magmatic pulses emplaced at shallow crustal levels. All plutons share several key features (e.g., A-type trace-element signature), but each has its own structural pattern and geochemical and isotopic identity.

The most voluminous unit is the ~153 km² Cabreúva Pluton (560.9±6.2 Ma; SHRIMP U-Pb zircon age, 2σ), with a normal textural zoning pattern defined by a predominant coarse-grained hololeucocratic syenogranite at the center varying to a medium to fine-grained border; an association of porphyritic granite and melagranite occurs at the intrusion's core. Granites from this pluton show a geochemical signature typical of fractionated reduced A-type granites, with low **mg#** (<20), low Sr, low Sr/Y (<2), relatively high Nb and Zr, and moderately fractionated REE patterns (La_N/Yb_N ~15) with deep negative Eu anomalies.

Two other intrusions are dominated by rapakivi granite. The Salto Pluton (576.6±3.8 Ma; SHRIMP zircon age) is largely formed of reddish to pink inequigranular coarse-to medium-grained hornblende-biotite rapakivi syenogranite with a leucogranite cupula strongly affected by hydrothermal alteration at its western portion. Abundant felsic microgranular enclaves and a porphyry granite body result from replenishment by repeated pulses of felsic magma. The Indaiatuba Pluton (579.1±3.9 Ma; LA-ICPMS U-Pb zircon age) is an early intrusion of coarse-grained rapakivi syenogranite bearing both felsic and mafic microgranular enclaves.

The Itupeva Pluton (584.3±5.2 Ma, granodiorite facies at the pluton's core; 576.6±5.2 Ma, inequigranular leucogranite intruding the Indaiatuba pluton; SHRIMP zircon ages) shows wide textural and compositional variety, with a rough inverse compositional zoning defined by border biotite leucogranites and central porphyritic biotite monzogranites associated with frequent hybrid mafic to intermediate rocks in the form of small intrusive bodies and microgranular enclaves. Preliminary zircon Hf isotope data by LA-ICPMS reveal significant inter-pluton variations, suggesting greater contribution from sources with younger crust residence for Salto (average εHf(t)= -11.6) as compared to Indaiatuba (average εHf(t)= 17.8), which is reinforced by parallel variations in εNd(t) (from -10.2 to -12.4). Wide intra-sample variations, particularly in the Salto sample (εHf(t)= -7 to -17), reflect the multi-source character of this rapakivi intrusion, where the less negative values overlap those of contemporaneous melts derived from enriched-mantle.

The sources of the Itu granites are inferred to be older granitic rocks and orthogneisses that were remelted at relatively high T (>800°C) under low a(H₂O). From similarities in εNd(t) and the ages of rare inherited zircons, the main source can be slightly older (650-620 Ma) calc-alkaline granites that constitute large volumes of the Socorro-Guaxupé crust. However, the presence of ~2.15 Ga inherited zircon and a shift towards more radiogenic Nd isotope signature indicates that Paleoproterozoic rocks and a juvenile Neoproterozoic component were also important sources for the Itu magmatism.



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PT.078

U-Pb zircon age constraints on the Mid-Miocene felsic magmatism of the Outer Zone of SW Japan

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In the forearc region of southwest Japan arc along the Nankai trench, intensive magmatism took place in the middle Miocene time. It is widely accepted that this episodic igneous activities were almost coeval with the initiation of the subduction of young hence hot Shikoku Basin of the Philippine Sea plate, immediately after the opening of the Japan Sea and clockwise rotation of southwest Japan. Distribution of the igneous rocks is up to 800 km along arc, 150 km across arc directions, respectively. Across arc variation of the lithology have been pointed out for the middle Miocene magmatism [1,2]. Closest to the Nankai trench, tholeiitic/alkaline basaltic igneous complexes with felsic intrusive rocks are distributed. To the north of these igneous complexes, voluminous felsic to intermediate volcano-plutonic igneous complexes are distributed (Outer Zone granitic rocks). These igneous complexes are composed of S-type granitic plutons and volcano-plutonic complexes including large scale caldera bearing bodies and I-type granitic plutons. Farthest to the trench, mafic to felsic volcanic rocks (Setouchi volcanic rocks) are distributed. Generation of S-type felsic magmas can be explained by melting of sediment above the subducting hot Shikoku Basin, with possible additional heat source by the injection of tholeiitic basaltic magma [3]. We have carried out precise U-Pb dating of zircon for the Outer Zone granitic rocks in Kii peninsula and Kyushu island to examine the variation of the age of the along arc and across arc directions. These two regions are separated approximately 500 km for along arc direction. U-Pb dating was performed by use of LA-ICPMS technique. U-Pb ages of the Outer Zone granitic rocks in Kii peninsula and Kyusyu island range 15.5 to 14.0 Ma and 15.6 to 13.4 Ma, respectively. Hence the along arc variation of the age of the Outer Zone granitic rocks is not observed. Though the oldest age samples of both regions were obtained from the igneous bodies in the closest area to the trench, obvious across arc trend of the age variation is not found. Our new U-Pb ages well constrain the felsic igneous activities of the Outer Zone granitic rocks within 2 m.y., comparing to the previously reported K-Ar and zircon FT ages ranging 18 to 12 Ma. These chronological constraint ensures that the majority of the igneous activities of the Outer Zone granitic rocks has occurred after the clockwise rotation of southwest Japan arc and felsic magmas were formed during the subduction of the hot Shikoku Basin.

[1] Nakada and Takahashi. 1979. J. Geol. Soc. Jpn. 85, 571-582.

[2] Kimura et al. 2005. Bull. Geol. Soc. Amer. 117, 969-986.

[3] Shinjoe et al. 2007. J. Geol. Soc. Jpn. 113, 310-325.



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Inherited and pre-magmatic zircon: timing the progression from mud to granite magma

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Inherited zircon (zircon significantly older than the igneous rock in which it occurs) is a common occurrence in granitic rocks. Although there is some debate over the source of inherited zircon, particularly when it is present in very small amounts, it is widely accepted that the ubiquitous inherited zircon found in magmas that have been produced through the partial melting of sedimentary rocks is remnant detrital zircon from those source rocks. That being so, the inherited zircon is a direct sample of the source rocks, and the age and composition of that zircon is a direct indication of the nature and age of the components of which that source was comprised.

Inherited zircon is highly abundant in the S-type granites of Eastern Australia, both the Early Silurian granites of the Lachlan Fold Belt and the Early Permian granites of the New England Orogen. The variety of ages obtained by ion microprobe U-Pb dating of large numbers of inherited zircon cores has long been used to determine detrital age spectra that constitute a 'fingerprint' from which the source rock might be identified. In the case of the Lachlan Fold Belt the large range of ages in the inherited zircon spectrum (Palaeozoic to early Archaean) is a close match for the detrital age spectra from the early Palaeozoic turbidite sequence into which the granites are intruded. In the case of the granites from the New England Orogen the inherited zircon appears to derive mostly from Carboniferous volcanoclastics, a common host rock in that region.

A question remaining unanswered in the Lachlan Fold Belt is the exact age of the sediments from which the granites are derived, namely is the source a deeper part of the Late Ordovician sequence exposed at the surface, or is it older rocks (Early Ordovician or Cambrian) that might lie below? The answer lies in finding the youngest inherited zircon, thereby constraining the deposition age of the youngest sedimentary rock in the source region. As the granite ages are known, doing so also provides an estimate of the maximum possible time interval between source sediment deposition and burial to the depths of partial melting, but distinguishing between young inherited zircon and early-formed igneous zircon when both look identical in CL images is extremely difficult.

The situation in the New England Orogen is fortuitously different. The inheritance in the granites has a relatively narrow range of ages (Early to Late Carboniferous), and because the source rocks were predominantly volcanoclastic, the oxygen isotopic compositions of the inherited zircon are distinct from those of zircon crystallised from the granite magma. Young inherited zircon and early-formed igneous zircon can be clearly distinguished. As a result, not only has it been possible to determine the maximum time interval between deposition of the youngest source rock and the initiation of partial melting at the start of granite magma genesis (ca. 15 Ma), but also to measure the time period between incipient partial melting and granite emplacement (ca. 5 Ma).



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MINERAL CHEMISTRY AND CRYSTALLIZATION PARAMETERS OF THE ARCHEAN PLANALTO SUITE, CARAJÁS PROVINCE - AMAZONIAN CRATON

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The Planalto Suite is located in the Carajás Province in the southeastern part of the Amazonian Craton. The suite has Neoproterozoic age (~2.73 Ga), ferroan character and affinity with A-type granites and is composed of foliated, synkinematic amphibole-biotite monzogranites to alkali feldspar granites. Magnetic petrology studies allowed the distinction of two groups: (1) Magnetite-free granites containing ilmenite as main iron oxide mineral and showing low magnetic susceptibility (MS) values (MS between 0.6247×10^{-3} and 0.0102×10^{-3} SI); (2) Granites containing magnetite associated to ilmenite displaying comparatively higher but still moderate MS values (between 15.700×10^{-3} and 0.8036×10^{-3} SI). In the rocks of group 2, textural evidence indicates that magnetite crystallized from the magma and coexisted with amphibole and ilmenite. Titanite is found in both groups, but it is not omnipresent and its chemical composition suggests that its origin may be related to secondary process. The amphiboles are hastingsite and ferro-pargasite [$Fe/(Fe+Mg) > 0.8$]. Biotite shows also high $Fe/(Fe+Mg)$ ratio and is classified as annite. Plagioclase is oligoclase to albite ($An_{23}-An_2$) and it was not observed compositional variation between porphyroclasts and fine crystals of the recrystallized matrix. The dominant group 1 granites of the Planalto Suite were formed under reducing conditions below the FMQ buffer. The group 2 granites crystallized under slightly more oxidizing conditions on or a little above the FMQ buffer or, alternatively, they were also formed in reducing conditions but were affected by oxidizing subsolidus hydrothermal processes. Geothermometers suggest initial temperatures of crystallization variable between 900°C and 870°C and it was estimated a pressure of 700 to 900 MPa at the magma source. On the other hand, ductile deformation, penetrative foliation and local lineation, as well as strong recrystallization in the Planalto Suite are indicative of the emplacement of the plutons in crustal depths equivalent to a pressure of 400 to 600 MPa. The comparison between the Planalto Suite and other ferroan Neoproterozoic granites and A-type Paleoproterozoic granites of the Carajás Province reveals that the Neoproterozoic granites show strong compositional analogies with the Planalto Suite indicating that they were probably formed under similar conditions. The amphibole and biotite compositions of the Planalto Suite are quite enriched in Al and differ in this from those of the Paleoproterozoic A-type granites that were emplaced at shallower crustal levels (100 to 300 MPa). The reduced character of the Planalto Suite approaches it of the reduced to moderately oxidized (Serra dos Carajás and Velho Guilherme suites) and distinguish it of the oxidized (Jamon Suite) Paleoproterozoic granites of the Carajás province. By analogy, the Planalto Suite differs of the Lingdal Granodiorite and similar oxidized granites and is more akin to the Neoproterozoic AMC suite of southern Norway and to the Mesoproterozoic Wolf River granite of USA. The Neoproterozoic Matok pluton of the Limpopo belt was formed in a collisional setting, is associated with granulitic assemblages and have also Al-enriched amphiboles but it evolved in more oxidizing conditions when compared with the Planalto pluton. The mineralogy of the Planalto Suite reflects its granulitic sources.



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How xenoliths are distributed inside magma reservoirs: contrasting examples from numerical modeling and field observations.

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In order to understand the factors controlling xenoliths distribution in plutons, numerical simulations of xenoliths transport inside magma reservoirs were made, considering a two-phase mixing fluid system, representing the magma (fluid phase) and stopped blocks that sink (solid phase). The physical properties of mixing are based on the temperature-dependence of density and viscosity of magma, which was obtained through simulations by MELTS. The solid phase transport considers a slip velocity, relative to the magma, which is given by the Stokes' law. Therefore, the sinking velocity of xenoliths depends on the thermal equilibrium and lithology differences between magma and xenoliths (controlling the density contrast) and the crystallinity of magma given by its temperature and composition (controlling the effective magma viscosity).

This model is applied to La Gloria and San Gabriel plutons: two silicic intrusive bodies with similar lithology (quartz-monzodiorite to quartz-monzonite with amphibole and biotite), located eastward Santiago, central Chile. Both plutons present similar ages (13-9 Ma) and were emplaced at shallow levels of the crust (~4 km depth), intruding basaltic to andesitic volcanic and volcano-sedimentary sequences. Xenoliths are preserved in both plutons, which mainly consist of ferromagnesian-rich andesitic blocks, varying in size from centimeters to a few meters long, some of which preserve the primary texture similar to the volcanic wall-rock. In La Gloria pluton, xenoliths are mostly concentrated near the border (with angular shapes) and at the lower-central part of the pluton (with rounded shapes). In contrast, xenoliths in San Gabriel pluton are all rounded and preserved as horizontal layers at intermediate levels, associated to internal contacts between textural units. Results indicate that, during the cooling of magma, the effective viscosity increases several orders of magnitude in a narrow temperature interval (~50°C) at around 800°C, mainly controlled by the increase of crystallinity of the magma and the eutectic character of the system. This variation strongly decreases the sink rates of stopped blocks, allowing preservation of their locations in the reservoir. From this, we interpret that the existence of rheological domains within the magma reservoirs in the final stage of solidification can be inferred from the distribution of xenoliths in plutons, which are defined by relatively high effective viscosity contrasts between magma and xenolith.

In both plutons, xenoliths may represent a continuous stopping process or discrete events of roof collapse. Based on field observations and numerical simulations, we interpret that only one viscosity contrast zone existed at the base of La Gloria pluton. On the contrary, San Gabriel pluton exhibits intermediate viscosity contrast zones with respect to the base and roof of the pluton, evidenced by the horizontal layers of xenoliths. Sinking xenoliths locked near the borders of the plutons mark the rapid increase of the effective viscosity of magma, associated to the last stopping event. We suggest that La Gloria pluton represents a simpler magmatic system, forming a single, integrated magma reservoir, while the San Gabriel pluton records several sub-reservoirs marked by sharp viscosity contrasts.



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PT.082

Old and new work on fabric development during crystallization of granitoids under stress

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Granitoid magma, cooling under stress, passes through different stages of physical and structural conditions. This leads to a variety of fabrics on the macro- and micro-scale, which vice versa provide information about physical and structural conditions and, consequently, about cooling-deformation history of the rock. The effective parameters can be classified into two main groups: (i) temperature (i.e. cooling), time, amount of crystals, and (ii) differential stress and flow rate. Both groups span a diagram, by which the various stages of fabric development of the crystallizing magma can be represented.

Macro- and microfabrics comprise (i) preferred orientations of crystals or wall-rock fragments; (ii) early macro-fractures in the crystal-melt mush, filled by melt of generally mafic composition; (iii) various mingling structures; (iv) late micro-fractures, mostly in feldspars, filled by melt of nearly eutectic composition; (v) quartz chessboard subgrain patterns solely generated in the stability field of high-quartz. In addition to these well-known fabrics, recent investigations have shown that grain-boundary microfabrics are a useful source of information on stress-temperature conditions during crystallization. Specifically coarse grain-boundary sutures in quartz and feldspars may indicate weak high-T deformation in a crystal-melt mush and, based on their geometry and crystallographic orientation allow estimating temperature conditions. Moreover, small polygonal grains of quartz, feldspars or biotite, which locally occur as groups of few grains in larger magmatic crystals, indicate deformation during crystallization, partly stress-transfer from melt to crystal, and may help to evaluate stress situations during different stages of crystallization.

Two trends of development during magma crystallization under stress can be distinguished. (i) At high temperature and low number of crystals or wall-rock fragments, preferred crystal orientations may develop, which reflect magmatic flow. During cooling the amount of crystals increase as well as the magma viscosity, leading to crystal interaction and stress transfer from melt to crystals. Consequently, a variety of deformation structures is formed in the crystals. (ii) With increased differential stress the intensity of preferred orientations as well as internal deformation structures increase. Transient highly increased flow rates may cause fracturing of crystals and melt. This is typically a short-term process that leads to cyclic flow and brittle behavior of the magma.

It is the purpose of this work not only to present new microfabrics-based analytic tools and an overview on their application but to indicate and discuss the advantage of integrated microfabrics analyses over classical single-fabric studies.



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Meso- and micro-scale fabrics as record of flow and crystallization of magma under stress: the Piquiri Syenite Massif (Dom Feliciano Belt, Southern Brazil)

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Meso- and micro-scale fabrics of syntectonic granitoids bear a wealth of information about (i) crystallization, deformation and rheology history, (ii) development of fabric inhomogeneity and anisotropy during flow processes, and (iii) interaction between local and regional kinematics. The Piquiri Syenite Massif is a crescent-shaped, ca. 150 km² large Neoproterozoic batholith within the Dom Feliciano Belt, emplaced in post-collisional setting of the Brasiliano/Pan-African Cycle. The syenite body contains locally up to 90 vol-% mm-cm large platy K-feldspars and mafic aggregates composed of μm -mm sized pyroxene, amphibole, titanite, apatite, opaque minerals, and minor amounts of biotite. Throughout the pluton the K-feldspar crystals, together with the elongate mafic aggregates define a mostly sub-vertical magmatic foliation generally parallel to the pluton contacts as well as a very weak, variably oriented lineation.

Analysis of macro- and micro-fabrics highlights the crystallization history of the pluton. (i) Crystallization of apatite was followed by crystallization of titanite, clinopyroxene, hornblende and K-feldspar. (ii) These minerals were affected by strong flow alignment, however, with K-feldspar probably at $\sim 2/3 - 3/4$ of its final size, i.e. with 20-25 vol-% melt present. Flow occurred without interaction of crystals, as indicated by the lack of internal deformation features in K-feldspar. (iii) This also argues for the decline of flow before full crystallization of the magmatic body. (iv) Within interstitial quartz weak chessboard subgrain patterns are only rarely present, flame albitization is concentrated in regions of locally increased stress, and hornblende shows weak subgrain patterns and slightly sutured grain boundaries. All this indicates only very minor deformation under magmatic conditions. (v) No medium- or low-temperature deformation features are present.

Most probably, the Piquiri Syenite crystallized in a weak regional stress field that caused a magmatic foliation but was not able to affect rock fabrics under late-magmatic or higher to lower metamorphic conditions. However, modification of magmatic fabrics by internal kinematics within the crystallizing magma chamber is conceivable.



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PT.084

Phase equilibria and trace element modeling of Archean sanukitoid melts

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Sanukitoids are Mg-rich, Late Archean granitoids, which are interpreted to have formed by the interaction of crustal and mantle melts possibly in a subduction zone setting. Geochemically and chronologically they seem to represent the transition between the tonalite-trondhjemite-granodiorite series rocks predominant in the Archean and the modern-style, subduction-related magmatic suites. Studying their formation conditions can therefore provide important insights into the geodynamic processes shaping the cratonic crust in the Late Archean.

We present a combination of phase equilibria and trace element modeling to study the melting conditions and protolith sources, which best reproduce the characteristic major and trace element concentrations of sanukitoid melts (high Mg#, V, Cr and Ni but enriched in LILE). After comparing our model to results from experiments for validation, we explore the formation conditions and melt sources for sanukitoids of two localities: the Amazonian craton and the Superior Province. Mixtures of 70% crustal melt (TTG) and 30% relatively undepleted peridotite are most favorable to reproduce major and trace element characteristics of granodioritic sanukitoids (62-67 wt.% SiO₂). The P-T conditions of melting vary significantly with the composition of the crust-mantle mixture but range within 1100-1250 °C and 2.0-3.2 GPa generating relatively high melt fractions between 50-65%. Less differentiated sanukitoid melts (49-53 wt.% SiO₂) can result from either 50/50 or 70/30 crust-mantle mixtures, depending strongly on the composition of the TTG source. The addition of small proportions of carbonatite can account for the elevated concentrations of Ba, Sr, P, Eu and LREE in most sanukitoids of the Superior Province.

In contrast to mere trace element models where the degree of melting and the P-T conditions are poorly constrained, the combination with phase equilibria calculations allows for a better-defined model that is consistent with formation conditions in the subcratonic lithospheric mantle or possibly a mantle wedge.



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PT.085

Pulsed granitic crust formation revealed by comprehensive SHRIMP zircon dating of the SW Japan granitoids: Enhanced subduction of the Pacific Plate triggered the voluminous granitic magma formation?

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Convergent plate margins, such as the Mesozoic circum-Pacific orogenic belts, are regarded as one of the plausible candidates for the post-Archean continental crust formation, as they are associated with abundant calc-alkaline I-type batholiths. However, the fundamental tectonic processes that triggered these voluminous granitic crust formations in the Mesozoic have remained largely unresolved due to the lack of precise temporal constraints on the granitic magmatism. We have conducted a comprehensive geochronological study of the granitic batholiths exposed in the Southwest Japan Arc, which is typical of the Mesozoic circum-Pacific orogenic belts utilizing SHRIMP zircon U/Pb geochronology.

Contrary to the results previously obtained using conventional geochronological methods (e.g. K-Ar, Rb-Sr whole-rock isochron ages), which suggested that the magmatism occurred gradually from ~100 to ~50 Ma, with the plutons forming over long time intervals, the newly obtained zircon ages reveal three clear pulses of granitic crust formation at 85, 60 and 35 Ma separated by 25 million year intervals. The 85 Ma magmatism was the most voluminous and was distributed in a broad zone that extends ~120 km across-strike, whereas the magmatism at 60 and 35 Ma were focused on the northern margin of the SW Japan Arc. Furthermore, the granitic magmatism at 85 Ma involved sediment-incorporated, ilmenite series granitic rocks, while the magmatism at 60 and 35 Ma involved more juvenile, mantle-derived, magnetite series rocks.

Thus, not only did the granitic magmatism in SW Japan occur in pulses, there was also a spatial and compositional transition in the magmatism through time. The ocean basin reconstruction model by Müller et al. (2008, Science) revealed pulsed oceanic crust production at the mid-oceanic ridges in the Pacific Plate during the Mesozoic, also showing ~25 million year interval, indicating that convergence rate of the Pacific Plate around the circum-Pacific region has experienced fluctuation of similar time interval. This suggests that pulsed Mesozoic granitic crust formation revealed in the SW Japan can be attributed to the enhanced subduction zone magmatism during the Mesozoic, rather than the previously proposed model in which it was suggested that the granitic crust was formed by the subduction of a mid-ocean ridge on the Pacific Plate during the Middle Cretaceous.



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PT.086

The Piracaia Monzodiorite, SE-Brazil: multiple injections and magma interaction in a dynamic magma chamber

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The 578±3 Ma old Piracaia Monzodiorite holds in its 30 km² a great variety of lithologies, which can be grouped in five units: coarse-grained monzodiorites (*Mdr*); fine-grained monzodiorites (*Mdf*); heterogeneous monzonites (*Mh*); syenites (*Sie*); quartz syenites and quartz monzonites (*Qsie*). The predominant K-rich monzodiorites are inferred to derive from a metasomatised subcontinental mantle, while the felsic rocks are akin to A-type granites. The magmas intruded in a late to postorogenic tectonic setting, resulting in a pluton with an ellipsoidal shape and moderate to strong foliation, especially along its borders. Mafic and felsic magmas interacted in different scales, generating hybrid rocks and a great variety of commingling structures, with characteristics that indicate the sequence of magma intrusion during the emplacement.

The physico-chemical crystallization parameters of primary and hybrid magmas were determined as references for the characterization of the magma interaction processes. *Liquidus* temperatures estimates based on apatite saturation are of 950-1050° C for the most primitive (*Mdf*) and 850-900° C for the more differentiated (*Qsie*) magmas. *Solidus* temperatures, based on hornblende-plagioclase equilibrium, are ca. 750° C for *Mdf*, and 650-700° C for *Qsie*. Depth of emplacement is estimated at 13-15 km (3,5 to 4,0 kbar), based on Al-in-hornblende geobarometry. H₂O contents estimated from the An content of plagioclase are 2.5-3.3% for *Mdf*, reaching up to 5% in quartz syenites. *f*O₂ estimates derived from Fe-Ti oxides oxythermometry and Fe/(Fe/Mg) ratios of amphibole and biotite show an important contrast among the units: whereas *Mdf* and *Mdr* are highly oxidized (~NNO buffer), *Qsie* and especially *Sie* and *Mh* are more reduced, often magnetite-free.

Two main events of magma interaction can be identified in the pluton evolution. In the first, monzodiorite (*Mdf*) magma mingled intensively with syenite (*Sie*), generating the heterogeneous monzonite (*Mh*) unit. The medium to fine grained texture of these rocks coupled with the relatively high *liquidus* temperatures estimated for both magmas suggests that cooling was relatively fast. On the other hand, the intense interfingering of monzodiorite and syenite portions, which maintain their identity in the millimeter scale, suggests a strong mechanical interaction, favoring the hypothesis that this took place, or at least initiated, during the ascent of magmas, previously to the emplacement. In a second event the chamber was replenished with a new batch of felsic magma (*Qsie*), followed by several batches of monzodiorite (*Mdf*), which occupied the center of the pluton. This center body shows abundant evidence of mingling along its borders, such as enclaves, pillows and load cast structures. The mafic pillows are often disrupted and locally mingled with the quartz syenite magma, generating hybrid zones with very peculiar mineralogical and trace element chemistry at their contacts. These zones have abundant allanite, zircon, apatite and amphibole, and correspondently are anomalously rich in trace-elements such as LREE, Zr and P relative to the endmembers (*Mdf* e *Qsie*). These high concentrations are consistent with “diffusion fractionation” due to physical dispersion processes at the interface between contrasted magmas, which were preserved upon cooling.



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Hydrothermal Alteration and Gold Mineralization of the Patrocínio Village on the Tapajós Mineral Province, Northern Brazil

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The Amazon Craton consists in one of the largest cratonic areas in the world. Its formation is interpreted as the result of a series of accretionary orogens that have been juxtaposed to a cratonic nucleus of archaean age represented by the Central Amazonian Province. In this tectonic setting the Tapajós-Parima Province is one of the geochronologic units of the Amazon Craton. The formation of this particular province is attributed to continent-ocean orogenies of 2.10–1.87 Ga, whose consequences involve expressive plutonic and volcanic rocks formation. Among the igneous manifestations that took place during this period the formation of calc-alkaline magmatic arcs represented by the granitoids of the Cuiú-Cuiú Complex (2.01-1.90 Ga), the Parauari Intrusive Suite (1.89 Ga) and the Creporizão Intrusive Suite (1,97-1,95 Ga) should be highlighted. An extensive plutonic and volcanic rock formation process of calc-alkaline/alkaline affinity also played an important role on the formation of the province. This magmatic event is denominated Uatumã and its lithotypes cover an area of approximately 1,100,000 km². This is the tectonic context where the Tapajós Mineral Province (TMP) is located. This particular province shows an important metallogenetic significance, it has already been responsible for the production of more than 750 tons of gold since the late 50's. On the central portion of the TMP, precisely on the surroundings of the Patrocínio Village, many artisanal miners are currently exploring and producing gold without any previous study. Despite this strong potential only a few number of researches were developed on the area aiming the characterization of the primary gold occurrences. The Canadian junior company Belo Sun Mining performed during the year of 2013 an exploratory drilling campaign, and agreed to gently provided the drill cores for this study. Through geologic mapping on the area of interest it was possible to assume that monzo and syenogranites with different stages of hydrothermal alteration are the dominant host rocks of the gold mineralization. Macroscopic description of the drill cores shows dominantly porphyritic and leucocratic monzogranites and syenogranites with hydrothermalism represented by a well-developed potassic alteration characterized by the formation of K-feldspar and a strong, sometimes pervasive, propylitic alteration with epidote, chlorite, quartz, ±albite, ±calcite. The former alteration commonly shows intersections of pyrite rich, quartz bearing Au mineralized veins. Under optical microscope these alterations are recognized by the replacement of Na-Ca igneous plagioclase by hydrothermal K-feldspar and veins of chlorite+epidote+ quartz with minor albite and calcite. Another type of mineralization on the target is associated with monzonites and quartz monzonites with disseminated pyrite with good grades of Au. These rocks are intrusive on the monzo and syenogranites and typically show disseminated pyrrhotite and Fe-carbonates (possibly ankerite and siderite). A strong carbonatization event of pervasive characteristic cross cut all lithotypes and together with the paragenetic association of the monzonites may represent fluids of different geochemical characteristics (fairly reduced and CO₂ rich when compared to magmatic fluids) implying in at least two distinct fluid sources, different styles of mineralization and possibly different tectonic settings for these Au occurrences.



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Inherited monazite from Nazaré Paulista anatectic granite: implications for monazite age determinations and timing of high-grade metamorphism in the Socorro-Guaxupé Nappe (SE Brazil)

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The present study takes advantage of the ability of electron microprobe analyzer (EMPA) to combine high spatial resolution information on textures, chemical composition and ages of monazite to investigate the petrochronology of the Nazaré Paulista anatectic granite from the Socorro-Guaxupé Nappe (SGN) in SE Brazil and thus contribute to understand the timescales of partial melting in the continental crust. The approach is similar to that previously used by us to date the partial melting of a migmatitic paragneiss associated with this granite, where we identified a protracted history of melt production and crystallization spanning ca. 25 My (from 635 to 610 Ma) (Martins et al. 2009, *Chem Geol* 261: 271–285).

A wide compositional and textural variety of “Nazaré Paulista granites” exists in the SGN, forming countless small bodies closely associated with migmatitic garnet-bearing paragneiss. The most abundant varieties are: gray Grt-Bt granite (typically veined by Grt leucogranite 1) and Grt leucogranite 2, forming independent bodies. The two garnet leucogranites have distinct origin, with the first being interpreted as a product of decompression remelting of gray granite in a mushy state, and the second as independent low-temperature magmas directly extracted from the sources.

A dataset of 37 determinations in 9 monazite crystals from a gray Grt-Bt granite resulted in a mean age of 614.9 ± 5.0 Ma (95% confidence level, MSWD = 1.6, probability of fit = 0.01). Twenty two determinations in 7 monazite crystals from associated Grt leucogranite 1 vein resulted in mean age of 605.4 ± 5.4 (MSWD = 1.18 and probability of fit = 0.26). Although these results are within error of each other, they are consistent with the structural relations and may indicate a ~10 Ma age difference between the two granites. Detailed textural examination indicates that some crystals from both granites have irregular higher-Y cores (0.54-1.44 wt.% Y), similar to monazite inherited cores found in leucosome from associated migmatitic paragneiss. Taken separately, these cores yield a mean age of 632.9 ± 7.1 Ma (N = 10, MSWD = 0.09 and probability of fit = 1.00). When these cores are excluded from regression, the ages obtained for both granites are lower, nearly identical, and statistically more consistent (gray Grt-Bt, 605.3 ± 4.5 Ma, N=23, MSWD = 0.87 and probability of fit = 0.64; Grt leucogranite, 602.2 ± 4.9 (N= 19, MSWD = 0.58 and probability of fit = 0.91). We conclude that the higher-Y cores are inherited and therefore the true ages of the studied granites are younger than those obtained from regression from the whole dataset, implying that the age difference between the vein and host gray granite is negligible. Preservation of inherited monazite in granites seems uncommon, but our results should caution against the use of monazite age without careful textural control, especially in anatectic granites. In our case the best-preserved inherited cores are found as inclusion in magmatic garnet from Grt leucogranite 1, where the reaction with melt was limited. The remaining cores are strongly resorbed and only can be dated at the high spatial resolution of EMPA.



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Rheological Control of the Nature of Magmatic Structures

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Most structural studies concerning emplacement mechanisms of granitoid rocks generally result in regional maps at the pluton (or batholithic) scale, where the structural pattern of the granitoid rocks are reconstructed. However, this mapping cannot be achieved without exhaustive field and laboratory works, involving outcrop description and measuring, combined with microstructural observations and anisotropy of magnetic susceptibility (AMS) studies. Thus, a large amount of structural information like foliations, lineations and microstructural data of the igneous bodies, is generated, but only in a few cases the meaning and origin of these structures are addressed. The present paper mostly deals with the significance and genetic aspects of these structures.

The study of magmatic structures is crucial for the understanding the growth and differentiation of silicic magma chamber. We performed field observations and measurements of meter-scale of magmatic structures complemented by AMS studies, to identify and illustrate different structures analyzed from some plutons of the Sierras Pampeanas, central Argentina. We will discuss the rheological state of the magma during their formation and the emplacement of the granitic body. Granitic bodies of the Sierra Pampeanas preserve, in excellent exposures, a series of magmatic structures that formed as magmas stepped through its different rheological states on the way to becoming a solid. These structures include hydrodynamic alignment of crystals and enclaves, interaction between liquids with different composition, large scale flow folds, magmatic banding and shearing, ladder dykes, and pipes, among others. Furthermore, the type of magmatic structures developed depends on their intrusion mode. Plutons that have grown by multi-pulse emplacement, comprising a large number of small magma batches, usually preserve the magmatic structures formed during their growth. Unlike multi-pulse emplacement, plutons crystallized from a few batches of voluminous magma that constitute large batholiths only occasionally preserve the structures developed during their emplacement.



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Petrographic and geochemical aspects of the plutono-volcanic Cambirela Suite, south Santa Catarina Island

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The Cambirela Suite is a plutono-volcanic suite that comprises granitic, hypabyssal and volcanic (pyroclastic and lava, basic and acidic) rocks. This suite is part of the late-stage (*ca.* 590-580 Ma), post-collisional Neoproterozoic magmatism that builds up the Florianópolis Batholith. The study area is located in the southern part of the Santa Catarina Island where the Cambirela Suite is composed of plutonic, hypabyssal and volcanic acid rocks. The plutonic units comprise the Ilha and Itacorumbi granites. Shallow-level units are represented by hypabyssal rocks that sometimes resemble the granites and sometimes the volcanics. The true volcanic rocks are represented by the Cambirela rhyolite and ignimbrite units, and rhyolitic to rhyodacitic dikes. The Ilha Granite is the most voluminous unit of the suite. It comprises biotite syeno- to monzogranites of allotriomorphic seriate or equigranular texture, medium or coarse-grained, with biotite clots; apatite, zircon and allanite are the characteristic accessory phases. This granite commonly presents evidence of brittle deformation and locally it seems to have been strongly heated resulting in back-veining and other evidences of melting. The Itacorumbi Granite is a biotite syeno- to monzogranite of porphyritic texture containing tabular or ovoid K-feldspar megacrystals immersed in a quartz-feldspathic matrix. Fine- to coarse-grained mafic enclaves are widespread and represent a diagnostic feature of this granite. The Cambirela Rhyolite is an effusive-explosive unit, with true rhyolites and highly welded ignimbrites, rheomorphic to lava-like, whose discrimination is not always straightforward. The lavas show porphyritic texture with euhedral quartz, K-feldspar and plagioclase set in fine-grained matrix. The pyroclastic rocks have eutaxitic porphyritic texture, with quartz and K-feldspar phenocrysts, as well as biotite clots set in fine-grained matrix. High amounts of crystals are locally found. The geochemical characteristics of the entire suite are broadly similar, as high SiO₂ (74.67 – 78.76 wt.%) and alkalis Na₂O+K₂O (7-8 wt.%), and low Ca (<1 wt%) contents. The whole-rock geochemical data classify these rocks as calc-alkaline, high-K granitoids, rhyolites to alkali-rhyolites of peraluminous character. Major and trace element contents such as MgO, FeO_t, TiO₂, P₂O₅, Ba, Sr define two distinct groups: (i) the Ilha Granite and one hypabyssal rock sample, with relatively high contents, and (ii) the other suite members, with lower values. These features may be explained by biotite fractionation and minor amounts of quartz-feldspathic matrix contents in the Ilha Granite when compared to the volcanic units. The REE patterns are very similar for all samples, with markedly negative Eu anomalies and (La/Yb)_N ~10 for the volcanics, 5-6 for the Ilha Granite, and ~3-5 for the hypabyssal units. One sample from the Ilha Granite where partial melting is described is anomalous for this ratio (~4). In the Rb vs (Y+Nb) discriminant diagram, the entire dataset plots in the field of post-collisional setting, which is in accordance with the geological data collected and the literature.



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Geology and petrogenesis of syntectonic composite dykes from the Zimbros Bay, Santa Catarina, Brazil

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The Zimbros Bay composite dykes (ZBCD) consist of mafic borders and rhyolite cores, the latter containing swarms of mafic microgranular enclaves similar in composition to the mafic borders. Together with two granite bodies and a large volume of individual rhyolite dikes and few isolated mafic dikes, the ZBCD form the Zimbros Suite (ZS) emplaced at *ca.* 590 Ma, at the waning stages of the Major Gercino Shear Zone transcurrent tectonics. The composite dikes are subvertical, NE-trending, m-thick tabular intrusions. All rock types are strongly foliated, with solid-state deformation restricted to the intrusion borders, and most developed at the contact between the mafic and felsic varieties. Structural relations between mafic enclaves and the foliation indicate emplacement during active dextral shearing, with mylonitic foliation and stretching lineation best developed in the rhyolites. The coeval character of basic and acid magmas within each composite intrusion is given by lobate and mutual intrusive contacts due to rheological inversion, with local evidence that the basic magma from the borders was emplaced shortly after the core ensemble. Ocellar quartz xenocrysts in the basic rocks, and dendritic to cellular plagioclase, mantled by K-feldspar in the felsic ones are interpreted as disequilibrium-related, mingling features. Basic rocks are medium-K tholeiitic, normative-hypersthene basalts, with trace-element patterns similar to OIB. Rhyolites, as well as the granites from the Suite, are A-type, ferroan, metaluminous to slightly peraluminous, with relatively high contents of HFS and RE elements, which is consistent with post-collisional settings. Both basic and acid rocks show compositional features like those of low-Ti types from Paraná-Etendeka LIP. Differences are slight and explained by crustal assimilation in the Zimbros Suite rhyolite dikes. The metaluminous rhyolites from the composite dike cores probably represent contamination of the peraluminous magma by highly-differentiated liquids from basic magmas, in a mixing process that occurred in shallow magma chambers, before final emplacement. The composition of peraluminous rhyolites is consistent with a derivation from the basic tholeiitic magma, through fractional crystallization with concomitant assimilation of crustal melts. Therefore, they are classified as rhyolites of medium-K tholeiitic affinity. Isotopic composition of basic rocks indicates a narrow range of Sr-Nd whole rock data with juvenile signature ($^{87}\text{Sr}/^{86}\text{Sr}_{(i)} \geq 0.7030$; positive $\epsilon\text{Nd}_{(t)} = 0$ to 1). The isotopic signature of rhyolites from isolated dikes and from those in the cores of composite intrusions is compatible with the ones found in late-orogenic granites from the Florianópolis Batholith ($^{87}\text{Sr}/^{86}\text{Sr}_{(i)} \geq 0.7110$; negative $\epsilon\text{Nd}_{(t)} = 3$ to -5), indicating more significant crustal contribution to the source. TDM ages vary from 1.1 to 1.5 Ga.



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Granite-lamprophyre petrogenetic connection in the Southern Brazilian Shield - a case study of the post-collisional Lavras do Sul intrusive complex

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The volcanoplutonic center (≈ 604 -590 Ma), encompassing the Lavras do Sul intrusive complex and the Hilário trachyandesitic sequence, formed in the western foreland during the post-collisional period of the Dom Feliciano Orogeny (640-620 Ma), Southern Brazilian Shield. Volcanic activity, initially controlled by NW-SE and WNW-ESE-striking dextral transtensive systems, started near the orogenic collapse. The intrusive complex was constructed from the north to the south accompanying slip change along the N70-75°W fault zone cutting it across (from dextral to sinistral). It includes: (1) the subvolcanic Tapera monzonite that was disrupted in the south during episodes of caldera collapse or cauldron subsidence controlled by this fault zone; and (2) the Lavras granite formed during events of resurgence also responsible for the uplift of the chamber marginal facies, represented by the Arroio do Jacques K-Mg-rich monzodiorite - a small body between the two intrusions. The Lavras granite consists of two compositional-structural domains evidenced by AMS petrofabric (anisotropy of magnetic susceptibility), which correspond to the central magnesian terms (granodiorite and monzogranite) and the border ferroan ones (syenogranite and alkali feldspar granite) respectively. Its multistage history involves the central laccolith formed through the emplacement of granodiorite beneath the monzogranite sill and annular intrusions of ferroan granites. The latter was formed during the last magmatic events induced by expansion of the high-level reservoir probably due to recharge with lamprophyric mafic-ultramafic magmas, occurring as WNW-ESE to NW-SE dykes (590 ± 2 Ma) in all granites. Most of these lamprophyres, commonly located near Au \pm Cu \pm Ag mesothermal ore occurrences, are potassic rocks ($K_2O > 3$ wt. % and $K_2O/Na_2O = 1$ to 3 mol., for $MgO > 3$ wt. %) varying from typical minette to olivine-rich ultramafic terms. Mafic, amphibole-biotite-bearing terms showing lower K_2O/Na_2O (0.6 to 1.0 mol.) are subordinate. We integrated original and compiled geochemical and Sr-Nd-Pb isotopic data for mafic-intermediate and felsic igneous rocks from the volcanoplutonic center to assess the connection between granites and lamprophyric rocks. Major and trace elements in the latter rocks suggest different enrichment degrees of mantle sources with varied contribution of previous subduction events. Minette and olivine-rich terms have values quite similar of $^{87}Sr/^{86}Sr$ (0.7047 – 0.7050) and variable ϵNd (-1.2 to -4.3) for an intermediate age of 596 Ma, and distinct Pb_i isotopic ratios with the first showing the lowest value. Trachyandesites show comparable $^{87}Sr/^{86}Sr$ values (0.7046-0.7051), but varied ϵNd (-1.2 to -9.7) and lower $^{207}Pb/^{204}Pb_i$ and $^{208}Pb/^{204}Pb_i$. K-Mg-rich monzodiorites have ϵNd and $^{87}Sr/^{86}Sr$ similar to the minette, and show higher Nb/Y, Ta/Yb, Th/La and lower Th/Ta, La/Nb and Ba/La ratios relative to trachyandesites, close to the values of some lamprophyres. Geochemical signatures of the Tapera monzonite and the Lavras granite follow trachyandesites and K-Mg-rich monzodiorites respectively, but most granites show ϵNd and $^{87}Sr/^{86}Sr$ close to olivine-rich lamprophyres. Together Sr-Nd-Pb isotopic and geochemical data reinforce the increasing contribution of lamprophyric mafic-ultramafic magmas or their derivatives during the development of the post-collisional volcanoplutonic center. The crustal contribution apparently more important in relatively early magmatic episodes can be ascribed to processes occurring along the magma-mush



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Magnetic Fabrics of the Piracaia pluton, SE Brazil

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Magnetic fabric and rock magnetism studies were performed on the four units of the 578 ± 3 Ma-old Piracaia pluton (NW of São Paulo State, southern Brazil). This intrusion is roughly elliptical (~ 32 km²), composed of (i) coarse-grained monzodiorite (MZD-c), (ii) fine-grained monzodiorite (MZD-f) which is predominant in the pluton, (iii) monzonite heterogeneous (MZN-het), and (iv) quartz syenite (Qz-Sy). Magnetic fabrics were determined by applying both anisotropy of low-field magnetic susceptibility (AMS) and anisotropy of anhysteretic remanent magnetization (AARM). The two fabrics are coaxial. The parallelism between AMS and AARM tensors excludes the presence of a single domain (SD) effect on the AMS fabric of the units. Several rock-magnetism experiments performed in one specimen from each sampled unit show that for all units the magnetic susceptibility and magnetic fabrics are carried by magnetite grains.

Foliations and lineations in the units were successfully determined by applying magnetic methods. Most of the magnetic foliations are steeply dipping or vertical in all units, and are roughly parallel to the foliation measured in the field and in the rocks which surround the pluton. In contrast, the magnetic lineations present mostly low plunges for the whole pluton. However, for two sites they are steep.

Thin section analysis shows that rocks from the Piracaia pluton were affected by the regional strain during and after emplacement since magmatic foliation evolves to solid-state deformation in the north and south of the pluton, indicating clearly that magnetic fabrics are related to this strain. Otherwise, the lack of solid-state deformation at outcrop scale and in thin sections precludes deformation in the SW of the pluton. This evidence allows us to interpret the observed magnetic fabrics as primary in origin (magmatic) acquired when the rocks were solidified as a result of magma flow, in which steeply plunging magnetic lineation suggests that a feeder zone could underlain this area.



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New Zircon U-Pb LA-ICP-MS ages on the São João Batista Granitic Suite, Santa Catarina state, Brazil

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In the southern Brazilian state of Santa Catarina the Dom Feliciano Belt, formed by the tectonic juxtaposition of different crustal blocks during the Brasiliano-Pan African Orogenic cycle, is divided into three domains. In the central domain, three granitic suites intrude the metavolcanosedimentary sequence of the Brusque Group and its basement, the Camboriú Complex: São João Batista (JSBS), Valsungana (VS) and Nova Trento (NTS), from the oldest to the youngest. This extensive magmatism is responsible for the thermal peak of the sequence's metamorphic evolution.

The SJBS comprises isotropic leucocratic to hololeucocratic, equigranular granites, usually grey to white in color. The presence of muscovite as the main mafic mineral is distinctive of this suite, along with the occasional occurrence of other peraluminous accessories such as garnet and tourmaline. It is intruded by the VS, indicating its stratigraphic position as the oldest intrusive suite. Differently from the other intrusive suites in the Brusque Group, the SJBS had not yet been dated by geochronological methods.

New U-Pb LA-ICP-MS dating of single zircons of the São João Batista (SJBG), Tijucas (TG) and Catinga (CG) granites obtained mean ²⁰⁶Pb/²³⁸U crystallization ages of 606±17, 601±5 and 594±9 Ma. In the SJBG, abundant rounded inherited zircon cores evidence an important contribution from the metasedimentary rocks, with Paleo- (2,00 – 2,21 Ga) Meso- (1,02 – 1,16 Ga) and Neoproterozoic (ca. 750 Ma.) ages. This pattern can be compared to the detritic zircon record of the Brusque Group. Zircon crystals from TG and CG do not show conspicuous rounded nuclei, but have inherited cores nevertheless. The Neoproterozoic record is especially evident in the TG, where they have a mean ²⁰⁶Pb/²³⁸U age of 627,1±7,5 Ma, but the sample contains only a very limited presence of Paleoproterozoic nuclei (ca. 2,15 Ga). Of the three studied rocks, the CG has the smallest record of older crystallization events, with only a restricted Neoproterozoic (638 – 683 Ma) contribution. All three suites show evidence of recent loss of radiogenic material, resulting in some young and discordant spot analyses.

The new crystallization ages add up to the majority of latest ages in the other two suites, which indicate that the granitic intrusions in the Brusque Group took place somewhere in the 590-610 Ma time span. However, field relationships such as intrusive contacts and the presence of xenoliths remain the best criteria for establishing the relative age of the different units. In fact, the available ages shows no evident trend between the three units. This rather scattered behavior suggests that not all granitic bodies belonging to a same suite were emplaced synchronically, and might have had long-lived crystallization histories. Little time, however, has separated each suite's intrusion, reflecting not the time of granite formation but mainly their different crustal level sources.



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Tracing F and Cl concentrations in alkaline felsic magmas

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Fluorine and Cl concentrations in melts have been estimated from whole-rock F and Cl contents, melt inclusions, and halogen containing minerals, notably biotite and apatite. Amphibole and titanite also contain F, and an empirical equation has been developed for F partitioning between amphibole and melt ($D^{F_{\text{amph}}/F_{\text{melt}}} = 1.03 + 0.06 * mg\#$) in alkaline felsic magmas. Amphibole, apatite, and biotite usually form at different times in the evolution and crystallization of magmas and when coupled with the appropriate geothermometers can be used to map the variation of F (and Cl) with magmatic evolution.

The F and Cl content of apatite, amphibole, and biotite from nepheline syenites, syenites and granites of the Chilwa alkaline province (Malawi), granites from western Argentina, and syenites and granites from the White Mountain batholith (New Hampshire, USA) was determined by electron microprobe. Melt F and Cl concentrations were calculated using the model of Webster et al. (2009) for apatite, the empirical equation reported above for amphibole (F only), and the model of Munoz (1992) for biotite.

Chilwa alkaline province (CAP): For the felsic silicate rocks, whole-rock concentrations range up to 0.8 wt.% F and 0.7 wt.% Cl. Cl/F ratios >1 are found for a number of the silica undersaturated felsic rocks while the syenites and granites usually have F/Cl ratios < 1. For the fluorapatites calculated F-melt values fall in a restricted range between 0.25 and 0.30 wt.%. For the biotites calculated F-melt concentrations range from 0.1 to 1.0 wt.%. In almost all cases these values exceed the measured whole-rock concentrations and are generally greater than the F melt concentrations determined from apatite chemistry. The biotites appear relatively late in the crystallization history of the magmas and are thus recording F values for the residual melts.

Argentina granites (AG): Biotite is the principal halogen containing phase. For the San Blas pluton, which contains late stage mineralization, F melt = 0.27 to 0.54 wt.% and Cl melt = 0.03 to 0.11 wt.%. For the Achala batholith, which has associated U mineralization, F melt = 0.13 to 0.33 wt.% and Cl melt = 0.02 to 0.06 wt.%. These values are in the same range as those determined for the granites of the Chilwa alkaline province.

White Mountain Batholith (WMB): The magmas are high T felsic melts and the early crystallizing amphibole generally indicates a high F (0.2-0.7 wt.%) content. With the exception of the Conway granite, (0.6-0.9 wt.% F) the late crystallizing biotites indicate low magmatic F content. Fluorine concentrations determined using apatite are relatively constant (~0.3 wt.%).

The CAP and WMB magmas are inferred to have a dominant mantle component while the AG magmas have a dominant crustal component. The granitoids found in all three provinces fit the A-type definition. Of note is the low F-content of the AG granitoids which implies that F did not play an important role in the formation of the magmas. The chemistry of the F-containing minerals can be used to map the variations in F and Cl in the co-existing magmas.



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Electrical conductivity of granite rocks and thermal structure beneath Tibet

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Magnetotelluric survey (MT) in Southern Tibet indicate a few distinct electrical conductivity anomalies in the crust at the depth 15-45 km. Due to limited experimental constraints, the cause of high electrical conductivity anomalies in the Tibetan crust remains debated. We collected typical granite samples from the Greater Himalayan Complex, the Songduo eclogite belt, the central Tethyan Himalaya, and the Gangdese magmatic arc. They represent medium- to coarse-grained augen granites, leucogranites, migmatites, and granite gneisses, with SiO₂ content varying from 66 to 75 wt.% (52% in amphibolitic melasome of migmatites). Electrical conductivity and dielectric constants of 8 granite samples were measured at pressure 0.6 GPa and in the temperature range of 200-790 °C. The electrical conductivities (σ) of all samples are quite similar and follows an Arrhenius equation: $\sigma = \sigma_0 \cdot \exp(-\Delta E_a/kT)$, where T is in Kelvin and k is the Boltzmann constant. The pre-exponential factor (σ_0) and activation energy (E_a) of electric conductivity of granites vary in the range of 10^1 - $10^{1.66}$ S/m and 0.87-1.03 eV, respectively, which are comparable with the previous measurements of Dai et al. (2014, *AmMin*, 99:1420-1428). Except trondhjemitic leucosome and amphibolitic melasome of migmatites, the relationship between the activation energy (E_a) and the ratio X_a can be fit by $E_a(\text{eV}) = 1.18 - 1.89 \cdot X_a$, where $X_a = (\text{Na}_2\text{O} + \text{K}_2\text{O} + \text{CaO})/\text{SiO}_2$ oxides in wt.%. The dielectric constant, which was measured at high frequencies ($\sim 10^5$ Hz), depends linearly on temperature $\epsilon = \epsilon_0 + C \cdot T$, where ϵ_0 varies between 3 and 8 and weakly increases with the ratio X_a , the constant C is about 0.004 grad^{-1} . The positive temperature dependence indicates an increase of polarizability per unit volume with temperature mostly due to the presence of quartz. Using thicknesses of upper, middle and lower crust determined from seismic observations, the geotherm beneath Tethyan Himalaya and Southern Tibet has been modelled. The estimated conductivity of granites at crustal temperatures (400-700°C) according this model varies between $9 \cdot 10^{-7} - 4 \cdot 10^{-4}$ S/m. The partially molten granites have the electrical conductivity 0.5 order of magnitude higher at $T > 750^\circ\text{C}$. Clearly, these values cannot reconcile with the observed electrical conductivity of $> 10^{-2}$ S/m in Southern Tibet. Combined with recent experiments on electrical conductivity of albite-water-NaCl system (Guo et al., 2015, *EPSL*, 412: 1-9), we propose that fluxing NaCl-rich fluid phase may partially resolve the high conductivity in MT observations, because NaCl aqueous solution with the salinity of 1.2-10 wt% can significantly increase the conductivity of granites by a factor of 10^2 - 10^3 .



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Intraplate alkaline monzogabbros-monzodiorites mixed with A-type syeno/monzogranites and production of expressive hybrid rocks with mixing textures in Neoproterozoic late to post-orogenic and anorogenic settings: An example from Palermo and Rio Negro stocks, Southern Brazil

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Palermo (PG), Rio Negro (RNG) are components of the expressive Neoproterozoic Serra do Mar granite stocks or Graciosa Granitic Province emplaced in extensional late to post orogenic and anorogenic settings, along the central and northern portion of the Archean - Paleoproterozoic Luis Alves Terrane (LAT). The mineralogical, petrographic and lithochemical investigations carried out by many researchers on these granite stocks revealed that they present A-type (alkaline and aluminous) and A/PA-type (slightly alkaline to peralkaline) granite characteristics. The presence of monzogabbros-monzodiorites mixed with granites and expressive occurrence of mafic and felsic hybrid rocks produced by magma mixing were mapped mainly in PG and RNG. The U-Pb zircon ages suggest the period between 595 and 580 Ma for the formation of the all Serra do Mar granitic stocks. The PG is mainly constituted by biotite and amphibole-bearing monzo-syenogranites, biotite and amphibole-bearing quartz-monzonites/quartz-syenites and biotite and amphibole-rich monzogabbros/monzodiorites with surrounding felsic and mafic hybrid rocks. The RNG is constituted by monzo/syenogranites at the margin of the stock and by expressive occurrence of monzogabbros/monzodiorites mixed with surrounding mafic and felsic hybrid rocks in the center. The monzogabbros form by mixing with the adjacent monzo-syenogranites mainly in the RNG, a large variety and chaotically distributed mafic and felsic hybrid rocks with typical mixing textures: quartz-ocelli with or without interstitial perthite mantled by biotite, amphibole and pyroxene; chaotic acicular apatite and rounded and elliptical mafic concentrations containing biotite, amphibole and pyroxene.

The monzo/syenogranites of PG and RNG and quartz monzonites/quartz syenites of PG present xenomorphic textures that suggest initial crystallization of quartz and feldspars and late and interstitial crystallization of biotite, amphibole, zircon, titanite apatite, allanite and fluorite. Mirolitic cavities with fluorite and granophyric intergrowths between quartz and feldspar are common textures that suggest synchronic crystallization of quartz and feldspar in low pressure conditions. These characteristics are typical of worldwide A-type granites. The monzogabbros present interstitial texture characterized by disordered and synchronic crystallization of pyroxene and plagioclase and late interstitial crystallization of biotite and amphibole.

The monzo/syenogranites of PG and RNG are alkaline and aluminous and the quartz-monzonites/quartz-syenites of the PG are slightly peralkaline and all rocks present trace element contents that are typical of A-type within plate granite signatures. The monzogabbros of PG and RNG are alkaline and present trace element content that are typical of within plate signatures such as Within Plate Basalts (WPB), Flood Continental Basalts (FCB) and CRF (Continental Rift Basalts).

The U-Pb zircon dating yielded ages of 593±12 Ma and 593±6 Ma for the crystallization of



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monzo/syenogranites and age of 584 ± 7 Ma for the monzogabbros. The (T_{DM}) ages of the monzogabbros are Paleoproterozoic with less negative $\hat{\text{N}}d^{(T)}$ than the monzo-syenogranites of both granitic stocks. All geological data available suggest underplating, intraplating and crustal contamination of enriched mantle derived monzogabbros and generation of A-type monzo-syenogranites by heating and partial melting of lower crustal sources and bimodal magma mixing in late- to post collisional and anorogenic extensional settings.



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Zircon chronology and geochemistry evidence of different granitoid sources and tectonic regimes in the Upper Paleozoic – Mesozoic evolution of the Central Chile Andes

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In the last decades, several efforts have been made to address the conditions that drive pluton construction and its duration. For this purpose zircon has become a clue petrogenetic phase due its refractory behavior, showing crystallization intervals ranging from tens of thousands of years for small intrusions to millions of years for large igneous bodies. This work is focused on zircon geochemistry and geochronology in order to characterize the magma source and differentiation processes of plutons formed in different tectonic settings.

We present contrasting zircon data from some plutons located in the High-Andes Cordillera and the Coastal Range of north-central Chile. These plutons are thought to be formed at different tectonic stages along the western Gondwana margin, and they can be divided into three groups: (1) Upper Paleozoic (pre-Andean) I- and S- type plutons formed during a compressional arc magmatism (crustal thickening, mantle- and crust-derived magmatism); (2) Late Triassic (transitional) S- and A-type plutons formed during an extensional arrested subduction regime, and (3) Andean Middle Jurassic-Cretaceous, I-type plutons, associated with a extensional subduction.

U-Pb dating of pre-Andean and transitional zircons from S- and A-type granitoids show a complex and protracted zircon crystallization span at sample-scale (up to tens of millions of years), without defining any crystallization peak. Conversely, Andean Middle Jurassic-Cretaceous I-type granitoids, outline Gaussian-shaped age distributions. Zircon geochemistry of pre-Andean and transitional granitoids renders lower Ti concentrations (less than 8 ppm) than Andean zircons (5 - 35 ppm). The first two groups show chondrite-normalized zircon REE patterns with highly enriched LREE values (and poorly developed Eu anomalies), whereas Andean zircons show the opposite. Ce(IV)/Ce(III) ratios of all analyzed zircons are broadly between 5 and 500, exhibiting the highest values in Upper Paleozoic and Middle Jurassic zircons.

Zircon crystallization temperatures of the studied pre-Andean and transitional granitoids (<750°C) are lower than those (between ~720 and ~850°C) of Andean plutons. Moreover, enriched LREE concentrations with slightly low Th/U<0.5 ratios in pre-Andean and transitional S- and A-type granitoid zircons are consistent with more crustal participation under conditions of garnet stability as a residual phase, and differ from low LREE zircons found in I-type Andean granitoids, which exhibit high Th/U>0.5.

Pre-Andean and transitional plutons should account for low-temperature crustal-derived magmas generated for protracted periods in a thickened crust (regardless the possibility of having zircons from different sources). Zircons from Andean plutons would reflect late-stage crystallization, in a continuously evolving magma. The higher Ce(IV)/Ce(III) values observed in the studied zircons of Pre-Andean and Middle Jurassic granitoids could indicate a greater magma oxidation state, probably reflecting source metasomatism, low-pressure volatile exsolution of reduced species (such as H₂ or H₂S), and/or assimilation of oxidized country rocks.



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Timing and mechanisms of sequential granitoid emplacement in collapsing orogens: insights from SHRIMP zircon U-Pb geochronology of the Serre Batholith (Calabria, southern Italy)

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Due to its ideal angle of exposure and internal architecture, the late Variscan Serre Batholith in central Calabria provides a particularly favorable opportunity for investigating the timescales and mechanisms of batholith construction. It represents the central portion of a continuous, and nearly complete, tilted crustal section exposed in its entirety from floor to roof. Further, it is a zoned batholith consisting of several granitoid types that were emplaced at depths ranging from ~23 to ~6 km. Strongly foliated quartz diorites and tonalites appear to have intruded earlier at deep structural levels, whereas weakly foliated to unfoliated tonalites, granodiorites and granites intruded later into higher crustal domains. Intermediate-depth granitoids are represented by two-mica porphyritic granodiorites and monzogranites with K-feldspar megacrysts up to 12 cm long. The uppermost granitoids consist of two-mica granodiorites and granites, grading to Bt±Am granodiorites, that represent the shallowest bodies. The basal quartz diorites and tonalites were emplaced into lower crustal migmatitic metapelites, while the uppermost granodiorites intruded upper crustal paragneisses and phyllites. Five samples, representative of the main granitoid types in terms of both composition and emplacement depth, have been dated by SHRIMP zircon U-Pb. Zircon from a lower crustal quartz diorite from the batholith floor gave an emplacement age of 297.3 ± 3.1 Ma; two middle crustal strongly peraluminous granites, with K-feldspar megacrysts up to 2 and 8 cm respectively, were emplaced at 296.1 ± 1.9 Ma and 294.9 ± 2.7 Ma; a middle-upper crustal two-mica monzogranite emplaced at 294.2 ± 2.6 Ma and, finally, an upper crustal Bt granodiorite from the batholith roof was emplaced at 292.2 ± 2.6 Ma. The difference in age between the lowest and highest granites is 5.1 ± 4.0 Ma (95% c.l.), placing an upper limit of about 9 Ma on the time taken to construct the Serre Batholith. This result supports a model of pluton overaccretion recently proposed for the Serre Batholith after LA ICP-MS dating of one sample from the bottom and one from the top of the batholith. That model envisaged emplacement of the batholith in two main pulses, deeper tonalites at ~306 Ma, and shallower granodiorites at ~295 Ma. We find instead evidence for sequential multipulse intrusion over a shorter period, a minor older (ca. 305 Ma) zircon component in the two-mica granitoids possibly recording incipient partial melting several million years prior to magma genesis. Structural evidence suggests that the emplacement of the first granitoid bodies into the top of the lower crust was tectonically controlled by the activation of a deep-seated shear zone; the shallowest weakly foliated to unfoliated granodiorites being emplaced during the waning stages of the shear zone activity, producing late- to post-tectonic contact metamorphism in the upper crust phyllites and mylonitic paragneisses.



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Paleoproterozoic felsic dykes of Tucumã in the Amazon craton (SW-Pará, Brazil): A-type granitic magmatism in relation with the amalgamation of Columbia supercontinent

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A large intraplate magmatism has covered various areas (1,500,000 km²) of the Amazon craton at ca. 1.88 Ga and defines a large felsic igneous province (SLIP) called "Uatumã event". The plutonic units have been studied in detail (Dall'Agnol et al., 2005. *Lithos*, v. 80, no. 1-4, p. 101-129) in contrast to the volcanic units and related dykes. This pluridisciplinary work aims to study the sheeted dykes complex to make the connection between the different parts of volcano-plutonic system in the province of Carajás. Oriented drill core sample and blocks were collected for rock magnetism, geochemistry and isotope geology. The study of felsic and mafic dykes cutting across the Archean basement near Tucumã (SW-Pará, Brazil) provides new data to constrain this magmatism. The Tucumã felsic dykes likely represent the subvolcanic equivalents of the A-type granites in the area, which were emplaced in relation with the amalgamation of Columbia supercontinent. The exact configuration of Columbia supercontinent is still debated, thus, the relation of this event with the amalgamation of the supercontinent is not yet constrained. Felsic and mafic dykes display field evidence for mingling (mafic enclave in felsic dykes and K-feldspar megacrysts in mafic dykes) suggesting that mafic and felsic magmas were coeval. The felsic dykes are more numerous than the mafic ones. They are ca. 15 m in width and a few hundred meters in length in average. They are made of A-type subsolvus microgranite characterized by subhedral phenocrysts of quartz, alkali feldspar and plagioclase in a quartz-feldspar matrix with granophyric texture. Green biotite is the only mafic silicate. The most frequently observed primary accessories are zircon, titanite and magnetite. Late phases are titanium oxide, ilmenite, allanite, REE-F-Carbonate, xenotime, barite, fluorite, calcite and monazite. Secondary minerals are chlorite, muscovite, albite, epidote, hematite, akaganeite. Syn- to post magmatic hydrothermal fluids involved minerals containing F, REE, and other HFSE type elements. The magnetic susceptibility values range between 100 and 400 μ SI, sometimes up to 1000 μ SI. The Mr/Ms and Hcr/Hc ratios show that the magnetization is carried by pseudo-single-domain (PSD) magnetite grains. Magnetization results from the contribution of a low-coercivity component (primary magnetite) and a high-coercivity component (secondary hematite). The magnetic mineralogy is used here as a proxy to quantify hydrothermal alteration. Felsic dykes are highly silicic (66-78 wt.% SiO₂), with high Na₂O + K₂O, relatively high FeO, low CaO, and very low MgO. They are also enriched in HFSE, and thus are typical A-type magmas. Associated basaltic dykes (49-54 wt.% SiO₂) are tholeiitic in composition. This study allowed to characterize a A-type magmatism for the sheeted dyke of Tucumã. It was shown that syn- to post-magmatic fluids changed the magnetic mineralogy of these dykes and therefore their magnetic properties that allow to quantify hydrothermal alteration. New isotopic data on felsic and mafic rocks are expected and will allow to precise the magmatic sources to build a petrogenetic model for the volcano-plutonic system of Uatumã event.

Keywords: A-type granite magmatism, Paleoproterozoic, Amazonian Craton, SLIP Uatumã, Columbia/Nuna supercontinent.



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Magmatic evolution of Pinheiro Machado Complex in Monte Bonito region, southern, Brazil

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The Pinheiro Machado Complex (PMC) is located in the eastern portion of Dom Feliciano Belt, in the southern segment of the Mantiqueira Province. This Belt was formed during the amalgamation of Gondwana, extending from southern Uruguay to Santa Catarina in Brazil and is considered to be a consequence of the Neoproterozoic collision between the Río de la Plata and Kalahari cratons, associated with the Brasiliano/Pan-African Orogeny. The PMC is part of the Eastern Domain of Dom Feliciano Belt, which represents a large volume of granitoids with subordinate contemporaneous mafic rocks and fragments of Paleoproterozoic basement, exposed along a NE-SW belt. The PMC consists of granitoids (~ 600 Ma) varying in composition from diorites to granites and xenoliths of amphibolites and calc-silicate rocks. Detailed studies in quarries at the Monte Bonito area, show us that the oldest rocks are amphibolite xenoliths, followed by diorite, biotite granodiorite, biotite granite and finally by magnetite granite. The granitoids show multiple intrusive phases giving rise to complex field relationships. There is evidence for mingling and hybridization between diorite and more evolved magmas, suggesting that the process may be at least in part responsible for the observed compositional range of igneous rocks. Further complexity is represented by centimetric felsic segregations in the diorites, including plagioclase and quartz as well as hornblende and titanite. This suggests that these rocks underwent water-fluxed melting, possibly linked with the origin of some of the granitoids. The granitoids belong to the calc-alkaline high-K series with metaluminous affinity, with relative enrichment in K and Al with the evolution of the system, suggesting genesis linked of a mature subduction-related magmatic arc environment. U-Pb zircon crystals of the diorites yielded the age of 618 ± 7 Ma whereas in the youngest rock, the magnetite-biotite granite, zircons yielded the age of 603 ± 6 Ma. Both ages are interpreted as crystallization ages. The titanite age of the diorite is concordant at 586 ± 6 Ma, only slightly younger than the granite zircon age, and mark the diorite magmatic cooling age. Rb-Sr and Sm-Nd isotopic data of the diorites and granitoids indicate mixing between melts derived from pre-existing Paleoproterozoic crust and juvenile material, with initial $87\text{Sr}/86\text{Sr}$ ratios between 0.707 and 0.717 and $\epsilon\text{Nd}(T)$ between - 4.4 and - 6.7, and Nd model ages from 1.4 to 1.6 Ga. In summary we envisage that the quarries at Monte Bonito record prolonged continental arc magmatism lasting between ca. 618 and 586 Ma, where juvenile mantle-derived magmas mixed with crustal material to give rise to the hybrid isotopic signatures, and preserved in mingling relationships. The evolution also included fluctuations in temperature and H₂O content leading to the remelting of older magmatic phases.



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Melt inclusions in zircons from granulite xenoliths of South America. Implications on granite magma generation in the lower crust

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Granitic (*sensu lato*) magma generation is still a controversial issue that needs a thorough testing of the several models proposed. Among currently used models, those implying melting of deep-seated sources at the lower crust are controversial. Most of post-Archaean lower continental crust is dominated by mafic granulites. In order to test the lower-crust melting model we study mafic xenoliths included in Palaeocene alkaline basalts from South America and in lamprophyre dikes in the Iberian massif (Spain). Zircons from granulite xenoliths of Paso de Indios (Chubut province, Argentina) contain melt inclusions that are composed of a high-silica glass (SiO₂ ca. 70 wt.%), orthopyroxene and occasionally K-feldspar. As a whole, granulite xenoliths show the common features of lower crust xenoliths regarding incompatible element depletion (Rb, Li, Zr, REE, etc.), enrichment in Sr and Eu, and a mineral assemblage dominated by the common association Pl, Cpx, Opx +/- Grt, +/- Spl. They typically have metamorphic-like textures with the characteristic polygonal packing that minimizes interfacial free energy in solid-state crystal growth. Also common is the presence of coronitic textures resulting by local reactions in response to changes in PT conditions, namely cooling and decompression. The South America xenoliths record a decompression path from 10 kbar at 1000 °C. Zircon crystals are formed in advanced stages of the melting/crystallization process when the system is saturated in zircon. Melt inclusions in zircons may represent a residual liquid left either after melting of a solid source at the lower crust, or a residual liquid trapped in a magmatic cumulate. The water content in melt inclusion are estimated from mass balance using microprobe data and tested by micro-Raman analyses. The low water content estimates (2-4 wt.% H₂O) is compatible with the high temperature of crystallization. These data rather support an origin of the granulite xenoliths as magmatic cumulates rather than solid residues left after partial melting of a solid source. The melt inclusion study is accompanied with results from an experimental study using the granulite xenoliths from Paso de Indios (Argentina) and the Spanish Central System. Both, experimental results and analytical data from granulite xenoliths are compared with phase equilibrium predictions from MELTS thermodynamic modelling for low SiO₂-high Al₂O₃ granulite systems. The studied xenoliths are also compared with other lower crust xenolith localities from different continental domains.



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Contribution of Columbian and Gondwanian assembly-related magmatism and magma mixing-mingling in the evolution of Meghalaya Plateau, Northeast India: Evidences from field relation, geochemistry and U-Pb SHRIMP zircon geochronology

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Meghalaya plateau is dominantly composed of basement granite gneisses, migmatites, granulites and rocks of Mesozoic-Tertiary Groups. Field relation, geochemistry and U-Pb SHRIMP zircon chronology of granitoids have been carried out in order to understand petrogenesis, supercontinent cycles and growth of Meghalaya plateau through time. High-K metaluminous (I-type) to peraluminous (S-type), post-collision Cambro-Ordovician granitoid plutons intrude the basement gneisses and Shillong Group of rocks. These granitoids are medium to coarse grained phenocryst-free equigranular and porphyritic containing megacrysts of K-feldspar embedded in medium to coarse grained groundmass mainly composed of bt(\pm hbl)-pl-Kf-qtz-mag-ttn-ap. Mafic to hybrid microgranular enclaves (ME) hosted in some granitoids indicate crystal-charged magma mixing-mingling of felsic and mafic magmas derived from crustal and mantle sources respectively, which are also supported by major and trace element geochemistry.

Zircons from granite gneiss of Rongjeng record oldest magmatism at 1778 ± 37 Ma. An inherited zircon core yielded 2566.4 ± 26.9 Ma rimmed by 531 ± 44.3 Ma old zone, which indicate recycled Neoproterozoic crust and Pan-African metamorphic imprint respectively. Zircons from Songsak granitoid yield two ages: one 523.4 ± 7.9 Ma and another 1620.8 ± 9.2 Ma, which indicate partial assimilation of older granite gneiss while ascent and emplacement of younger granitoid melt. Zircons from granite gneiss of Mikir Hill yield crystallization age of 1430.4 ± 9.6 Ma, which metamorphosed at 514 ± 18.6 Ma. Zircons from younger granitoid plutons have yielded mean age for Kaziranga (528 ± 5.5 Ma), South Khasi (519.5 ± 9.7 Ma; 516 ± 9.0 Ma), Kyrdem (512.5 ± 8.7 Ma), Nongpoh (506.7 ± 7.1 Ma), and Myllem (484.7 ± 8.9 Ma; 496 ± 9.4 Ma; 508.2 ± 8.6 Ma), which are products of global Pan-African tectono-thermal event remarkably coinciding with later stage of East Gondwanian assembly at 570-500 (Kuunga orogen) culminating the formation of Gondwana (Pannotia). Inherited core of a zircon from Kyrdem granitoid yields an age of 1758.1 ± 54.3 Ma, and a rim over the core yielded 750.6 ± 35.6 Ma. Another inherited zircon core gives an age of 1134 ± 15 Ma. These ancient inherited zircon cores imply timescale recycling of basement gneissic complex which most likely played significant role in the generation of Cambro-Ordovician granitoids. Zircons from microgranular enclave hosted in Myllem granitoid yield mean age of 529 ± 22 Ma whereas enclave in south Khasi granitoid provides age of 515 ± 13 Ma, which are similar to the ages of respective host granitoids suggesting that mafic (enclave) and felsic (host) magmas were coeval. Some zircons in hybrid ME have rounded (partially dissolved) cores under high-T regime, which appear inherited from protolith but interestingly determine the same ages as observed for magmatic rims grown over the cores. It is therefore inferred that these zircon cores were formed originally in granitoid melt and then mechanically transferred into a hybrid zone during mixing-mingling.



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Meghalaya plateau records major magmatic episodes at ca 1800 Ma, 1600 Ma, 1400 Ma and 500 Ma with recycled Neoproterozoic (2560 Ma) component forming the granite gneisses, and later partial contribution of gneissic sources producing Cambro-Ordovician granitoid plutons with a small input of mafic to hybrid magmas particularly in the evolution of South Khasi, Myllem, and Kyrdem plutons. Meghalaya plateau thus records Columbian and Gondwanian continental affinities during its crustal growth history.



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Transformation of juvenile oceanic arc into mature continental crust:& Neogene granitoid plutons in the Izu Collision Zone, central Japan

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Granitic rocks (*sensu lato*) are major constituents of the upper continental crust. Recent reviews that provide estimates of the composition of continental crust have established that the average composition of the upper continental crust is granodioritic (e.g. Rudnick and Gao, 2003. In: *The crust, treatise on geochemistry*. Oxford. Elsevier-Pergamon, 3, 1–64). On the other hand, intermediate to felsic igneous rocks occurring in the modern oceanic arcs are dominantly tonalitic to trondhjemitic in composition and have lower incompatible element concentrations than the average upper continental crust. Therefore, there is a remarkable compositional differences between juvenile oceanic arcs and mature continental crust although the oceanic arcs are regarded as a site producing continental crust material in an oceanic setting (e.g. Stern et al., 2003. In: *Inside the Subduction Factory*. Geophys Monogr Ser 138, 175–222).

Neogene granitoid plutons are widely exposed in the Izu Collision Zone in central Japan, where the northern tip of the Izu–Bonin arc (juvenile oceanic arc) has been colliding with the Honshu arc (mature island arc) since middle Miocene. The plutons in this area are composed of various types of granitoid ranging from tonalite to trondhjemitic, granodiorite, monzogranite and granite (*sensu stricto*). Three main granitoid plutons are distributed in this area: Tanzawa plutonic complex, Kofu granitic complex, and Kaikomagatake pluton. Tanzawa plutonic complex is dominantly composed of tonalite and trondhjemitic and characterized by low concentration of incompatible elements and shows geochemical similarity with modern juvenile oceanic arcs. In contrast, Kofu granitic complex and Kaikomagatake pluton consists mainly of granodiorite, monzogranite and granite (*sensu stricto*) and have chemical compositions broadly comparable to the average upper continental crust. Previous petrogenetic studies on the plutons have been suggested that (1) the Tanzawa plutonic complex formed by lower crustal anatexis of juvenile basaltic rocks occurring in the Izu–Bonin arc (Kawate and Arima, 1998. *Island Arc* 7, 342–358), (2) the Kofu granitic complex formed by anatexis of ‘hybrid lower crust’ comprising of both basaltic rocks of the Izu–Bonin arc and metasedimentary rocks of the Honshu arc (Saito et al., 2007. *J Petrol* 48, 1761–1791), and (3) the Kaikomagatake pluton formed by anatexis of ‘hybrid lower crust’ consisting of K-rich back-arc crust of the Izu–Bonin arc and metasedimentary rocks of the Honshu arc (Saito et al. 2012. *Contrib Mineral Petrol* 163, 611–629). These studies collectively suggest that the chemical diversity within the Izu Collision Zone granitoid plutons reflects the chemical variation of basaltic sources (i.e., across-arc chemical variation in the Izu–Bonin arc) as well as variable contribution of the metasedimentary component in the source region. These granitoid plutons provide an exceptional example of transformation of a juvenile oceanic arc (represented by Tanzawa plutonic complex) to mature continental crust (represented by Kofu granitic complex and Kaikomagatake pluton) in an ongoing arc-arc collision zone.



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Hydrothermal alteration in the Furnas iron oxide-copper-gold deposit, Carajás Province: evidences of a high-temperature magmatic-hydrothermal system.

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The Carajás Mineral Province, located in the southeastern portion of the Amazon Craton, hosts a variety of world-class iron oxide-copper-gold deposits (IOCG), which have been considered as formed in multiple events during the Neoproterozoic and/or Paleoproterozoic.

The Furnas copper-gold deposit (500 Mt @ 0.7% Cu) occurs along a 9 km-long WNW-ESE trend within the Cinzento Transcurrent Fault. The deposit is hosted by the Furnas granite and metavolcano-sedimentary units of the Neoproterozoic Grão Pará Group, Itacaiúnas Supergroup. The latter are intercepted at the eastern part of the Furnas deposit by the ca. 1.88 Ga Cigano Granite. The footwall zone of the Furnas deposit comprises andalusite-muscovite-biotite-rich rocks, whereas in the hanging wall zone (garnet)-biotite-actinolite-bearing rocks with expressive intercalations of garnet-biotite-rich rocks occur. Relicts of the Furnas granite are also recognized within extremely hydrothermally altered rocks.

All host rocks record intense hydrothermal alteration. The Furnas granite underwent an early stage of sodic alteration (albite) followed by silicification and potassic alteration (biotite), resulting in variably mylonitized quartz- or biotite-rich rocks. Silicification controlled by mylonitic foliation was previous to potassic alteration, as evidenced by biotite crosscutting quartz. However, silicification also overprinted zones with potassic alteration, obliterating the mylonitic foliation and reflecting recurrence of silicification stages.

Garnet-biotite-rich rocks have syn- to post-tectonic almandine porphyroblasts and layers composed of fine-grained euhedral garnet. In some zones, these rocks evolved to garnet-rich rocks made of coalescent garnet crystals, which may represent hydrothermal alteration fronts. Widespread grunerite formation in garnet-biotite-rich rocks and andalusite-muscovite-biotite-rich rocks results in conspicuous grunerite alteration zones with garnet and andalusite “ghost” crystals.

Hydrothermal magnetite formation was expressive, forming rocks composed of up to 50-60% of magnetite. Initially magnetite replaces almandine porphyroblasts and coalescent garnet crystals and also defines thin layers parallel to the mylonitic foliation. Magnetite alteration evolves to partial or total replacement of previous alteration zones with grunerite. Late silicification fronts controlled by brittle-ductile structures are accompanied by proximal coarse-grained hornblende-(actinolite) and distal chlorite halos.

The main copper-gold ore is composed of chalcopyrite and bornite, which occur in replacement fronts in garnet-grunerite-magnetite-rich rocks, veins and veinlets. In silicified zones, bornite and chalcopyrite infill network of fractures and represent the cement of hydraulic breccias within quartz fragments. Minor late mineralization is associated with quartz-(actinolite-chlorite) veins with open-space filling texture.

Alteration styles at Furnas deposit are associated with different deformational regimes and crustal levels, suggesting multiple stages of alteration and mineralization. The succession of almandine, grunerite and magnetite implies in high-temperatures during the early alteration stages controlled by ductile to ductile-brittle structures. Copper mineralization likely occurred at the brittle-ductile and brittle transition. This could point to an evolved hydrothermal system developed at relatively shallow



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crustal levels. Late hydrothermal events possibly were related to fluid circulation associated with the emplacement of the Orosirian Cigano Granite, however the role of the Furnas Granite in the genesis of the high-temperature hydrothermal system should be better evaluated.



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The history of crustal formation and re-organization in relation to episodic granitic magmatism in Southwest Japan

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Southwest Japan has been located since Late Paleozoic at the site where oceanic plate was subducting, but the granitic magmatism has been highly episodic. It is conceived that those pulses of magmatism have formed and re-organized the lower to upper crust of SW Japan. Those magmatism took place at Middle to Late Cretaceous, Paleogene, and Middle Miocene.

The extensive Cretaceous granitic magmatism in SW Japan constitutes a part of the Late Mesozoic circum-Pacific granitic provinces. The Cretaceous granitoids occupy more than 80% of surface exposure area of all granitoids in SW Japan. They include arc-parallel two granitic provinces; integrated volcano-plutonic complexes of San-yo zone on the back-arc side and plutono-metamorphic Ryoke zone on the fore-arc side. A transect across the juxtaposed two zones is regarded as a tilted crustal cross section of a continental margin type orogen. The origin of the granites is mainly mafic lower crust derived from arc-type lithospheric mantle. The upper crustal materials have been involved in the granitic magma to some extent but are not a major component since these granitoids don't include typical S-type ones.

The strong age concentration of the Cretaceous granitoids suggests that they were not formed by the steady-state subduction, but produced under the particular situation such as a collision of oceanic ridge to the trench or a global pulse of relative plate motion. The huge total volume of the Cretaceous granitoids and associated felsic volcanics covering nearly whole SW Japan show the entire re-organization or replacement of the whole crust.

The Paleogene granitic magmatism produced clusters of cauldrons at back-arc side in SW Japan during an extensional stage after the huge Cretaceous magmatic event. Its main component is Eocene granitoids with initial ⁸⁷Sr/⁸⁶Sr ratios of 0.704 – 0.706, which suggests relatively juvenile source material. It is potentially related to asthenospheric upwelling which predates the back-arc opening of Japan Sea. They locally re-organized the crustal materials.

The 14-15Ma shallow-level granitoids are exposed sporadically but widely along the Pacific coastal area of SW Japan, in the more fore-arc side than Cretaceous granitic province. They are short-lived fore-arc magmatism in an anomalous tectonic setting where the opening of the Japan Sea made SW Japan fore-arc sliver obducted southwards over just born oceanic crust of Philippine Sea plate, which realized a geography of virtual subduction zone. As those granitoids were emplaced into young accretionary wedge which developed just above the oceanic crust, they contributed to forming the new arc crust at the oceanward growth front of the arc.

Some of these Miocene granites show S-type-like nature and include xenoliths of migmatites which presumably are highly metamorphosed part of the accretionary complexes. These facts show the involvement of upper crustal sedimentary rocks in the granitic magma generation. But their main origin is not those sediments because the amount of the S-type-like granitoids is below 50% of all those Miocene granitoids and the initial ⁸⁷Sr/⁸⁶Sr ratios of those S-type-like granitoids are much



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lower than that of the accretionary complexes.



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Thermal conductivity versus typology of ediacaran granitoids in Rio Grande do Norte domain, Northeastern portion of Borborema Province (NE of Brazil)

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Along the years many proposals to typological classifications was presented for ediacaran granitoids of Borborema Province, especially in Rio Grande do Norte Domain-DRN, mainly based in geochemistry and petrographic aspects of different plutons studied, however is still possible see in articles some areas of superposition between subtypes/typologies proposals.

Recent studies realised with granitoids from Rio Grande do Norte Domain, show that physical properties of rocks, like density and thermal conductivity can be additional parameters to differentiate typologies of granitoids in Rio Grande do Norte Domain.

In igneous rocks, the thermal conductivity is substantially controlled by mineral composition. One way to obtain the thermal conductivity of rocks, beyond direct measurements realized in laboratory, is through utilization of theoretical models, that could be based in parameters as mineralogical and chemical composition of rocks. For this, is necessary a previous study of theoretical models to validate the results obtained in the reproduction of the values to thermal conductivity experimentally obtained in laboratory.

In this study the estimated thermal conductivity is used as parameter of characterization to different typologies of ediacaran granitoids in the Taipu region, east portion of Rio Grande do Norte Domain, Northeastern of Borborema Province. The thermal conductivity was obtained through the utilization of theoretical models, for a group with 195 samples, based on parameters as chemical and mineralogical composition of rocks. Between the three theoretical models used in this study, the series model was the one showing the most satisfactory results concerning the reproduction of the experimental thermal conductivity through an estimated thermal conductivity, considering an error range of $\pm 10\%$.

From the series model was possible to estimate the thermal conductivities for different types of ediacaran granitoids in the area of Taipu, the granitoids have different medium values for this parameter, Taipu granitoid with $2,92 \text{ W.m}^{-1}.\text{K}^{-1}$, Pitombeira granitoid with $2,82 \text{ W.m}^{-1}.\text{K}^{-1}$ and Gameleira granitoid with $2,49 \text{ W.m}^{-1}.\text{K}^{-1}$. The results obtained show that different types of ediacaran granitoids from this area can be differentiated using the estimated thermal conductivity.



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Geophysical Studies of the Galway Granite Batholith, Western Ireland

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The work presented here is part of the IREThERM project, an investigation into the deep geothermal energy potential of radiothermal granites, sedimentary basins and warm springs in low-enthalpy settings across Ireland. Within this framework, magnetotelluric (MT) data were acquired at 75 locations across the Caledonian calc-alkaline Galway granite in western Ireland. We present an update on the results of 3D inversions of the MT data and the integration of these results with existing gravity and magnetic data to delineate the main structural features of the Galway granite and to constrain the depth to the base of the batholith.

Preliminary 3D inversions of MT data show an electrical resistor associated with the Galway granite extending to depths of 6 km in the area west of the Shannawona Fault Zone (SFZ) and thickening to maximum depths of 11 – 12 km beneath the central block of the batholith, to the east of the SFZ and to the west of the Bearna Fault Zone (BFZ). These observed depths for the granite are in disagreement with previous studies of Bouguer anomaly data across the region which demonstrated a significant thinning of the granite beneath the central block. The previous gravimetric studies were, however, constrained by assigning one density to the whole batholith. Surface density data from across the batholith show that the central block is denser (typically in the range of 2.61 – 2.70 g cm⁻³) than the region of the batholith west of the SFZ (2.59 – 2.66 g cm⁻³). Using these density constraints, the Bouguer anomaly data can be re-interpreted to allow for a greater batholith depth beneath the central block. Recent studies of teleseismic P-wave receiver functions show an elevated V_p/V_s ratio (1.83) at a station on the Galway granite. Interpreted in terms of mineralogical composition, this indicates that the bulk composition of the crust beneath this station, integrated over its entire depth, is depleted in silica compared to the average Irish crust (V_p/V_s of 1.73) and therefore supports the presence of denser mafic rocks at depth.

Preliminary 2D gravimetric forward modelling, constrained by the deeper structures emerging from the MT data, demonstrates that the central block must include denser material at depth. A significant volume of mafic rocks, inferred from the requirement for denser material within the central block, is consistent with the surface geology, with a magma mixing-mingling zone (MMZ) mapped along the axis of the central block. Within the MMZ, mafic sheets and enclaves consist of lithologies ranging from quartz-diorite through diorite to mela-diorite with reported specific gravity up to 2.97.

Further modelling of MT data, Bouguer anomaly data and magnetic data is ongoing to investigate the distribution of mafic rocks, associated with low heat-production, within the batholith. Modelled lithological distributions are being incorporated with heat-production data, thermal conductivity data and geothermal heat flow density calculations to constrain temperature at depth and to assess the geothermal energy prospectivity of the Galway granite batholith.



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Petrography and magnetic susceptibility of the Paleoproterozoic granitoids from the Bacajá domain, Transamazonas Province, northern Brazil

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The Bacajá domain, located in the east central Pará State (northern Brazil), comprises siderian tholeiitic metabasites and several elongated bodies of rhyacian sinkinematic granitoids. Foliated quartz diorites, tonalites, granodiorites, monzo and syenogranites are described. Monzonites and syenites can locally be found. Chemical data point to medium to high K calc-alkaline signature. Both structural and petrological data suggest an continental magmatic arc where magmas are controlled by oxidizing conditions. Magnetic susceptibility (MS) data and mineralogy of these paleoproterozoic granitoids are presented in this paper. The identified oxides magnetite, hematite, ilmenite and subordinately chalcopyrite and pyrite. Amphibole and biotite are the paramagnetic minerals. Primary euhedral sphene are relatively frequent and may locally coexist with magmatic epidote. The later may occur as inclusions within ferromagnesian minerals. Biotite and amphibole may present partial corrosion along the faces parallel to the synmagmatic foliation. Such corrosion features give rise to symplectites which are composed of vermicular fine-grained sphene or magnetite. Symplectites suggest crystallization coeval with deformation under oxidizing conditions and decreasing temperatures. MS values of the granitoids from the Bacajá domain vary from 0 to 0,03503 emu/g. When MS values are compared to opaque modal amounts, magnetite-series granitoids predominate over the minor ilmenite-series rocks. Oxidizing conditions would have predominated during the origin and evolution of the intermediate to acid magmas from the Bacajá domain. Their magnetic behavior and mineralogy are coherent with the continental magmatic arc environment. The geotectonic evolution and crystallization conditions of these magmas are strongly favorable to Cu-Mo porphyry deposits and gold mineralizations.



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THE REWORKED RHYACIAN BASEMENT OF WESTERN GONDWANA: HIGHLIGHTS FROM U-PB GEOCHRONOLOGY

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The Araçuaí Belt is a Brazilian orogenic domain developed during the Gondwana assembly, whose African counterpart is the West Congo Belt. The Araçuaí Orogen basement evolved from the assemblage of Archean and Paleoproterozoic crustal blocks during a Paleoproterozoic orogenic process that lasted approximately between 2.2 and 2.0 Ga. This event marked the consolidation of San Francisco-Congo continental block that was probably part of an extensive Paleoproterozoic continent (e.g. Atlântica Paleocontinent). The ancient Archean cores from San Francisco and Congo were amalgamated along an orogenic belt known as Itabuna-Curaçá-Salvador in Brazil, and Eburnean in Africa. The reconstruction of these orogenic systems was possible along a cratonic connection on both sides of the Atlantic Ocean, the Bahia-Gabon cratonic bridge: a bond that remained from Paleoproterozoic to Mesozoic and was not deformed by the Neoproterozoic orogeny. But the reconstruction becomes much more complex in the dismembered and reworked Araçuaí orogen basement, where the units are exposed in the form of gneissic-migmatitic complex, constituting highly deformed para-autoctonus terrains. This work focuses on the polycyclic evolution of the easternmost unity of the Araçuaí Orogen basement, the Pocrane Complex, composed by amphibolite facies orthogneisses. The Pocrane Complex occurs eastside of the granulitic rocks of the Juiz de Fora Complex, it's composed by a fine-grained, thinly banded biotite-hornblende orthogneisses with deformed porphyroclasts and porphyroblasts of plagioclase and deformed porphyroclasts of quartz-feldspathic aggregates wrapped in fine-grained matrix (suggesting a possible volcanic origin (lato sensu) for unless part of the of the Pocrane Complex). The thickness of the alternating light and dark bands varies from millimetric to centimetric, and concordant amphibolite boudins, lenses and layers are very common. The gneissic banding can be explained either by migmatization and/or by intense deformation of distinct magmatic protholits, where tectonism erased any original discordant contacts between individual bodies and stretched them into concordant layers. Regional gneissic banding/foliation trends N-S to NNE-SSW and is parallel to the Brazilian structures, resulting from intense folding and transposition of an earlier banded structure. Chemically, it's an expanded calc-alkaline, medium to high potassium suit that shows compositional variability, with predominance of granitic to granodioritic terms. Spidergrams shows that the Pocrane Complex orthogneiss presents large ionic lithophile enrichment elements. Crystallization ages ranging from 2.08 a 2.19 Ga. The absence of inherited zircon grains (only one in six samples) and the slightly positive ϵ_{Hf} values link to an island arc environment. The Pocrane Complex discloses an intricate and prolonged magmatic and metamorphic evolution prior to the Pan-African tectonic reworking. This Paleoproterozoic belt represents the external sector of a larger orogen whose internal zones are preserved in the Itabuna-Salvador-Curaçá belt that runs along the eastern side of the São Francisco Craton facing the Atlantic Ocean. Evolution of the Brazilian-Pan African Araçuaí-West Congo Orogen disrupted and deeply reworked a segment of this Paleoproterozoic orogen to the south of the Itabuna-Salvador-Curaçá belt and its African counterpart. Contributions for achieving this task must consider the correlations between basement units of the West Congo Belt and Araçuaí Orogen.



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Interaction between felsic and mafic magmas within the arc middle crust in the Ryoke belt of central Japan: origin of various types of biotite-quartz-bearing mafic plutonic rocks

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The Ryoke belt is distributed along the northern side of the Median Tectonic Line (MTL) of southwest Japan and extends over a length of 700 km from east to west. It consists of a High-*T* Ryoke Metamorphic Complex (RMC) and a Ryoke Plutonic Complex (RPC). The main protoliths of the RMC are sedimentary rocks of the Jurassic Accretionary Complex. CHIME monazite dating of RMC metamorphic rocks yields an age of ca. 100 Ma. The RPC consists mainly of granitic rocks with minor amounts of dioritic and gabbroic rocks, with a CHIME monazite age of 102–76 Ma. It is important to elucidate the heat source(s) of the high-*T* metamorphism and contemporaneous granitic magmatism in order to gain an understanding of island-arc crust evolution. In general, understanding the mafic magmatic processes involved is key to clarifying the heat- and materials-supply system from mantle to crust. In this respect, the possible products of mantle-derived mafic magma in the Ryoke belt are small bodies of gabbroic rocks and mafic magmatic enclaves (MMEs) within the granitic rock. Such MMEs preserve a semblance of the melt composition, but whole rock (WR) compositions of MMEs are generally “evolved”, and thus, primary information relating to the source mantle is unclear. Furthermore, although MMEs and small gabbroic bodies occur closely together, their genetic relationship is unclear.

The WR trace element patterns of MMEs and gabbroic rocks in the study region of the Akechi area, central Japan, are very similar, and derivation from common parental mafic magma is suggested. WR major elements show a compositional trend, but the trend cannot be explained by magmatic differentiation under presumed arc-crustal conditions. The gabbroic rocks commonly contain biotite and quartz with minor amounts of pyroxene, while the MMEs contain hornblende and biotite as colored minerals. Plagioclase (Pl) crystals in gabbroic rocks commonly show a dusty zone along their borders, and a bimodal compositional distribution of ~An₈₀ (core) and ~An₅₀ (rim). However, the Pl in MMEs has a unimodal composition of ~An₅₀. Since the surrounding granite (host of MMEs) contains Pl of An_{35–40}, it is interpreted that an interaction between felsic magma (equilibrium with ~An₃₅ Pl) and mafic magma (~An₈₀ Pl) formed the MMEs, which are thus hybrid magma (~An₅₀ Pl). The WR geochemical variation between the gabbroic rocks, MMEs, and the surrounding granite is well explained by a mixing curve between the mafic end-member of gabbro and granite, and is concordant with features of mineral composition and texture. Therefore, it is concluded that the MMEs and gabbroic rocks were derived from a common mafic magma and biotite- and quartz-bearing various lithologies were formed by an interaction with felsic magma. This conclusion suggests that although the MMEs generally show morphological characteristics of “frozen” mafic magma in outcrops, they have actually chemically interacted in various degrees with the host granitic magma, irrespective of the apparent shape. This study is an important case study considering the evolution of felsic magma and mantle-derived mafic melt in the arc crust.



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Petrology, geochemistry and emplacement of Flores granite pluton, Ediacaran of Borborema Province, (Northeast Brazil)

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The Flores pluton is part of the large granitic magmatism which marks the final stage of the Brasiliano / Pan African in the Borborema Province, being here the subject of geological, petrology, geochemistry and emplacement study. The pluton is located near the city of Afonso Bezerra, in north-central portion of the Rio Grande do Norte State, it occurs in subcircular form with about 8 km² of outcropping area. Geologically, it is intrusive into Paleoproterozoic orthogneiss (Caicó Complex), and augen gneiss granite (the edge Northwest) in Rio Grande do Norte Domain, northern portion of the Borborema Province, Brazilian Northern.

The rocks that compose the Flores Pluton are homogeneous, have texture between fine to middle, pink color, and containing xenoliths from the basement. The main mafic phase is biotite and the accessories minerals are: chlorite, muscovite, zircon, allanite, titanite and opaque. The petrographic analysis classifies these rocks, mainly, as equigranular monzogranites.

Based on sixteen geochemical analysis, mineral chemistry in biotite and K-feldspar, textural and petrographic particulars the Flores Pluton was classified as equigranular high K Calc-Alkaline. The ETRs showing enrichment pattern in LREE, in the liquid, in relationship the HETR, that is characteristic pattern of source from crustal rocks. Based on bi-logarithmic diagram that suggest a magmatic evolution by Fractional Crystallization and the graphic A/CNK that indicate metaluminous affinity is possible inferred that the basement rocks (Caicó Complex) are the parent source of Flores pluton.

U-Pb isotopic analyses (LA-ICP-MS) on zircons gives an age about 545 +/- 11 for the Flores Pluton. Dating, preserved igneous textures, absence of ductile tectonic, and consistence of samples with the trend of monzonitic to high-K calcic-alkaline series all are indications that the Flores granite pluton was emplaced in the context of magmatic complex post-collisional post-orogenic (Brasiliano Orogeny) described in the literature.



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The journey of Tuscan basement blocks from Gondwana to Europe as recorded by U-Pb dating of detrital zircons

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The configuration of the northern Gondwana margin throughout the Paleozoic is difficult to reconstruct owing to the complex tectonic history of the Mediterranean region during the Mesozoic and Cenozoic. Therefore, reconstruction of ages and provenances of potential northernmost Gondwana basement units based on either fossil content or tectonostratigraphic correlations left us with too many uncertainties.

Thus, in this work we performed provenance reconstructions based on U-Pb chronological data of zircons from metasedimentary rocks originally deposited at the Gondwana-Europe transition, such as early Cambrian, Ordovician and Permo-Carboniferous metasedimentary and metavolcanic rocks from Elba Island and mainland Tuscany.

The LA-ICP-MS technique has been applied in order to analyse ca. 1500 detrital zircons from eleven metasedimentary units, and SIMS/SHRIMP have been used to precisely determine the age of two metavolcanic units. Maximum deposition ages are inferred for all units, mainly based on the youngest age probability peak, so that the deposition ages presented here have to be regarded as conservative, robust estimates.

Metasedimentary rocks originally deposited during early Cambrian times on Elba Island and Tuscany were mostly fed by Neoproterozoic African belts, along with a minor Paleoproterozoic contribution from northern African craton(s), mostly seen in Elba sediments. At the middle-late Ordovician transition, a widespread igneous event at the northern margin of Gondwana is traced by metavolcanic rocks in Elba and the Apuan Alps (Tuscany), correlative to a coeval magmatic activity in Sardinia, and linked to the separation of the European Hun terranes from northernmost Gondwana. These igneous materials were soon re-deposited in Elba Island sedimentary basins. The Permo-Carboniferous rocks show the most complex zircon age distribution. The widespread appearance of Permo-Carboniferous zircons stands witness to the erosion of the Variscan orogen, even if the dominant age contribution is still from Ordovician rocks. The minor Neoproterozoic zircon population is a Gondwana/Africa inheritance likely recycled through the European Hun terranes.

In synthesis, African sediments were fed to Elba-Tuscany basins during the Cambrian, until the middle-late Ordovician igneous event marked the shut-off of this supply. At this time, Tuscany/Elba basins were fed by Ordovician igneous materials, joined in Permo-Carboniferous times by Variscan materials along with minor Neoproterozoic African materials recycled through the European Hun Terranes.



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Archean A-type granites from Bundelkhand Craton, India.

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Granitoid associations found in Bundelkhand Craton, India can be categorized into two broad classes, highly deformed Paleo- to Meso-Archean Bundelkhand Gneissic granitoids comprising of migmatized TTG (tonalite-trondhjemite-granodiorite) gneisses and the younger (Neoarchean), relatively undeformed, compositionally variable K-rich granitoids that can be subdivided into several subgroups, one of which is the subject of discussion in this work.

We have studied petrography, whole-rock geochemistry, U-Pb (SIMS) zircon geochronology, and petrology of a granitoid group that shows typical A-type geochemistry. These granites yield U-Pb age of 2546 ± 3 Ma; contain phenocrysts of K-feldspars and quartz in fine grained groundmass with apatite, titanite, Fe-oxides, zircon, and allanite as accessory phases. In thin section, they commonly display myrmekite texture and few samples have ovoid shaped K-feldspar megacrysts that are mantled by oligoclase. In terms of geochemistry, the rocks show consistent A-type character; they are peraluminous, with high contents of silica, K₂O as well as Zr. MgO, Sr contents as well as Mg# are low. Further, these rocks show consistent A-type geochemical character according to several major and trace element classification schemes. The chondrite normalized rare earth elements patterns show enrichment in light rare earth elements compared to heavy rare earth elements with strong negative Eu anomalies (avg. $Eu/Eu^* = 0.30$). In addition primitive-mantle normalized spiderdiagrams of studied samples display negative Ba, Nb, Ta, Sr, P, and Ti anomalies.

Compared to the other granitoids in Bundelkhand Craton, the A-type granites stand out compositionally and must represent different petrogenetic process for their origin. We propose that partial melting of pre-existing continental crust would be capable to produce the observed geochemical composition of the studied rocks. Combined geochemical and geochronological data from all igneous and associated minor volcanic lithologies of relatively unknown Bundelkhand Craton help us to better understand the compositional changes with time. Eventually this will lead us to better elucidation of the crust forming processes operative during Neoarchean in Bundelkhand Craton.



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POST-COLLISIONAL LATE NEOPROTEROZOIC HIGH-BA-SR GRANITIC MAGMATISM OF ADAKITIC AFFINITY FROM THE DOM FELICIANO BELT AND ITS CRATONIC FORELAND, URUGUAY

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New geochemical and isotopic data, and new U-Pb ages are presented for the recently recognized post-collisional, Late Neoproterozoic, high-barium-strontium (HiBaSr) granitic magmatism of adakitic affinity from the southern section of the Dom Feliciano Belt and its cratonic foreland, Uruguay. This group of granitic rocks with distinctive age, mineralogy, and chemistry and field characteristics represents part of the widespread post-collisional Late Neoproterozoic granitic magmatism taking place in Uruguay.

New zircon U-Pb LA-ICP-MS analyses for three of the plutons confirm them as of Late Neoproterozoic age; 648 ± 7.2 Ma (Sierra de los Caracoles) and 604 ± 3.0 Ma (Cortez Blanco) and 597 ± 1.0 Ma (Guayabo). Similar ages were published for Solis de Mataojo Granitic Complex (584 ± 13 Ma) and Las Flores (586 ± 2.7 Ma) and Sobresaliente plutons (585 ± 2.5 Ma).

Mineral assemblages comprise quartz, two alkali feldspars (orthoclase and microcline), plagioclase (Ab₁₀₋₃₀), hornblende, green biotite, apatite, titanite and allanite with rock normative mineralogical compositions plotting on a QAP Streickesen diagram as quartz-monzonite, quartz-monzodiorite, granodiorites and monzogranites.

These HiBaSr granitoids generally bear the hallmark of adakitic rocks (ex. K-continental adakites): high K₂O contents and high K/Na ratio (0.73 to 0.87); relatively high Na₂O (normally > 4.5 wt. %) in intermediate to felsic varieties (SiO₂ > 65 wt. %) decreasing to between 3-4 wt. % for more mafic types; K₂O normally >3.5 wt. % but as low as <2 wt. % for the mafic varieties; they display high abundances of Ba (>700 ppm) and Sr (>500 ppm) and light REEs alongside low Nb, Ta and heavy REEs with negligible to slightly positive Eu anomalies; Sr/Y (33 – 205) and La/Yb (20 – 98) ratios are moderate to high.

High Ba-Sr granitoids of adakitic affinity have been recognized in diverse post-collisional orogenic areas worldwide such as the Northern Highlands of Scotland and Ireland and Tibet Plateau where usually are spatially associated with shear and strike-slip fault systems. In Uruguay, this granitic magmatism seems to be spatially associated with major regional shear zone systems: Sarandi del Yí and Sierra Ballena in the southeastern section of the Dom Feliciano Belt and the Rivera Shear Zone at the Isla Cristalina de Rivera in the cratonic foreland of the country northwest.

Field evidence of coeval mafic and silicic magmatism is generally scarce, although signs of magma mingling and mafic microgranular enclaves are particularly abundant within the Solis de Mataojo Granitic Complex.

Calculated values of ⁸⁷Sr/⁸⁶Sr (0.7077 to 0.7090), ¹⁴³Nd/¹⁴⁴Nd (0.510876 to 0.511058) with very low epsilon Nd = -15.76 to -19.31 at 600 Ma and T_{DMs} of around 2.2 – 2.8 Ga for some of the



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granitic plutons suggest a protracted recycling process from an ancient Paleoproterozoic to Late Archean source.

Thus on the grounds of our current field and analytical data, we suggest that Late Neoproterozoic HiBaSr granitic magmatism of Uruguay is of post-collisional character, shear/strike-slip fault related and mostly generated through the partial melting of lower continental crust.

Keywords: Dom Feliciano Belt, Uruguay, Neoproterozoic, granitoids, Barium, Strontium, adakitic, post-collisional, strike-slip faults, shear zones



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New geochemical and geochronological data from Ediacaran magmatism in Central Ribeira Belt, southeastern Brazil: implications for the assembly of West Gondwana

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Widespread Ediacaran magmatism of the Ribeira Belt is generally interpreted in terms of successive generation of magmatic arcs and accretion of terranes during the evolution of the Neoproterozoic fold-and-thrust belts in southeastern Brazil. This voluminous magmatism includes large high-K calc-alkaline porphyritic batholiths, elongated peraluminous granitic plutons and A-type alkaline to subalkaline plutons. The high-K calc-alkaline batholiths are mostly composed of Bt±Hbl porphyritic granites and granodiorites and occur as large bodies elongated along major shear zones in the entire Ribeira Belt. Syn-tectonic Bt and Ms-Bt granites represent the peraluminous granitic plutons that occur wrapped by the strike-slip shear zones. Two roughly linear belts of A-type subalkaline to alkaline plutons, closely associated with coeval high-K calc-alkaline granitic rocks, characterize the post-orogenic magmatism (Itu and Graciosa provinces) that also includes the Ubatuba Charnockite. Based on new geochemical data and a large compilation of data available for granitoids and mafic rocks of Embu and Costeiro domains, we interpret the S-type magmatism as extensive melting of the middle-upper crust during decompression, as documented by migmatites, while generalized geochemical evidences for hybridization in Hbl granitoids and associated mafic rocks indicate mixing of deeper crustal and mantle-derived magmas. Both magmatic processes occurred simultaneously at 585–575 Ma (new U–Pb SHRIMP zircon data), coeval with A-type and high-K calc-alkaline magmatism of Graciosa and Itu Granite provinces. This timespan was associated with extensional and wrench tectonics characterized by migmatite-cored gneiss domes and wide strike-slip shear system in the Costeiro and Embu domains, respectively. We hence interpret that the widespread magmatism in the whole Ribeira Belt is related to a post-thickening (or post-collisional) extension-related partial melting event affecting the lithospheric mantle and crust, and not to successive accretion events of magmatic arcs. This new interpretation is in agreement with the late Ediacaran-Cambrian Rift System of the southeastern South America.



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Age and Petrogenesis of tungsten-bearing, highly-fractionated I-type granites in the Nanling Range, South China

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The Nanling Range, located in the central part of South China, is the most important W-Sn metallogenic province in China, even in the world. The W-Sn mineralization is genetically related to granites. However, it remains controversial about the age, magmatic source and petrogenesis of these granites. In this paper, we present zircon U-Pb age, geochemical, whole rock Sr-Nd-Hf isotope and zircon Hf-O isotope data of eight typical tungsten-mineralized granitoids in the southern Jiangxi Province, South China to constrain their ages, petrogenesis and relationship with W-Sn mineralization. The granitoids display a differentiation sequence: biotite granite, garnet-biotite granite, muscovite-garnet-biotite granite and garnet-muscovite granite. Among them, the tungsten deposits are generally associated with the last two types. Zircon SIMS and LA-ICPMS U-Pb and monazite SIMS U-Th-Pb dating gives their crystallization ages of 155.4-161.5 Ma, suggesting they are coeval and were emplaced within a short period of less than 6.1 m.y. Geochemically, they exhibit an affinity of fractionated I-type granites, i.e. from metaluminous to weakly peraluminous, having high SiO₂ (74.4-79.2 wt.%) and K₂O concentrations (3.7-6.0 wt.%), low P₂O₅ contents (<0.06 wt.%), and positive correlations between Rb and Th or Y. The W-free granites are enriched in LREEs relative to HREEs with weakly negative Eu anomalies, and depleted in Nb, Ta, P, Ti. In contrast, the W-bearing granites have tetrad REE patterns with evidently negative Eu anomalies and are relatively depleted in Ba, Nb, Ta, Sr, P, and Ti. Further, magmatic garnets mainly consist of almandine and spessartine in composition, exhibiting a specific Mn zoning, i.e., Mn increases from core to the rim. They are stable at shallow depth (<3 kb). The granites are characterised by variable initial ⁸⁷Sr/⁸⁶Sr ratios (0.7053-0.7174), relatively homogeneous ε_{Nd}(t) values of -11.3 to -9.4 and ε_{Hf}(t) values of -12.3 to -10.1 for whole rocks, and negative ε_{Hf}(t) values of -15.5 to -8.6 for zircons with Paleoproterozoic Nd-Hf model ages, suggesting an ancient crustal source for them. Plenty of old zircons and high zircon δ¹⁸O values of 8.0 to 9.6 ‰ suggest contamination of metasedimentary wallrocks. Collectively, all of these geochemical and isotopic characteristics are consistent with the interpretation that, these fractionated I-type granites were mainly derived from partial melting of the infracrustal source rocks, with subsequent crystal fraction and contamination of metasedimentary rock. It is the contamination of metasedimentary materials that increase the W, Sn, Al and Mn concentrations in the evolved granitic rocks, whereas, crystal fractionation induces crystallization of garnet and muscovite and W-Sn mineralization.



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Geochemistry and petrogenesis of Mesoproterozoic A-type granitoids from the Danish island of Bornholm, southern Fennoscandia

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Various granitoids and gneisses from the Danish island of Bornholm in southernmost Fennoscandia have been investigated using whole rock geochemistry, Sr and Nd isotope geochemistry and Hf isotopes in zircon. Recent U-Pb dating shows that these rocks were formed during a short time interval at 1.47 to 1.44 Ga, in spite of highly variable degrees of deformation, suggesting that deformation occurred penecontemporaneously with crystallization (Zarins & Johansson 2009, *Int. Journ. Earth Sci.* 98, 1561-1580; Waight et al. 2012, *Bull. Geol. Soc. Denmark* 60, 23-46). Strong similarity in geochemical signatures indicate that all these rocks belong to a single igneous suite composed of alkali-calcic biotite-hornblende granodiorites or quartz monzonites to more evolved biotite granites, albeit with an apparent gap in SiO₂ content at around 70 wt%, dividing the suite into an intermediate and a felsic part. These dominantly metaluminous rocks are strongly ferroan (Fe* = 0.81-0.93) and potassic (4.3-6.0 wt% K₂O), and with highly elevated concentrations of many incompatible trace elements, traits that are typical for A-type granitoids. They fall in the A₂ subgroup of Eby (1992, *Geol.* 20, 641-644), and in the group of alkali-calcic metaluminous ferroan granitoids of Frost & Frost (2011, *Journ. Pet.* 52, 39-53). Initial whole rock Eps_{Nd} values, calculated at 1455 Ma, range between +1 and -2 (with one outlier at +4), and initial zircon Eps_{Hf} values between +3 and -4, and do not clearly discriminate between relatively juvenile crust and enriched mantle as source. There are no systematic differences in isotope characteristics between the orthogneisses and the less deformed granitoids, suggesting similar origins for both rock types, and no systematic changes in isotopic composition with SiO₂ concentration.

Trace element tectonic discrimination diagrams indicate a within-plate setting, similar to other 1.45 Ga granites in southwest Fennoscandia, in spite of the close relation between magmatism and deformation on Bornholm. We therefore suggest intracratonic A-type magmatism within an active continental shear zone as a tentative model for the Mesoproterozoic magmatism on Bornholm. Ponding of enriched mantle-derived basaltic magma at the crust-mantle boundary or within the lower crust, followed by extensive fractional crystallization and cumulation without any replenishment from below of the magma chamber, in combination with extensive partial melting and assimilation of overlying crustal rocks, may have changed the magma composition from basic through intermediate to acidic and made the magma highly concentrated in incompatible elements, while retaining part of its primitive isotopic signature. Partial melting of mafic rocks in the lower crust, followed by crustal assimilation and fractional crystallization, however may conceivably produce similar geochemical and isotopic signatures.



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Contrasting Precambrian, Paleozoic and Mesozoic cordierite-bearing granitoids in South America

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Neoproterozoic, Paleozoic and Early Jurassic cordierite-bearing granitoids, respectively in Brazil, Argentina and Chile, were emplaced at distinct tectonic environments and structural levels reflected in their mineralogy, geochemistry and host rocks. In the Araçuaí Belt, states of Bahia and Minas Gerais in eastern Brazil, cordierite-bearing monzogranites (760 Ma, $T_{DM} = 1.879$, $\epsilon_{Nd} = -5.15$) of the Nanuque suite intruded mid-crust granulite/metatexites. Syn-collisional Early to Middle Ordovician (Mazan=484 Ma; Capillitas=470 Ma; Sierra de Velasco=465 Ma), post-collisional Late Devonian (Señor de La Peña, 376 Ma) cordierite-bearing granitoids in the Pampean Ranges, western Argentina, intruded greenschist- to amphibolite facies host rocks at shallow depth. Los Tilos pluton (215 Ma) in the Chilean Andes (30°S), part of the Ingaguá Complex, was emplaced at shallow level into early Permian plutons during extensional/ transitional period between contractional Late Paleozoic and mid-Jurassic arc magmatism. Granitoids from Brazil and Argentina are coarse-grained, porphyritic and in plutons at Nanuque, Brazil, cordierite is associated to garnet or appears as β -quartz-cordierite nodules of magmatic origin. Garnet-spinel granulites are mingled with granitoids suggesting in situ partial melting. $La/Yb > 40$ ratios suggest presence of garnet in the source. In the Mazán, Capillitas and Señor de La Peña plutons, Argentina, migmatitic restites in garnet-free granitoids contain spinel, andalusite, muscovite and high amounts of biotite. $La/Yb < 25$ ratios suggest almost absence of garnet in the source and the cordierite from migmatites and granitoids shows similar chemistry but different from that of cordierite produced by contact metamorphism. In the Los Tilos pluton, Chile, rocks are equigranular, coarse- to medium-grained and lack garnet. $La/Yb = 23-30$ ratios suggest presence of garnet in the source. In Los Tilos pluton, cordierite-quartz nodules are similar to those from the Nanuque pluton. Cordierite displays the highest Fe and Mn contents (0.9 and 1.6–1.8, respectively) whereas at Nanuque and Capillitas–Mazán, cordierites exhibit 0.7–0.8 and 0.04–0.4, respectively. Values of zircon $\delta^{18}O$ from 10.9 to 11.8‰ V_{SMOW} were measured in the Nanuque pluton and calculated whole-rock values are 12.8 to 13.7‰. Magnetic susceptibility (MS) ranges from 0.10 to 0.20 $\times 10^{-3}$ SI (ilmenite series) in Capillitas and Mazan plutons, but values as high as 3.0 to 4.8 $\times 10^{-3}$ SI (magnetite series) were recorded in the Señor de La Peña pluton. Values of zircon $\delta^{18}O \sim 9.5$ ‰ and quartz between 9 and 10‰ V_{SMOW} were measured in these rocks and calculated whole-rock values are ~ 10.4 and 11.4‰. MS ranges from 1.40 to 2.5 $\times 10^{-3}$ SI in the Los Tilos pluton and whole-rock $\delta^{18}O$ values (calculated from zircon values) from 6.3 to 9.5‰ V_{SMOW} were determined. High abundance of biotite, cordierite and andalusite and absence of garnet associated to migmatite enclaves in the four plutons from Argentina indicate melting with little migration from the source. Cordierite nodules in Nanuque and Los Tilos plutons could represent near-liquidus mineral assemblages, formed and equilibrated in the source region, and further transported to emplacement levels, under stress regime related to extensional arc plutonism.



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REVIEWING THE STATHERIAN TO CALYMMINIAN PLUTONIC MAGMATISM IN THE CENTRAL DOMAIN, BORBOREMA PROVINCE, BRAZIL

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The eastern part of the Central Domain of Borborema Province, NE Brazil, contains the main record of plutonic activity during the transition from the Paleoproterozoic to the Mesoproterozoic periods (1.7 to 1.5 Ga) in the Central Domain of the Borborema Province. It is represented by orthogneisses from Serra da Barra Suite (1645±20Ma -Sucuru/PB), Carnoió-Caturité Suite (inedit; 1638±13Ma -Barra de Santana/PB) which is associated with the undated Boqueirão anorthosite, augengneisses of Serra de Taquaritinga/PE (1521±7Ma) and by the Passira anorthositic complex (1718±29Ma) and associated Calymnian orthogneisses (Bengala 1.58±0.09Ga; Passira 1.58±0.09Ga and Candiais 1.68±0.1Ga). These rocks cover an area greater than 20,000 Km² and have a northeast trend. They are inferred to have been intruded during an extensional event characterized by intraplate magmatism in Rhyacian/Orosirian basement rocks from the Alto Moxotó and Rio Capibaribe Domains (which are part of Central Domain). This interpretation is consistent with the global statherian tectogenesis event attributed by some authors as the beginning of the fragmentation of the Columbia Supercontinent. Furthermore, east-west-striking, locally garnet bearing granitic gneisses in the northern portion of the Alto Moxotó Domain occur in an area where geophysical background is characterized by sharp change from strong positive to negative gravity anomaly and high to low magnetic anomalies. Inedit U-PB zircon data from the Coloete granite gneiss yield an age at 1611± 15 Ma, interpreted as crystallization age.

This gneiss has syn-collisional/volcanic arc geochemical signature and an $\epsilon\text{Nd}_{(1.6 \text{ Ga})}$ value of -9.47. These characteristics point to a source formed during arc-continent collision with participation of an old crustal component. If this magmatic event represents an important crustal thickening stage, it implies that episodic collision was still occurring during the break-up of Columbia.

Recent paleogeographic reconstructions argue that Columbia Supercontinent was not fully consolidated till 1.53 Ga holding various orogens peripheral to stable margins as seen in the Rondonian-Juruena segments and parts of Laurentia and Baltica blocks. The eastern part of the Central Domain can provide vital geochemical and geochronologic information on the break up history of this pre-rodinian supercontinent wherein the Coloete orthogneisses may either be a part of a dismembered fragment or related to small episodic collision during the break-up event. This magmatic event represent an important crustal thickening stage and a proximal source for the supracrustal sediments as indicated by the detrital zircon population.

KEYWORDS: STATHERIAN, TECTOGENESIS, COLUMBIAN SUPERCONTINENT.



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The Rio Doce magmatic arc revisited (Araçuaí-Ribeira orogenic system, SE Brazil)

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Described half a century ago, the Galiléia tonalite represents the first milestone for the discovery of a calc-alkaline magmatic arc in the Araçuaí orogen. In the late 1990's, geochemical and geochronological studies on the Galiléia tonalite finally provided evidence for the existence of a magmatic arc in the central Araçuaí orogen. Meanwhile, the name Rio Doce magmatic arc was applied to calc-alkaline plutons found in the southern Araçuaí and northern Ribeira orogenic domains. After those pioneer studies, the calc-alkaline plutons showing a volcanic arc signature and age in the range of 630–585 Ma have been grouped under an informal designation, the G1 supersuite, representing the plutonic portion of the Rio Doce arc. In this paper, we revisit the Rio Doce arc with a robust database (302 lithochemical analysis, and 51 U-Pb, 42 Sm-Nd, 25 Sr/Sr and 7 Lu-Hf datasets), including new and compiled data. The G1 supersuite consists of regionally deformed, tonalitic to granodioritic stocks and batholiths, generally rich in melanocratic to mesocratic enclaves, and minor gabbro-diorite-rich plutons. Many enclaves, representing gabbro to diorite autoliths, show evidence of magma mixing processes. The lithochemical and isotopic signatures clearly reveal a volcanic arc formed on a continental margin setting. Major contributions to magma generation are melts from a Rhyacian basement. Gabbroic plutons and enclaves record the minor contribution from mantle magmas. In the northern sector, tonalitic stocks (zircon U-Pb age: 618–575 Ma; ϵ_{Nd} : -5.6 to -7.7; TDM ages: 1,28–1,68 Ga; $^{87}\text{Sr}/^{86}\text{Sr}$: 0.7085–0.7121; ϵ_{Hf} : -5.2 to -11.7) form the northernmost segment of the Rio Doce arc, which dies out in the ensialic sector of the Araçuaí orogen. In a small area of the eastern sector, we found an example of the whole arc development, starting with pre-collisional intrusions, the gabbro-diorite Chaves pluton (age: 599±15 Ma; ϵ_{Nd} : -4.8 to -6.7; TDM ages: 1,48–1,68 Ga; $^{87}\text{Sr}/^{86}\text{Sr}$: 0.7061–0.7068; ϵ_{Hf} : -4.3 to -9.6) and the Brasilândia tonalite (age: 581±11 Ma; ϵ_{Nd} : -8.3 to -10.3; TDM ages: 1,63–1,68 Ga; $^{87}\text{Sr}/^{86}\text{Sr}$: 0.7064–0.7111; ϵ_{Hf} : -12.3 to -14.8), followed by a very late intrusion, the Guarataia granodiorite (age: 576±9 Ma; ϵ_{Nd} : -20.1; TDM age: 1,74Ga; $^{87}\text{Sr}/^{86}\text{Sr}$: 0.7104; ϵ_{Hf} : -12.9 to -21.5). The Muriaé (age: 620±3 Ma to 593±4 Ma; TDM age: 1,41–1,91 Ga; ϵ_{Nd} : -8.4 to -13.5) and Baixo Guandu (621–589 Ma) batholiths, and Conceição da Boa Vista stock (586±7 Ma) represent a segment of the Rio Doce arc correlated to the Serra da Bolívia (620–575 Ma) and Marceleza (618–582 Ma) calc-alkaline plutons, making the link between the Araçuaí and Ribeira orogenic domains. We suggest three phases of arc development: i) eastward migration of the arc front (630–605 Ma), ii) widespread magma production in the whole arc (605–585 Ma), and iii) late plutonism related to the pre-collision to collision transition (585–575 Ma). These phases can be explained by usual processes of volcanic arc generation and growth, like subduction of oceanic lithosphere under a continental margin, followed by asthenosphere ascent related to slab retreating and break-off.



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AN EARLY EDICARIAN MAGMATIC ARC AT THE NORTHERNMOST PART OF THE “TRANSVERSAL ZONE”, CENTRAL DOMAIN OF THE BORBOREMA PROVINCE-BRAZIL

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The aim of this paper is to introduce the concept of an Early Ediacaran magmatic arc (ca. 635-580 My) at the northernmost part of the Transversal zone, the central sub-province of the Borborema Province, northeast South America. This is based on the synthesis of different theses and dissertations, and other papers, carried out on this subject in the last 30 years.

The arc is now positioned between 35°15' and 40°30' W (about 600 km long) and 7°15' and 8°00' S (up to 100 km wide), following a general E-W structural trend.

Based on field, geochemical, petrological and isotopic data, about 80 different stocks and batholiths of I-type granitic rocks have been mapped along this arc. These granitic rocks are preferentially intruded into low grade schists of the Neoproterozoic (Cryogenian-Ediacaran) Piancó-Alto Brígida (“SPAB”) orogenic branching system (but not exclusively).

Three classical supersuites of granitic rocks have since long time been recognized along this tectonic zone: a) epidote-bearing granodiorites and tonalites (“Conceição” type); b) high-K calc-alkaline granites (“Itaporanga type”) and c) trondhjemites (“Serrita”). A fourth group, of per-alkalic and shoshonitic rocks occurs to the south of the previous ones, but they appear to reflect a special tectonic condition, following Paleoproterozoic basement segments, and may represent a superposed (rift-related?) tectonic setting.

The continental part of the lower plate (to the north) is characterized by NNE-SSW trending Paleoproterozoic fold belts, circumscribing important Archean nuclei. The oceanic part of this plate was completely recycled in the mantle by subduction, but some scarce ophiolitic remnants may be seen either among the low grade schist of the “SPAB” or as xenoliths within the granitic (“Conceição” type) intrusions.

The upper continental plate presents a WSW-ENE general structural trend and is composed of Neoproterozoic fold belts (Tonian and Cryogenian-Ediacaran), and with a linear segment of Paleoproterozoic basement, the Alto Moxotó terrain (“TAM”), to the south.

The limit between these two plates is now represented by a boundary transform (“Patos Lineament”) of dextral character, which displays a very important linear belt of tectonites, 5 to 20 km wide (“keirogen”) and more than 600 km long, at the southern edge of the continental lower plate (the so-called Rio Grande do Norte domain). A forearc belt, the Rio Salgado belt, is recognized immediately to the south of the Patos Lineament, comprising a volcanic-sedimentary sequence with meta-andesites and meta-keratophyres.



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NEW GEOCHEMICAL AND ISOTOPIC DATA FROM THE SANTA CLARA INTRUSIVE SUITE, RONDÔNIA TIN PROVINCE: PROPOSING NEW SUITES

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The Santa Clara Intrusive Suite (SCIS) comprises one of the seven suites of the Rondônia Tin Province and is mainly composed of (amphibole)-biotite syeno and monzogranites. The SCIS was already studied by Kloosterman (1966, 1968), Leite Júnior (1992, 2002), Bettencourt et al. (1997, 1999), Leite Júnior et al. (2006), Nogueira (2010, 2012), Quadros et al. (2011) and Nogueira et al. (2013). Some authors suggest that the Santa Clara Suite comprises a subalkaline subsuite, with quartz-monzonites, monzogranites, syenogranites, syenites, alkali-feldspar granites and lithium-mica albite granites, and an alkaline subsuite composed of alkali-feldspar syenites and microsyenites, alkali-feldspar microgranites, peralkaline microgranites, porphyritic granites, alaskites, rhyolites and lithium-mica granites (Bettencourt et al., 1999; Leite Júnior, 2002). According to Quadros et al. (2011), the Santa Clara Suite is composed of seventeen intrusive massifs: Santa Clara, Oriente Novo, Oriente Velho, Massaranduba, Retiro, Moisés, Manteiga, Primavera, Montenegro, Jararaca, Jatuarana and some others bodies with no name so far.

In this work, new unpublished geochemical and U-Pb/Lu-Hf isotopic data are presented and a new subdivision for the Santa Clara Suite is suggested. It is important to highlight that no alkaline nor basic rocks were observed during the mapping and no evidence of magma mixing and bimodal magmatism are described in this work. A total of 87 major and trace elements analysis is now available for the granitoids of the SCIS and, though all the samples show some similarities regarding the major elements patterns, three different groups were identified in the trace elements diagrams. The group "A" comprises the granitoids of the Santa Clara, Montenegro, Oriente Novo, Oriente Velho, Manteiga, Ramos and Primavera massifs. The group "B" is composed of the rocks from the Retiro massif and the group "C" is represented by the granitoids of the Jararaca and Jatuarana massifs. A small SiO₂ compositional gap is also observed between 67,06 and 69,15 SiO₂ wt%. All the 87 analysed samples show negative correlations for Al₂O₃, Fe₂O₃, MnO, MgO, CaO, TiO₂, P₂O₅, Ba, Sr, Zr and Hf, and subtle positive correlations are observed for Rb, Y, Pb, Th and U, in some samples. However, it is important to emphasize that the granitoids of the Retiro massif appear to be different, showing higher Sr, Th and U contents when compared to the others samples. The rocks of the group "C", on the other hand, have low MgO, P₂O₅, Ba, Sr and U contents, though these are clearly more enriched in Y than the granitoids of the groups "A" and "B". U-Pb LA-ICP-MS ages range from 1075±9 Ma (Manteiga massif) to 1138±16 Ma (Jatuarana massif), suggesting a long period of granitic magmatism in the SW Amazonian Craton. Lu-Hf and Sm-Nd isotopic data show negative ε_{Nd} values and Paleoproterozoic T_{DM} ages.



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Archean crustal evolution in the Quadrilátero Ferrífero, Southern Sao Francisco craton (Brazil): constraints from U-Pb and Lu-Hf isotope analyses

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In the Neoproterozoic, the composition of the continental crust experienced a major change, from rocks displaying chemical similarities with Archean tonalite-trondhjemite-granodiorite (TTG) (e.g. low K₂O/Na₂O, high Al₂O₃, (La/Yb)_N, no significant Eu anomaly) to rocks resembling modern calc-alkaline granitoids. This transition is recorded in the Bação and Bonfim complexes of the Archean Quadrilátero Ferrífero district in the Southern São Francisco craton.

Our geochronological data confirm the formation of the basement of the Quadrilátero Ferrífero during three main magmatic pulses at 2.92-2.85 Ga (Rio das Velhas I – RVI), 2.80-2.76 Ga (Rio das Velhas II – RVII) and 2.75-2.70 Ga (Mamona). Combined U–Pb and Lu–Hf data suggest that the two complexes underwent different magmatic evolutions. The ϵ_{HF} values of gneisses and granitoids from the Bação complex show initial superchondritic signatures (+1 to +5) during RVI decreasing to near-chondritic values (-2 to +2) during the Mamona event. These samples plot along a well-defined single array of decreasing ϵ_{HF} with time, suggesting progressive recycling of juvenile crust formed during RVI. Whole-rock geochemistry further supports this interpretation with a clear transition between « primitive » TTG-like gneisses emplaced during the RVI and RVII events and small K-rich granitic domains formed during the Mamona event. The gneisses from the Bonfim complex formed during the RVI and RVII events, display more evolved compositions than rocks from the Bação complex, indicating reworking of an older continental crust. Additionally, the Bonfim complex is characterized by the occurrence of large undeformed batholiths of Ms- and/or Bt-bearing granitoids emplaced during the latest magmatic pulse, chemically similar to K- rich Late Archean calc-alkaline series. These rocks display significantly lower ϵ_{HF} values (of 3-5 epsilon units) than those of the Bação complex, defining a more crustal array with T_{DM} model ages of 3.2-3.4 Ga. This is 200 Ma older than the model ages predicted from the first array, implying a contribution from older crustal components in their petrogenesis.

We suggest that in the Quadrilátero Ferrífero, Paleoproterozoic crust extraction was significantly more important than previously inferred. This idea is supported by old T_{DM} ages in the rocks from the Bonfim complex (up to 3.35 Ga) as well as detrital zircons found in the rocks of the Greenstone belt yielding concordant ages up to ca. 3.5 Ga. In the Neoproterozoic, the RVI and RVII events are characterised by the emplacement of magmas derived by partial melting of basaltic oceanic crust, in concert with substantial recycling of early continental crust (further supported by negative ϵ_{HF} down to -10 in the detrital record). During the post-collisional Mamona event, the reworking of rather unfertile TTG-like crust in the Bação complex generates small K-rich granitic domains, dikes and veins, whereas the production of the more voluminous and crustally evolved calc-alkaline batholiths in the Bonfim complex reflect the involvement of immature meta-sediments in their petrogenesis. The deposition of these sediments, mostly originating from erosion of Paleoproterozoic felsic crust, and their reworking at depth mark the stabilization of this portion of the crust.



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Further constraints on the depositional ages and sources of the Paleoproterozoic Minas Supergroup (Quadrilátero Ferrífero): Tracking the Archean magmatic record in the southern São Francisco Craton

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After the thermal stabilization of the Archean crust in the south São Francisco Craton, the Minas Basin began opening. The infill, the Minas Supergroup, involves a highly deformed 6 km-thick metasedimentary package that registered the track of a Wilson cycle during early Paleoproterozoic times [1]. This passive margin sequence encompasses basal alluvial to fluvial quartzites, open marine phyllites (Caraça Group), banded iron-rich and carbonate rocks (Itabira Group), and coastal clastic rocks (Piracicaba Group). At the top, the sequence evolves into a synorogenic foreland basin (Sabará Group) related to the Rhyacian orogeny [2]. Even though the sequence hosts a world-class iron deposit, the timing of sedimentation and sources have remained elusive. Hf-data combined with U-Pb dating in detrital zircons from the Serra de Ouro Preto are here presented. The base of the Caraça Group, Moeda Fm., yields two main detrital zircon peaks at 2720 and 2870 Ma with the youngest cluster occurring at *ca.* 2665 Ma (N=209). These peaks correspond to the Mamona and late Rio das Velhas I magmatic events [3]. The zircons that belong to these events display ϵHf_t values between -7 and +3 units (N>200), with a superchondritic cluster found for the Rio das Velhas I Event, suggesting a juvenile addition to the crust during this TTG episode. A clastic lens within the overlying BIF (Itabira Group) exhibited a different inheritance with a single peak at 2790 Ma and minor low-frequency Meso and Paleoarchean peaks (N=95). The age of its main population coincides with the climax of Rio das Velhas II magmatic event, displaying sub to chondritic ϵHf_t values (-4 to -1). A single-highly concordant Paleoproterozoic age was found (2453±18 Ma) but it is not fully reliable until more data are produced. On the other hand, an Fe-rich metasandstone of Piracicaba Group, which marks the beginning of the closure of the basin, yields a main peak at *ca.* 2960 Ma followed by a smaller 2870 Ma peak, as well as a wide range of basement ages between 2666 and 3462 Ma (N=80). This pattern contrasts with the populations previously obtained at Serra do Curral [4] and, with the sources found during the opening of the basin. The deposition of Piracicaba has to be younger than the 2.42 Ga Pb-Pb age of the carbonates topping the Itabira Group [5]. The lack of Paleoproterozoic detritus in Caraça, Itabira and Piracicaba groups, reinforces the absence of Syderian magmatic events and the tectonic stability of the area until the inception of the 2.1 Ga Transamazonian orogeny. Moreover, this new Hf isotope dataset supports the hypothesis of an evolved Archean continental crust for the São Francisco Craton.

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Constraining the timing of the Transamazonian metamorphic event in the Southern São Francisco Craton (Brazil) by U–Pb titanite and monazite dating

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The São Francisco Craton (eastern Brazil) is an Archean–Paleoproterozoic block surrounded by Neoproterozoic belts related to the Brasiliano orogeny (ca. 0.7–0.45 Ga) and partially covered by Late Proterozoic platformal sequences. On the southern sector of the craton, domes of Archean gneisses and granitoids surrounded by the Archean Rio das Velhas greenstone belt as well as by the Paleoproterozoic Minas supracrustal sequence are mainly exposed in the Quadrilátero Ferrífero area. Structural analysis reveals two main deformational events (Alkmim and Marshak, 1998. *PR* **90**, 29–58): i) northwest-verging and north–northeast-trending regional-scale folds and thrusts with associated regional low- to medium-grade metamorphism affecting the supracrustal rocks; and ii) domal structures, defined by the basement and surrounded by polydeformed supracrustal rocks, and associated with a medium-grade contact metamorphic aureole. This dome-and-keel structure was formed during the Paleoproterozoic Transamazonian orogeny (ca. 2.0 to 1.9 Ga) based on two lines of evidence. Firstly, a limited number of detrital zircon grains from the uppermost unit of the Minas metasedimentary sequence, which is involved in the folding and thrusting, yielded U–Pb ages as young as 2125 Ma (Machado et al., 1996. *EPS Letter* **141**, 259–276). Secondly, Sm–Nd dates on garnets in the dome-related metamorphic contact aureole yielded an age of 2095±65 Ma (Marshak et al., 1997. *G* **25**, 415–418). However, the age, geographic extent and metamorphic conditions reached during the Transamazonian event in the southern São Francisco Craton are still largely unknown since only few Paleoproterozoic ages have been found in the basement.

To establish the absolute age of Transamazonian metamorphic events, monazite or titanite crystals from different rocks of the Bação, Bonfim and Belo Horizonte Complexes were selected for U–Th–Pb isotope analysis using LA-ICPMS technique. In the Bação Complex, metamorphic ages vary from 2080 to 1940 Ma; however, an upper intercept at around 2.5 to 2.6 Ga is also observed in granitoids and dikes. Moreover, monazite data obtained from one granitoid provided an age identical within error to the crystallization age obtained by zircon analyses (2744±10 Ma; Lana et al., 2013. *PR* **231**, 157–173). In the Bonfim Complex, two gneisses and a granitoid register ages from 2040 to 1964 Ma, whereas a tonalite and an amphibolite record the same magmatic age obtained by zircon (2772±6 Ma and 2719±14 Ma; Farina et al., accepted. *PR*). The preservation of the ages between 2800 to 2600 Ma in these complexes suggests that the metamorphism did not reach the temperature required to reset completely titanite or monazite. In the Belo Horizonte Complex, titanite crystals from an amphibolite dike yield an age of 2066±6 Ma.

The ages obtained for the Transamazonian metamorphic event indicate that this event took place between 2080 to 1940 Ma. These data are well correlated with the age of metamorphism determined for the northern sector of the craton, where zircon ages vary from 2100 to 1900 Ma.

Geochronological data indicate that the regional metamorphism, which results from crustal thickening associated with collision process, took place around 2.0 Ga.

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Evidence for Paleoproterozoic continental crust generation events at 2.15 and 2.08 Ga in the basement of the southern Brasília Orogen, SE Brazil.

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Juvenile crust additions from the mantle can provide important clues about crust generation processes and continental crustal growth. Juvenile rocks generated near the Archean-Proterozoic boundary are of particular interest as this period marks important changes in the crustal growth processes. In this contribution, Paleoproterozoic juvenile rocks of the Pouso Alegre Complex in the basement of the Neoproterozoic southern Brasília Orogen are investigated by a combination of field relationships, petrography, U-Pb geochronology, Nd-Hf isotopes and whole-rock geochemistry. The Pouso Alegre Complex comprises mainly metatexitic tonalitic to granodioritic orthogneisses, with metamafic lenses and boudins. Compositional layering is mostly parallel to the main foliation and is interpreted as a result of reorientation and parallelization of original igneous cross-cutting relationships during later deformation and foliation development. A coarse-grained porphyroclastic granite body is recognized in the northern portion of the study area.

New U-Pb zircon LA-ICP-MS data of eleven samples divide into two main crystallization age groups at 2078.9 ± 6.5 Ma and 2146.7 ± 6.7 Ma (weighted averages for the groups). Older zircon inheritance is almost completely absent. Whole-rock Nd data of fourteen samples show juvenile signatures with T_{DM} ages between 2.16 and 2.37 Ga associated to positive $\epsilon Nd(t)$ values up to +2.85. Zircon Hf LA-ICP-MS data of three analyzed samples are in good agreement with the Nd whole-rock data and all analyzed spots yield positive $\epsilon Hf(t)$ values from +1.87 to +8.66. The Nd and Hf isotopic data together with the absence of inheritance of older zircons are strong evidence of the juvenile character of the Pouso Alegre Complex. The whole-rock geochemical data show arc-related signatures mostly with continental arc affinities. An active continental margin or an evolved accreted oceanic arc are favored as the tectonic setting of the Pouso Alegre Complex because of predominance of felsic rock types. The Pouso Alegre Complex is therefore the southernmost and youngest recognized part of an arc complex emplaced at the southern edge of the São Francisco paleo-continent during the Paleoproterozoic. This was completely reworked by the Neoproterozoic collisional event related to the southern Brasília Orogen. The cratonic counterpart of this arc complex is the Mineiro Belt at the southern portion of the São Francisco craton. The Pouso Alegre Complex and the juvenile suites of the Mineiro belt represent a major continental crust generation event at the southern edge of the São Francisco paleo-continent during the Paleoproterozoic between 2.35 and 2.08 Ga. This study supports the importance of the recognition of reworked juvenile rocks to better constrain models of continental crust generation and preservation.



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Cambro-Ordovician post-collisional granites of the Ribeira Belt, SE-Brazil: geological and geochemical characteristics

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This work presents an overview of the geologic and compositional characteristics of the Cambrian-Ordovician post-collisional (COPC) granites of the central segment of the Ribeira belt, southeast Brazil. These granites make up some of the highest (> 2000 m a.s.l.) and picturesque rocky peaks and cliffs of the Rio de Janeiro state, constituting an accessible case of post-collisional magmatism associated with gravitational collapse of a hot Ediacaran-Cambrian (Brasiliano-Panafrican) orogen. The COPC granites and associated rocks (pegmatite, aplite) pervasively intruded the tonalitic to granitic orthogneisses of the roots of the Rio Negro Magmatic Arc (~790-600 Ma), and of the Neoproterozoic paragneisses of the São Fidelis Group. In amphibolite to granulite facies, these two rock associations make up the Oriental Terrane, which accreted against the former Neoproterozoic passive margin of the southern São Francisco paleocontinent between ~605 Ma and 576 Ma. Syn-collisional melting of orthogneisses and paragneisses generated voluminous granitogenesis of both metaluminous and peraluminous character, many displaying in situ partial melting of the of the country rocks. U-Pb ages of COPCL indicate crystallization ages between ~511 Ma and 470 Ma following the late (ca. 535-520 Ma) accretion of the Cabo Frio Terrane. Regional cooling is given by numerous K-Ar biotite ages widely scattered between 500 Ma and 450 Ma. The 15 largest intrusive bodies in Rio de Janeiro State are referred to in the literature as the Parati, Vila Dois Rios, Pedra Branca, Suruí, Silva Jardim, Mangaratiba, Favela, Andorinha, Frades, Teresópolis, Nova Friburgo, Conselheiro Paulino, São José do Ribeirão, Sana and Itaoca granites. They outcrop as rounded/elliptical stocks or in the form of inclined and subhorizontal sheets, always with sharp contacts with the enclosing rocks. Pegmatite and aplitic veins and dykes are also observed in virtually all outcrops of the host gneisses. Most outcrops display undeformed biotite-bearing leucocratic granite with medium grained equigranular, serial or porphyritic (megacrystic) textures, with Fe-Ti oxides, zircon, apatite, monazite, titanite, allanite as accessory minerals. Primary muscovite also occurs in more peraluminous varieties. Although these rocks did not undergo any tectonic deformation, most display slight to strong magmatic flow foliation. Peripheral xenolith zones are common, as well as isolated xenoliths from the country rocks. Also common but of less clear origin are the mafic enclaves (gabbros and diorites), which display varying affiliations. Some of them display tholeiitic affinity suggesting a bimodal setting of magma generation with magma mingling features. Other ones are calc-alkaline and may be derived from the mafic portions of the Rio Negro Arc. Biotite-rich enclaves are interpreted as assimilation residue. The leucogranites are high-K calc-alkaline rocks with SiO₂ contents (wt%) mostly between 65% and 76%. Metaluminous varieties are predominant and probably derived from the Rio Negro Magmatic arc orthogneisses of tonalitic to granitic composition, as suggested by zircon xenocrysts. In contrast, peraluminous varieties, commonly muscovite-bearing, are related to melting of metapelitic garnet-biotite sillimanite paragneisses of the São Fidelis group. Negative Epsilon Nd values and initial Sr isotope ratios higher than 0.710 indicate predominantly crustal sources.



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Snapshots from a late orogenic collapse: Cambro-Ordovician complex granitoids in the Araçuaí orogen, SE Brazil

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Along the Brazilian Coast deep segments of an Ediacarian-Cambrian orogen (Araçuaí-West-Congo) generated over 150 Ma of successive magmatic episodes.

During the post-collisional stage, mostly calc-alkalic to alkalic plutons intruded older geologic units. Structural mapping of flow patterns, additional geochemical and isotopic data point towards different compositional domains, which have been generated during a time span of 30 to 40 Ma. Results from detailed mapping revealed the architecture of some 10 large plutons in 3-D.

In the silica-richer structures concentric disrupted and folded layers of granite in a K-gabbroic matrix contrast with more homogeneous K-gabbro/noritic regions. These may be separated by stretched filament regions where mixing is enhanced. This process originates hybrid to differentially homogenized rock units. Sharp to pillow-like contacts between granitic and less evolved rocks depict different frozen-in thermal/compositional conditions and distinct intrusive episodes. In the silica-poorer plutonic bodies gradational contacts are more frequent. They may be the result of convection enhanced diffusion. For all plutons, however, mostly sub-vertical internal contacts between most- and least-differentiated rocks suggest generation from large cylindrical to balloon-like magma bodies, which crystallized while crossing the lower to middle crust (< 20 km depth). They have been caught in the act on their way up. Accordingly mushroom- to funnel-like magma-chambers and/or conduits could register snapshots of the interaction dynamics between the contrasting magmas. Different erosional levels along the Araçuaí belt in southern Espírito Santo unravel distinct internal morphologies for each of the individual structures. In general, crustal depth increases from north to south and from west to east, so that small bodies with least evolved cores crop out preferentially in the southern and eastern regions, along a north-south trending corridor.

Metaluminous to peraluminous, tholeiitic, high-K calc-alkalic, I- to A-type granitoids progressively evolve into markedly alkalic to peralkalic rocks. These magmas originated from contrasting sources, involving contributions from an enriched mantle, partial remelting from a mainly metaluminous continental crust and dehydration melting from slightly peraluminous rocks.

Plutonic bodies from this study register the interplay of convective and diffusive processes between granitic and least evolved magmas with the production of hybrid compositions providing, therefore, outstanding evidence for mixing between different sources of magmas. A major decompression episode is thought to have followed the orogenic collapse, which provided coeval production of crust- and mantle-derived magmas changing interaction conditions in space and time from c. 520 Ma to c. 480 Ma.



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Secular trends in Archean felsic magmatism in the Yilgarn and Pilbara Cratons, Australia: implications for Archean crustal growth

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Large geochronological and geochemical data sets for the Paleo- to Mesoarchean Pilbara and Meso- to Neoproterozoic Yilgarn cratons, Western Australia, show that both cratons exhibit similar evolutionary trends in felsic magmatism, providing important constraints on Archean tectonics. The most obvious trend is a transition from sodic magmatism—the ubiquitous tonalite-trondhjemite-granodiorite (TTG) series with their high pressure (high-Al) signature—to potassic magmatism. In the Pilbara craton this transition is marked by two periods of potassic magmatism separated by 50 Myr. In the Yilgarn, the transition is mostly diachronous with potassic magmatism broadly younging to the west, except for one terrane where potassic magmatism begins ~40 Ma earlier. The change from sodic to potassic magmatism is, in part, a continuation of trends observable within the sodic granites themselves, which become more LILE-enriched with decreasing age.

It is also evident in both cratons that sodic magmatism derived from basaltic precursors is not confined to high-pressure formation of High-Al TTGs but includes lower pressure variants. The latter include low-Al TTGs (significant in the Pilbara Craton), and a group with high-HFSE and low- to moderate LILE-contents typical of A-type magmas. In the Yilgarn Craton such rocks form a locally common, often bimodal, association, representing formation at high-temperature and low-pressure. They are not often recognised as belonging to the sodic magmatic group but clearly reflect a magmatic pathway that starts with a largely mafic protolith, albeit at lower pressures and, unlike the low-Al TTGs, higher temperatures.

Another shared trend is the appearance of a diverse group of rocks not unlike those seen in modern-day convergent tectonic settings. These comprise high-Mg diorites (or sanukitoids) (and related rocks), boninite-like rocks, calc-alkaline basalts and andesites, calc-alkaline lamprophyres, but also syenites and monzonites. These rocks appear well after the first appearance of high- (and low-) Al TTGs and are most abundant just prior to major onset of potassic magmatism. In both cratons they are largely confined to younger linear geological terranes or marginal to/within the larger, generally older, terranes, and this, along with their enriched geochemistry permits the interpretation that they tap enriched mantle along crustal-scale structures. Such rocks form a significant local component but overall are not abundant.

The trends documented above are evident in many Archean terranes. The simplest way to explain the variation in the TTGs (high- and low-pressure variants) and the trends from sodic to potassic magmatism is via progressive reworking (maturation) of existing continental crust (for crustal-derived magmatism) and increasing involvement of felsic crust (for non-crustal magmatism). The chemical and isotopic evidence suggests a role for both mechanisms. It is, however, clear that crustal reworking played an early and persistent role in the compositional evolution of both the Pilbara and Yilgarn cratons (and probably Archean cratons in general), suggesting that models advocating a switch from slab-derived TTGs to crustal-derived potassic magmas are too simplistic. The



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appearance of magmas with an arc-like signature suggests that proto-subduction-like tectonic processes operated, at least intermittently, but not necessarily that they dominated Archean crustal evolution and crust formation.



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Further evidence of Early Cryogenian subduction-related continental arc magmatism (777 Ma) in Eastern Dom Feliciano Belt, southern Brazil: the Chácara das Pedras Orthogneiss, Porto Alegre city

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This study presents new SHRIMP U-Pb zircon data to the Chácara das Pedras Gneiss in Porto Alegre, southern Brazil. They represent a small exposure of the crust which was intruded by a large volume of orogenic to anorogenic granitoids in ca. 618-562 Ma in the Eastern Domain of the Dom Feliciano Belt. The Chácara das Pedras orthogneiss is tonalitic and have geochemical similarities with subduction-related magmatic rocks of continental arcs. They present high Sr initial ratios (~ 0.708), negative $\epsilon_{\text{Nd}}(t=777)$ values (~ -8), T_{DM} varying from 1.8 to 2.0 Ga and $^{207}\text{Pb}/^{204}\text{Pb}$ varying from 15.628 to 16.026. The igneous protoliths of these orthogneisses were previously considered to be Paleoproterozoic based on upper intercept age of discordant zircon analyses. In the present study these orthogneisses were re-sampled and re-analysed in an attempt to obtain more concordant analytical data. The U-Pb zircon analyses were carried out using the SHRIMP IIe at the Laboratório de Geocronologia de Alta Resolução of the Universidade de São Paulo. The U-Pb concordia age obtained for igneous textural domains of the zircon grains is 777 ± 4 Ma. A few analyses on zircon rims give poorly defined late Cryogenian ages of ca. 650 Ma. Older ages, mostly discordant, were obtained in a few zircon cores, showing an upper intercept age of ca. 1.9 Ga. One sample of the Três Figueiras Granodiorite, that crosscut the orthogneiss in the same outcrop, was also investigated. The zircons of this granodiorite are, however, mostly metamitic, preventing the determination of a reliable age. Some concordant analyses from a few grains define ages ranging in the interval between ca. 603 and 1,022 Ma. The youngest (ca. 603 Ma) may represent a minimum age for the granodiorite crystallization. Older ages, with discordance $< 10\%$, are of 745, 777, 836 and 1,022 Ma. The 777 ± 4 Ma age obtained for the Chácara das Pedras orthogneiss is the first Early Cryogenian magmatic age determined for granitoids in the Porto Alegre region, although records of similar ages (780-800 Ma) are recognized within the Eastern Domain of Dom Feliciano Belt. Examples are the Piratini Gneisses (Piratini region) and in the Cerro Bori Gneisses (Rocha region, Uruguay). All these units show subduction-related continental arc affinities. The identification of a magmatic event of ca. 780-800 Ma in the Porto Alegre region implies that: (i) the collisional magmatism (650 Ma) is ca. 130 Ma younger than the subduction-related magmatism; (ii) the younger granitoids (< 618 Ma) of Eastern Domain were emplaced in a hot/weak lithosphere due to the presence of Early Cryogenian magmatic arc rocks; (iii) the tectonic evolution of this region in western Gondwana suggest a more complex geotectonic scenario than those put forward by previous models involving the amalgamation of the Rio de La Plata and Kalahari cratons



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REE geochemistry of the Carboniferous Huaco granitic complex, Sierra de Velasco, Argentina
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The REE geochemistry of facies of the Huaco granitic complex, Velasco range (Sierras Pampeanas) of Northwestern Argentina is presented. The Huaco granitic complex has a more or less circular shape and occupies an area of around 1200 km². It has a Lower Carboniferous age and geochemical and geologic features of A-type granites. We can distinguish several petrographic facies within the Huaco complex. Their lithological compositions vary between granodiorite and syeno-monzogranite, but they have notable differences in occurrence, texture and accessory minerals. The identified facies are:

BG –Border Granite- is the border facies of the complex that grades transitionally into the main facies, RPG. It has a slightly porphyritic texture and biotite > muscovite.

RPG –Regional Porphyritic Granite- constitutes the bulk of the Huaco granite. The texture is predominantly porphyritic with ~30-35% megacrysts of perthitic microcline, and the biotite/muscovite ratio is ~2.

APG –Adjacent Porphyritic Granite- is a facies that surrounds Be-pegmatites, which are abundant in the complex. The contact with the RPG is transitional, but with the MAP facies it is sharp. The APG has a porphyritic texture, but the microcline megacrysts are smaller and slightly less abundant than in the RPG. It contains slightly more muscovite and less biotite than the RPG.

MAP –Marginal Aplite of Pegmatite- constitutes the granitic border of the Be-pegmatites. The texture is equigranular and the biotite/muscovite ratio is ~0.3.

LGE –LeucoGranite Enclaves- are small, up to 2 m in diameter, leucogranitic enclaves hosted within the RPG in sharp contact. They have equigranular textures, and biotite and muscovite are found in variable amounts; some contain garnet.

EqG –Equigranular Granite-, are granites bodies hosted in the RPG with dimensions from < 100 m in diameter to over 1 km². The texture is equigranular and muscovite > biotite; tourmaline is often present.

Geochemically, the facies are calc-alkaline and peraluminous (ASI > 1); they show enrichments in LIL and HFS elements.

The ΣREE is higher in the RPG (avg. 236 ppm), followed by the BG (205 ppm), the APG (175 ppm), the EqG (86 ppm), the LGE (68 ppm) and the MAP (13 ppm). LREE > HREE, except for one garnet-bearing sample belonging to the LGE facies.

Chondrite-normalized REE patterns for the BG, RPG, APG and EqG facies are similar, with negative slopes attributed to LREE fractionation by accessory minerals, essentially monazite; the average value of La_n/Yb_n is ~15 for the BG facies and ~9 for the other three. The MAP facies shows a flatter pattern (La_n/Yb_n ~ 2), while the LGE patterns are very irregular, with variable La_n/Yb_n (0.4 – 8.4). The negative Eu-anomaly is notable in all facies (Eu/Eu* < 1), except for garnet-bearing sample of the LGE facies.

In light of the REE geochemistry, the BG, RPG, APG and EqG facies can be formed by fractional crystallization from a common Huaco magma source. Although the granites of the MAP and LGE facies are spatially related to the main phase of Huaco granitic complex (RPG), they seem to have



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had an independent magmatic evolution.



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Ilhabela Precambrian geology and crustal evolution, São Paulo State, SE - Brazil

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Ilhabela is located in the SE-Brazil, north coast of São Paulo State, and is included in the Mantiqueira Province, as part of the Central Ribeira Belt (CRB), West Gondwana. Remarkable NE-SW shear zones, subparallel to the Brazilian coast, characterize the CRB. In a local context, Ilhabela and the adjacent continental areas are designated as Costeiro Domain. The island is a detached continental fragment constituted by Precambrian basement rocks that include gneisses, metasedimentary rocks, migmatites and granitic intrusions. Mafic dikes, three major alkaline syenite intrusions, stratified gabros and trachyte dikes intruded the Precambrian rocks during the Mesozoic.

The Precambrian rocks of Ilhabela were subdivided into: coarse-grained granite gneisses; mesocratic biotite gneisses; fine-grained mylonitic biotite gneisses; leucocratic mylonitic granites; banded gneisses; calcsilicate rocks and foliated porphyritic granitoids. These units, excluding the foliated porphyritic granitoids, are metamorphosed in upper amphibolite facies with a weak retrogression at greenschist facies conditions. The main structural feature is a strong mylonitic foliation (Sn), oriented NE-SW and dipping ~30° towards NW. The stretching lineation associated to Sn is oriented NNE-SSW, gently dipping to both directions. Kinematic indicators suggest sinistral sense of movement with the top to the SSW.

Geochemical studies revealed two groups of granite gneisses, one perquartzous and the other with $60 < \text{SiO}_2 < 70$, but both sodi-calcic with $\text{Na}_2\text{O}/\text{K}_2\text{O} > 1,5$, evidencing properties of TTG metagranitoids, possibly indicative of Archean protoliths. Subordinated felsic mylonites showed distinct geochemical characteristics when compared with each other and with the granite gneisses, pointing to different origins. Pseudoconcordant pegmatitic veins with high Ba and low Pb may have been produced by initial partial melting of the granitic gneisses during late stages of mylonitization. Mylonitic leucocratic granite with low Ba and high Pb, possibly was derived from highly differentiated granitic magma, of unknown origin, that intruded the premylonitic protoliths of the granite gneisses.

The foliated porphyritic granitoids are intrusive in the granite gneisses unit and are characterized by oriented euhedral to subeuhedral phenocrysts of K-feldspar (~5 cm) and antiperthitic plagioclase (~1 cm) and medium to coarse-grained matrix, varying from monzogranite to granodiorite in composition. In these rocks, the major mafic minerals comprise green amphibole, biotite and opaque minerals. Microgranular mafic enclaves, classified as diorite, are common and usually appear stretched concordant with the magmatic foliation. Mingling structures of porphyritic granitoids with mafic magmas were also observed.

First geochemical data of these granitoids were discussed by Meira (2014) in a comparative context of the Ediacaran post-collisional granitic magmatism in the CRB. They are in agreement with generally extensional tectonics, possibly as early magmatic stages of the Ediacaran-Cambrian Rift System of Southeastern South America. Additional geochemical and geochronological studies of the Ilhabela foliated porphyritic granitoids are in progress for further comprehension of this magmatism and the Precambrian geology and crustal evolution of this part of West Gondwana.



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Reference:

Meira, V. T., 2014. Evolução tectono-metamórfica neoproterozóica dos Complexos Embu e Costeiro no contexto de formação do Gondwana Ocidental (leste do estado de São Paulo). Tese de Doutorado, IGc, Universidade de São Paulo. 348 p.

Keywords: Ilhabela basement, Costeiro Domain, Central Ribeira Belt, West Gondwana



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Geochemistry and isotope geology from Cambrian pre to syn-collisional shoshonitic rocks in the Ribeira Orogen (SE Brazil)

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This is a study on a deformed pluton with shoshonitic affinity within the Oriental Terrane of the Ribeira Orogen, a belt made up by a complex collage of reworked basement domains, arc-domains and microplates. The Neoproterozoic Oriental Terrane is considered an arc-domain constituted by magmatic rocks that intrude supracrustal sequences. The studied unit crops out near the contact with the Cabo Frio Tectonic Domain, a Paleoproterozoic terrane attributed to the continental margin of the Congo Craton in Africa that collided with the Oriental Terrane in the Cambrian. This pluton (Tingui Unit) is mostly represented by fine- to medium grained mesocratic biotite hornblende bearing gneisses, quartzdioritic to granodioritic in composition, with quartz, plagioclase, biotite, hornblende, microcline, sphene, apatite, zircon and opaque, showing local migmatization. Tonalitic to granodioritic fine grained dykes cross cut the gneisses with irregular to sharp contacts. These present igneous flow marked by biotite and hornblende aggregates. Geochemical analyses of the Tingui gneisses and associated dikes indicate that these are intermediate to basic rocks with silica content in between 50.16 and 59.71%. Low Fe contents besides high alkalis, Ca, Ba, Sr, Zr and LREE values are comparable to shoshonitic rocks of the literature. In addition, high K₂O/Na₂O (0.79 to 2.06) and LREE/HREE ratios, low Nb contents and lack of negative Eu anomalies, and samples plotting in the shoshonitic field of the SiO₂ x K₂O diagram reinforce this shoshonitic signature. U-Pb zircon SHRIMP data from the Tingui unit were obtained from three samples. The gneiss shows preserved igneous zircons with 530 Ma. Otherwise, two samples from the felsic and mafic phases of the dykes, gave ages at ca. 500 Ma. These younger igneous zircons presented some inherited cores of ca. 530 Ma, the same age obtained for the dated gneiss. Nd data reveal a range of negative E_{Nd} (-13.2 a -4.38) and T_{DM} Nd model ages from the Paleoproterozoic (1.7 to 1.2 Ga). The crystallisation age interval (530-500 Ma) is coeval to the continental collision in the Ribeira Orogen named Buzios Orogeny, in between the Oriental Terrane and the Cabo Frio Tectonic Domain. And the Nd data indicate a Paleoproterozoic mantle extraction with a mixture of mantle and crustal sources. We conclude that this magmatism could be pre- to syn-collisional regarding the Buzios Orogeny. This is compatible with the field evidence that exhibits partial melted portions of the older magmatic phases (pre-collision nature) and also the igneous orientation of the younger magmatic pulses, the felsic and mafic dykes (syn-collision nature). In addition, a calc-alkaline pluton is also coeval with the Tingui gneiss (Marica pluton). The heat that generated this shoshonitic magma could still be related to the dehydration of a subducting slab and its subsequent break off. The Tingui Unit cross cuts all para- and ortho-derived gneisses from the Oriental Terrane. It is clear that the occurrence of these basic to intermediate magmas residing on this continental crust contributed to the high temperature metamorphic event that melted all Neoproterozoic units.



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Continental growth through accreted oceanic arc: Zircon Hf-O isotope evidence from granitoids in the Qinling orogen

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The continental crust is commonly viewed as being formed in subduction zones, but there is no consensus on the relative roles of oceanic or continental arcs in the formation of the continental crust. The main difficulties of the oceanic arc model are how the oceanic arcs can be preserved from being subducted and how the oceanic arcs can generate the high-Si-K granitoids with similar composition to the upper continental crust. The eastern Qinling orogen provides an optimal place to address this issue as it preserves the well-exposed Erlangping oceanic arc with large-scale of granitoids. In this study, we present an integrated investigation of zircon U-Pb age and Hf-O isotopes for four granitoid plutons in the Erlangping unit. In situ zircon SIMS U-Pb dating gives that the emplacement ages of the Zhangjiadazhuang, Xizhuanghe, and Taoyuan plutons were 472 ± 7 , 458 ± 6 and 443 ± 5 Ma, respectively, postdated the accretion age (UHP metamorphic age of ca. 490 Ma) of the Erlangping intraoceanic arc onto the Qinling microcontinent. The Zhangjiadazhuang, Xizhuanghe and Taoyuan granitoids are sodic and have highly positive $\varepsilon_{\text{Hf}}(t)$ (7.91 to 13.27) and relatively low $\delta^{18}\text{O}$ (4.76 to 5.02‰) values, which were suggested to result from prompt remelting of the Erlangping juvenile oceanic arc crust that had been hydrothermally altered by seawater at high temperatures. The Manziying monzogranitic granitoids have similar zircon Hf-O isotopic compositions to those of the Xizhuanghe pluton, indicating that they were likely derived from dehydration melting of previous tonalites as exemplified by the Xizhuanghe pluton. The formation of the early Paleozoic granitoid plutons can be divided into two stages (ca. 475-460 and 450-410 Ma). The first stage of granitoid magmatism was suggested to result from the break-off of the subducted Prototethyan oceanic slab soon after arc-continent collision, and the second stage was ascribed to the northward subduction of the Prototethyan Ocean along the Shangdan suture. Overall, arc-continent collision provides an effective way for preventing oceanic arcs from being completely subducted. Moreover, the highly positive $\varepsilon_{\text{Hf}}(t)$ and relatively low $\delta^{18}\text{O}$ values for zircons from the granitoids in the Erlangping unit reveal that the continental crust can acquire its high-Si-K nature from oceanic arcs through differentiation by post-accretional magmatism, and thus highlight the significance of oceanic arcs in generation of continental crust.



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Tonian granitic magmatism of the Borborema Province, NE Brazil: A review

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Tonian granitoids, today augen-gneisses and migmatites, showing crystallization ages ranging from 851Ma to 1000Ma (Cariris Velhos event) occur in the Borborema Province, NE Brazil. The majority of them have ages within the interval 925 - 970Ma. Few intrusions with ages of ~1.0Ga and within the 851Ma - 870Ma interval occur in the Central and South domains. In the Central Domain, most of the studied granitoids (herein CVG -Cariris Velhos granitoids) constitute a 50 to 100 km wide belt that extends for more than 700 km west-southwestwards from the Atlantic coastline, within the Alto Pajeú Domain. The CVG intrude slightly older bimodal (but mostly felsic) volcanic successions and metasedimentary sequences. More recently, several occurrences of CVG were identified in the South Domain. They include granitoids from the Riacho do Pontal Belt (Afeição orthogneisses), migmatites (Poço Redondo), and augen-gneisses (Serra Negra Pluton) of the Poço Redondo-Marancó Domain (Sergipano Belt) and orthogneisses and migmatites from the PEAL Domain. CVG are unknown in the North Domain. The CVG comprise mainly coarse-grained augen-gneisses of granite to granodiorite composition. Fe-rich biotite (annite) is the main mineral mafic phase, constituting up to 15% of the mode. Garnet, muscovite and tourmaline occur as accessory phases in many plutons. The CVG augen-gneisses have high SiO₂ (>71%) and alkali contents, vary from slightly peraluminous to slightly metaluminous, and from slightly magnesian to typical ferroan. Trace element variations in the CVG are likewise extensive, reflecting the migmatization recorded in some plutons. They are Ca-, Sr- and Nb-poor, show variable Ba (100 - 1260 ppm), Rb (164 - 400 ppm) and Zr (144 - 408 ppm) contents and high abundances of Y (> 40 ppm). The chondrite normalized REE patterns are characterized by (Ce/Yb)_N ratios ranging from 2.5 and 10.0 and strong to moderate negative Eu anomalies (Eu* = 0.23 - 0.70). The spidergram patterns show deep troughs at Ti, P, Ba and Sr and less pronounced Nb-Ta troughs. These patterns are reported in anorogenic granites evolved from mixtures of magmas from both crustal and mantle sources. Most of the studied CVG have similar geochemical signatures. Some geochemical differences do occur and they are interpreted as reflecting migmatization and/or distinct sources. The CVG exhibit T_{DM} model ages ranging from 1.9 to 1.1Ga, with slightly negative to slightly positive εNd(t) values, suggesting the involvement of distinct proportions of mantle and crustal components in the source of their protholiths. ¹⁸O/¹⁶O data reported in one CVG sample from the South Domain, suggest typical mantle component.

There is no consensus in the literature about the tectonic setting of the CVG. The CVG with crystallization ages < 970Ma are interpreted as related to either continental margin magmatic arc, with possible back-arc association or rift-related. The CVG, with crystallization ages within the 980 - 1000Ma interval, are interpreted as either continental arc, syn collision or rift-related. Thus, the CVG geotectonic environment is not yet clear and needs further improvements.



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Granitoids intruded along E-W trending shear zones in the Borborema Province, NE Brazil

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Large volume of granitic magmatism associated with large-scale shear zone and metamorphism under high-T conditions, characterize the Brasiliano/Pan African Orogeny in the Borborema Province, NE Brazil. Granitoids from plutons and late dykes intruded along the dextral sense E-W trending Coxixola – Timbaúba (CTSZ) and Remígio Pocinhos shear zones (RPSZ) show distinct crystallization ages and geochemical signatures. The oldest granitoids (U-Pb zircon SHRIMP age of 618 ± 5 Ma), Serra de Inácio Pereira (SIPP) and Timbaúba (TIP) plutons intruded along the CTSZ and the Curral de Cima Pluton (CCM) intruded along the RPSZ are epidote-bearing granites. They have high (6 wt%) alkali contents, K_2O/Na_2O ratios <1 , are metaluminous to slightly peraluminous with $A/CNK \sim 1.1$. They show medium to high Zr (321 a 378 ppm), low Y (19.5 a 25.4 ppm) and Nb (14.7 to 17.0 ppm) contents. Their REE patterns are characterized by small or absent Eu anomalies ($Eu/Eu^* = 0.92 - 1.15$) and $(Ce/Yb)_N$ ratios ranging from 28.34 to 40.09. In contrast, the granitoids showing crystallization age of ~ 570 Ma, intruded along the CTSZ (Serra do Marinho, Serra Branca, Coxixola and Aroeiras plutons) and intruded along the RPSZ (Pilõezinhos Pluton) have higher Zr (755 to 846 ppm), Y (40 to 75 ppm) and Nb (39 to 51 ppm) contents compared to the values recorded in the oldest (618Ma) granitoids. The granitoids of the Serra Branca Pluton share some geochemical characteristics, although it has much higher Nb contents. This group of intrusions have REE patterns less fractionated, with $(Ce/Yb)_N$ ratios ranging from 6.6 to 20.2, and characterized by negative Eu anomalies ($Eu/Eu^* = 0.39 - 0.59$). Rapakivi granitoids occur as dykes, 30 m wide in average, and are cut by dykes of leucogranites, with crystallization age of 527 ± 6 Ma and A-type geochemical signature. They occur only intruded along the CTSZ. Leucogranites occur as dyke swarm, along the CTSZ, showing a general NE- SW trending. They were emplaced after the rapakivi granites, during extensional event. Zircon grains, analyzed from the rapakivi granites, show concordant ages at ~ 500 Ma. This age are probably related to the leucogranites intrusions. Dyke swarm of pegmatites intruded according to a NW-SE trending, along the CTSZ, constitute the later intrusions recorded in the area. However, we cannot discharge up to now, that they have the same age of the leucogranites. The ages of the oldest granitoids, associated to migmatization recorded in the TIP and SIPP, and flat-lying foliation recorded in these plutons, suggest that they are coeval with the peak of regional metamorphism. The granitoids of Serra do Marinho, Aroeiras and Serra Branca plutons show geochemical signature of post-collisional A-type granites. The rapakivi granites have geochemical signature of A-type granitoids and their intrusion ages suggest that they are coeval with the deposition of small sedimentary interior basin. The data suggest a long history of magmatism along the CTSZ, However, the magmatism along the RPSZ appears to have stopped about 570 years ago.



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Paleoproterozoic arc and collisional magmatism in central Brazil: a Rhyacian orogeny recorded in Brasília Belt basement

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Paleoproterozoic rocks in Brasília Belt are interpreted as basement of sedimentary layers deposited from Meso to Neoproterozoic. Sedimentary rocks and the older basement were metamorphosed and deformed in Neoproterozoic during Brasiliano Orogeny, when São Francisco, Amazonian and the conjectural Paranapanema cratons collided.

Rocks in the basement of Brasília Belt are volcano-sedimentary sequences in which tonalites, granodiorites and granites are intrusive. U-Pb analyses indicate Rhyacian ages for magmatic crystallization of plutonic bodies. Ages vary from 2.12 to 2.46 Ga, but during this interval, at least two different types of magmatism are recognized.

The older tonalites and granodiorites, of ages between 2.16 and 2.46 Ga, evolve through calc-alkaline trend, by enrichment in potassium, have Volcanic Arc Granite signature and $\epsilon\text{Nd}(t)$ values are near zero. These rocks are metaluminous or slightly peraluminous and belong to Conceição do Tocantins suite.

In contrast, the younger rocks (2.12 to 2.17 Ga) are mainly granites, do not present a clear evolutionary trend and have higher contents of potassium. They belong to Aurumina suite, are clearly peraluminous and have $\epsilon\text{Nd}(t)$ values strongly negative.

Data converge to the interpretation of these rocks as formed in an orogenic episode during Rhyacian. First, tonalites and granodiorites intruded an arc system between 2.46 and 2.16 Ga, forming Conceição do Tocantins suite. Then, collision of landmasses triggered crustal melting, generating syn-collisional peraluminous granites of Aurumina suite.

Thus, as Brasília Belt's basement is considered a prolongation of São Francisco craton underneath thick sedimentary layers of the belt, the Paleoproterozoic arc probably developed in the western margin of São Francisco craton during the convergence of another landmass. During the Rhyacian, São Francisco did not behave as a cratonic entity yet, but existed as a recently formed sialic core. It is still unknown what is the landmass which convergence produced arc magmatism and resulted in collision against the craton, although Goiás Archean terrane is a consistent candidate.

This Rhyacian orogeny seen in Brazil is coeval with continental agglutination during the transition Paleo-Mesoproterozoic described in other parts of the world and responsible for the formation of a supercontinent pre-Rodinia.



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Origin of I- and A-type granites from the northeastern coastal area of Zhejiang Province, SE China: Constraints from zircon U-Pb ages, whole-rock geochemistry and Nd-Hf isotopes

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The Cretaceous regional extension geology of the coastal area of Fujian and Zhejiang provinces, SE China, is characterized by sporadically distributed A-type granites within voluminous I-type granites along the Changle-Nan'ao Fault. Despite many recent studies done in these granites, their petrogenesis especially concerning the genetic link between the I- and A-type granites remains poorly constrained. In order to contribute to such discussion, we report zircon U-Pb ages, major and trace element geochemistry, and Nd-Hf isotopic data for granitic plutons from the northeastern coastal area of Zhejiang Province, with the aim of understanding their petrogenesis and the genetic link between the I- and A-type granites.

The studied granites are exposed in the Zhoushan archipelago and occur roughly in a NNE-trending belt that contains five main plutons (from north to south): the Putuoshan (PTS), Dadong'ao (DDA), Daqingshan (DQS), Taohuadao (THD), and Xiazhidao (XZD) plutons. The PTS and DDA plutons, consisting mainly of alkali-feldspar granites, are I-type, whereas the DQS, THD, and XZD plutons, composed mainly of peralkaline granites, are A-type, as indicated by the presence of Na-rich mafic minerals (e.g., aegirine and arfvedsonite). LA-ICP-MS zircon U-Pb dating yields ages of 97.6 ± 0.9 Ma (MSWD=0.26, 2σ) – 95.8 ± 1.0 Ma (MSWD=0.87, 2σ) for the I-type plutons and 89.2 ± 1.0 Ma (MSWD=0.74, 2σ) – 86.1 ± 0.8 Ma (MSWD=0.26, 2σ) for the A-type plutons. All the granites are highly evolved with differentiation index (D. I.) values ranging from 93 to 98. Compared with the I-type granites, these A-type granites have higher SiO₂, FeO*, Nb, Zr, Hf, Ga, Rb/Sr, and Ga/Al, and lower Al₂O₃, MgO, CaO, Sr, Ba, and K/Rb, along with less fractionated REE patterns and more pronounced negative Eu anomalies. Nd isotopic compositions for both granite types are largely homogeneous, but the A-type granites show slightly higher $\epsilon_{Nd}(t)$ values (-6.32 to -5.66) than the I-type granites (-7.53 to -7.05). Zircon Hf isotopic compositions for both are highly variable, with $\epsilon_{Hf}(t)$ values ranging from -12.3 to -3.1 for the I-type granites and from -7.7 to -1.6 for the A-type rocks. As with the $\epsilon_{Nd}(t)$ values, the zircon $\epsilon_{Hf}(t)$ values are comparatively high in the A-type granites.

Based on a synthesis of geology and geochemistry, we propose that the I-type granites were generated by mixing between mantle-derived melts and felsic crustal magmas that resulted from partial melting of lower crustal rocks during the early stages of Cretaceous regional extension. After extraction of the hydrous I-type felsic melt, a large amount of residual granulitic source accumulated in the lower crust. An increase of the dip angle of the subducted slab and the oceanward retreat of the trench result in enhanced extension, thereby further thinning the lithosphere and inducing more intensive underplating of mantle-derived magmas. This would have led to high temperatures and partial melting of the residual granulitic source, producing a relatively anhydrous F-containing felsic melt. Finally, the mixing of this unusual crustal melt with a larger amount of mantle-derived mafic magma generated the parental magma of the peralkaline A-type granites.



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Genetic relationships between the Mesozoic volcanic rocks and Granites in the eastern Zhejiang, China

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The formation of average andesitic middle crust and granitic upper crust is enigmatic. Concerning the proportions of felsic rocks in the shallow crust, the andesitic average composition need a large proportion of diorite beneath highly evolved felsic layer to reconcile the average composition. Thus, where is the dioritic rocks and how the magmas evolve to highly felsic in the shallow crust is the essential problem to solve this issue. Since the high viscosity of the crystal-enriched felsic magmas, the generation of the high silica rocks, particularly the high silica rhyolites ($\text{SiO}_2 > 75 \text{ w.t. } \%$), is also controversial because that separation of large proportions of crystals is necessary for the unique chemical compositions of these rocks.

Mesozoic felsic volcanic rocks are widespread in the coastal area of southeastern China, particularly in the Zhejiang Province, in which they cover half of this region (*ca.* 50000 km²). They mainly formed in the Early Cretaceous, i.e., 130 Ma and 110 Ma. Of them, felsic tuffaceous rocks occupy large proportions, with minor basaltic rocks (< 10 % in volume). Rocks of the early episode comprise rhyolites and tuffaceous rocks that are both crystal-enriched and crystal-poor. In contrast, the late episode rocks are high silica and crystal-poor.

The volcanic rocks are associated with intrusive rocks, including diorite, monzonite, granodiorite, syenite, biotite granite, and porphyries, with locally occurrence of diorite enclaves. These porphyry facies are always gradually grade into coarse-grained granites and volcanic rocks, indicating their co-generation and shallow emplacement, which is supported by the zircon U-Pb dating (*ca.* 110 Ma). The granites and rhyolites of *ca.* 110Ma have similar isotopic compositions. They display consistent trends in both major and trace elements vs. SiO_2 . For those rocks with SiO_2 contents < 75 *w.t. %*, MgO, Fe_2O_3 , CaO and Al_2O_3 are all monotonous decrease with increasing SiO_2 . The incompatible trace elements, such as Rb, Th, U and K, increase with the increasing SiO_2 , excepting the decreasing Ba. Besides, Sr, P, Ti, and Eu also decrease. However, all the elemental trends abrupt kink at 75 *w.t. %* SiO_2 , such as the abrupt decrease trends of K, Ba, Zr/Hf ratios, and increase in Rb and Rb/Sr ratios.

Similarities in geochemistry and petrology indicate that the temporal- and spatially-associated granites and volcanic rocks were cogenetic and formed in the same magmatic episode, that is, by-products of the same magma mush. The granites are cumulates while the volcanic rocks are separated melt. Nevertheless, the concentration and eruption of these highly evolved felsic volcanic rocks were aided by the episodic activities of the mafic magmas added to the base of the crust.



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Angra Fria Magmatic Complex in the Kaoko Belt of NW Namibia – a continuation of the Neoproterozoic Granite Belt in the Dom Feliciano Belt (Uruguay and SE Brazil)?

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Magmatic rocks exposed in the northwestern part of the Coastal Terrane in the Kaoko Belt of Namibia show evidence for two distinct periods of granitoid magmatism. An older suite of intermediate–felsic granitoid rocks with well developed magmatic to solid-state fabric is intruded by granites with no solid-state deformation. The suite intruded a complex of migmatitic metasediments intercalated with amphibolites. U-Pb zircon dating of the older granitoid suite provided ages of 622 ± 2 and 620 ± 2 Ma (2 sigma) for the intermediate magmatic rocks and an age of 627 ± 2 Ma for the deformed granites. Granitic sample of the younger granitoid suite that crosscuts the fabric developed in older granitoids gave an age of 574 ± 2 Ma. Dating of dykes of undeformed diorite that intruded the migmatitic metasediments yielded an age 585 ± 2 Ma.

The ages of the younger granitoids are known also from other large plutonic bodies in the western part of the Kaoko Belt, whereas the ages obtained from granitoids of the older suite are similar to those known for the older granitoid members of the in the Aiguá, Pelotas and Florianópolis batholiths of the Dom Feliciano Belt of Uruguay and southeastern Brazil. The tectonic evolution of the Coastal Terrane correlates well with that of the Punta del Este Terrane of the Dom Feliciano Belt. Accordingly, the finding of c. 620–625 Ma old plutonic bodies intruded by c. 575 Ma old granitoids in the Coastal Terrane suggests that the whole Angra Fria magmatic complex could represent the NE continuation of the Granite Belt of the Dom Feliciano Belt on the African side of the orogen. Jiri Konopasek appreciates funding of the Czech Science Foundation (P210 15-05988S).



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The Glória Sul Stock: An example of a leucogranite in the Macururé Domain, Sergipano Orogenic System, Northeastern Brazil

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The Sergipano Orogenic System leucogranites occur mainly as intrusives rocks in the Macururé Domain, which is a 13 km thick metaturbidite sequence, oriented EW and located in the central-north part of the state of Sergipe, and which has lateral continuity in the states of Bahia (W) and Alagoas (E). In this domain granitic bodies occur with various shapes (round or elongated) and were named by previous work, along with other monzonites and granodiorites, as Glória Type granites. This plutonism is considered as post-tectonic in relation to the Brazilian orogeny. Studies carried out by our team in Glória Type (granitic) bodies have identified several different types of magmas that were intrusive in the Macururé Domain: a Shoshonitic (monzonite), a Leucogranite, and a high potassium Calcium-Alkali (granodiorite). The Glória Sul Stock (GSS) is composed of syenogranites, leucocratic to hololeucocratic, essentially with muscovite. Their contacts with the enclosing metasediments are occasionally well defined, or other times diffuse, but marked by the presence of hornfels that sometimes exhibits migmatitic features. Within the GSS we identified the presence of the following facies: muscovite and biotite granite (major), muscovite granite, biotite granite, granite with garnet (minor) and microgranular mafic enclaves (MME). The granites have as accessory minerals: garnet, epidote, allanite, titanite, zircon, apatite, carbonate and opaque minerals, monazite and thorite. The chemical data of these rocks reveal contents of: 70.62%-73.19% SiO₂; 0.07%-0.22% TiO₂; 14.95%-15.86% Al₂O₃; 0.64%-1.36% Fe₂O₃; 0.01%-0.02% MnO; 0.10%-0.38% MgO; 0.69%-1.18% CaO; 4.28-4.67% Na₂O; 4.40% -5.16% K₂O; 0.02% -0.09% P₂O₅; 38,58-132,35 ppm ΣETR; 13.33-137.22 ppm [La/Yb]_N; 0,72-1,11 ppm Eu/Eu*. The muscovite granites are peraluminous and have affinity with the high potassium calc-alkaline series, except for the biotite granites and the MME which are metaluminous and have affinity to shoshonitic rocks. In geochemical diagrams indicative of sources for leucogranites the compositions of the studied rocks plot in felsic pelites and greywacke areas, with high CaO/Na₂O and plagioclase. Moreover, the alignment observed in several binary chemical diagrams between the MME, biotite granites, and muscovite granites, suggests that the genesis of the GSS involves the mixing of crustal felsic and mantle mafic melts. Pearce diagrams indicate that the rhyolitic magma(s) responsible for generating the studied stock, position themselves in the field of syn-collisional granites. However, the absence of the usual evidence of deformation in the syn-collisional granite rocks of the GSS is interpreted as indicative that their emplacement occurred after the collision of the Sergipano Orogenic System. With the new evidence presented in this work we reason that the GSS could have been formed by mixing between mafic mantle magma of shoshonitic nature and rhyolitic crustal magma, resulting from melting of the enclosing metasediments and placed on a post-collisional period. [LAPA-UFS contribution - Laboratory of Petrology Applied to Mineral Research. Thanks to: FAPITEC / PRONEX, MCT / CNPq, CAPES and FINEP].



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Extensional magmatism related to the Coxixola Shear Zone: Aroeiras Pluton, Borborema Province, Northeastern Brazil.

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The Aroeiras Pluton comprises an oval shaped intrusion emplaced during synchronous activity of the dextral E-W trending Coxixola Shear Zone and the unknown NE-SW trending sinistral shear zone, which created space for the intrusion of biotite monzogranites as small plutons. The Aroeiras Pluton is intruded in between a supracrustal sequence (Surubim Complex) and Neoproterozoic orthogneisses in the south and Paleoproterozoic orthogneisses in the north, showing steeply dipping foliation, associated to the transcurrent event on the Transversal Zone Domain of Borborema Province. Dikes of biotite syenogranites composition with WSW and ENE trending cut the Aroeiras pluton. Mixing features such as rapakivi texture and rounded enclaves with crenulated borders are common. The amphiboles composition range from ferro-edenite in the granites to ferro-pargasite to hastingsite in the hybrid rocks and hastingsite to ferro-tschemakite in the diorites. Al-content in amphiboles from the granites and using the Schmidt's calibration (1992) defined solidification pressures within the 5.1 – 6.2 (± 0.6 kbar) intervals and temperatures of plagioclase amphibole equilibrium ranging from 720°C to 755°C for the granites of the Aroeiras Pluton.

The major elements geochemistry distinguish two groups of rocks within the Aroeiras Pluton: 1) The diorites are alkalic, ferroan and have OIB-like signatures; 2) the granites are ferroan ($\#Fe > 0.8$), alkali-calcic, metaluminous to peraluminous. Trace elements also distinguish between diorites and granites: 1) Diorites show enrichment in incompatible elements in the MORB normalized spidergram patterns, similar to those recorded in OIB and the chondrite normalized REE patterns highly enriched, fractionated ($Ce/Yb_N = 6.9 - 7.35$), with small negative Eu anomalies ($Eu/Eu^* = 0.83 - 0.84$). 2) The granites have chondrite normalized spidergrams patterns characterized by troughs at Sr, P, Ti, and fractionated REE chondrite normalized patterns ($Ce/Yb_N = 8.15 - 15.11$), with deeper negative Eu anomalies ($Eu/Eu^* = 0.45 - 0.68$).

The Sm-Nd model ages in the diorites are slightly younger (2.15-2.18Ga) than those recorded in the granite (2.35Ga). The $\epsilon Nd(t)$ values are very low in the diorites (-11.5 and -11.6); 2) and even lower in the granitic sample (-13.97). U-Pb zircon TIMS data defined a crystallization age of 572 ± 5 Ma. U-Pb zircon ICP-MS-LA data for one orthogneiss country rock sample gave an age of 603 ± 5 Ma, similar to those recorded in the early calc-alkaline granitoids intruded along the same shear zone (Serra do Inacio Pereira pluton). The field relationships, geochemical, isotopic and geochronological data suggest that the Aroeiras granites are not co-genetic with the diorites. Both magmas had in their sources, contribution from Paleoproterozoic crust however, the granites have even more contribution. They were intruded together in an extensional environment associated to the synchronous activity of E-W and NE-SW Shear Zones. The diorites appear to be generated by melting of a metasomatized mantle of Paleoproterozoic age. The diorites and extension were probably the heating sources promoting fusion in the lower crust and generating the granitic magmas.



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The Vinqis granitic complex: an example of Carboniferous F-rich peraluminous A-type granite in the pre-Andean SW Gondwana margin, Sierras Pampeanas, Argentina

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A-type granites are rocks with distinct mineralogical and geochemical characteristics. However, the genesis of A-type granites has been controversial, leading to much discussion over the past 30 years. In general, petrogenetic models for A-type granites commonly invoke igneous source rocks and petrogenesis of peraluminous A-type granites is especially poorly known. In this article we report in situ U-Pb and Hf isotope data from zircons, whole-rock Sm-Nd, and whole-chemistry data from a peraluminous A-type granite (named here as Vinqis granitic complex, VGC), in order to evaluate their origin. The VGC, Sierras Pampeanas, Argentina, is formed by unusual F-rich peraluminous A-type monzogranites. A precise LA-MC-ICP-MS U-Pb zircon crystallization age of 353 ± 9 indicates that the VGC was emplaced during Early Carboniferous time, along with an extensive metaluminous A-type magmatism previously reported by Dahlquist et al. (2010) and Alasino et al. (2012). The VGC displays high and restricted SiO₂ contents between 71.6% and 74.8 wt.%. On both [FeO^t/(FeO^t+MgO)] vs. SiO₂ and [(Na₂O+K₂O)-CaO] vs. SiO₂ diagrams (Frost et al. 2001) the samples plot in the ferroan and alkali-calcic to calc-alkalic fields with $Fe^* = [(FeO^t)/(FeO^t+MgO)] = 0.79\%$ and $[(Na_2O+K_2O)-CaO] = 7.38\%$ (average values, n = 6), thus showing an metaluminous A-type granitoid signature. Relatively high concentrations of the some High Field Strength Element = HFSE (average contents in ppm, Nb = 19, Th = 15, and Ga = 21) and moderately fractionated to flat REE patterns $[(La/Yb)_N = 11.42]$ showing significant negative Eu anomalies ($Eu/Eu^* = 0.41$) are also typical features of metaluminous A-type granites. A high F content in the magma is inferred from biotite compositions with high F concentration (average F = 1.17–1.44 wt%), a distinctive characteristics of metaluminous A-type granites. Conversely, the VGC is peraluminous with aluminium saturation index ranging from 1.11 to 1.22 and distinctive high P₂O₅ content (average 0.32 wt%). In addition, the VGC has some minor geochemical differences from Carboniferous metaluminous A-type granites of the Sierras Pampeanas (Dahlquist et al. 2010). The latter have a strong ferroan signature ($Fe^* = 0.94$), lower P₂O₅ content (0.08 wt%), higher HFSE concentrations, flat REE pattern $[(La/Yb)_N = 6.47]$, and pronounced negative Eu-anomalies (0.20). The Rb/Ba and Rb/Sr ratios reported for the metaluminous A-type granites (Dahlquist et al. 2010) are higher than in the VGC.

The peraluminous composition of the VGC and Hf isotope data from magmatic zircon and granite whole-rock Sm-Nd (average $\epsilon_{Hf353} = -6.32$, $\epsilon_{Nd353} = -7.1$), together with abundant inherited Ordovician and Cambrian zircon (n = 10), strongly suggest a dominant metasedimentary source. Therefore, the particular A-type geochemical signature of the VGC can be attributed to a metasedimentary source as suggested by Anderson and Bender (1989) for the anorogenic peraluminous granites of the USA.

The data indicate that VGC was emplaced during the Carboniferous magmatic event that included intraplate- and arc-type magmatism in SW Gondwana (Dahlquist, this volume). We conclude that the VGC was emplaced in an intraplate setting and that this magmatism included both metaluminous and peraluminous A-type granites.



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Geochemical implications for mantle-derived magmas and crustal recycling processes in late Archean granitoids from Bonfim Complex, southern São Francisco Craton, Brazil

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The late Archean Samambaia pluton (ca. 2.78 Ga; Machado and Carneiro, 1992) crops out in the eastern part of the Bonfim metamorphic complex (BC), which is located in the southern segment of the São Francisco Craton (Brazil). The pluton is mainly composed of tonalites and scarce granodiorites that intrude the Alberto Flores trondjhemitic to granitic gneiss and are intruded by the Souza Nouchese granitic gneiss in the north. The Samambaia granitoids are gray rocks with medium to coarse-grained equigranular and hypidiomorphic textures. The major mineral assemblage consists of euhedral to subhedral plagioclase, quartz, hornblende, biotite and scarce K-feldspar. The accessory assemblage is formed of apatite, zircon, allanite, titanite, and opaque minerals. They are magnesian, calc-alkalic, medium- to high-K and mainly metaluminous with 63.1-68.5 wt.% SiO₂, 0.46-0.81 wt.% TiO₂, 3.10-4.95 wt.% FeO, 1.50-2.40 wt.% MgO. They are rich in ferromagnesian components (FeO_t+MgO+MnO +TiO₂ > 5 wt.%) with relatively high Mg-number (molar MgO/(FeO_t+MgO) = 0.42-0.48) for such silica-rich rocks, which, together with relatively high Cr and Ni values (mostly higher than 20 ppm) suggests a mantle contribution in their genesis. The Samambaia granitoids are also enriched in incompatible elements and REE, showing chondrite-normalized REE and Silicate Earth-normalized trace-element patterns similar to those of Archean sanukitoids, except for even higher HREE.

The tonalites present mantle-like Nb/Ta, Zr/Hf and (Ce/Pb)_N ratios along with crustal-like (Th/Nb)_N and (Th/Ta)_N ratios, whereas the granodiorites have crustal-like values with the exception of Zr/Hf ratio, which is very close to the chondritic value (37.1). These features could be due to a different degree of interaction between a mantle-derived component and crustal rocks, which also agrees with the interpretation of the units from BC having formed at least in part by reworking of older crustal material.

Because of their geochemical features we rule out the possibility of classifying the Samambaia rocks as a TTG suite, as previously thought. Instead, they show a better correlation with the characteristics of sanukitoid-like suites, except for moderately high Ba (402-790 ppm) and too low Sr (147-380 ppm) contents. Therefore, we suggest treating them as late Archean hybrid granitoids formed by the interaction of a sanukitoid-like melt with other Archean granitoids (Laurent et al., 2014). The Samambaia rocks could have formed by crustal assimilation and fractionation of an enriched, mantle-derived high-Mg dioritic to Q-dioritic magma. Since these processes implicate crustal reworking, they could be related to either slab breakoff or lithospheric delamination in a post-collisional setting.

Deciphering the sources and processes involved in the generation of these Archean hybrid granitoids can improve our understanding of crustal recycling and crustal growth mechanisms in the late Archean time.

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Six-stage Mesozoic granitoids in an Andean-type orogenic cycle in South China

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Six-stage Mesozoic granitoids in an Andean-type orogenic cycle with different ages, textures and geochemical characteristics can be identified in South China.

The first stage (Middle–Late Triassic) of granitoids in South China is composed of syn-/post-orogenic granitoids. The main rock types are syenogranite, monzogranite, quartz monzonite and syenite. They have high melting temperatures, high melting pressures, variable water contents and redox conditions. Oxidized and reduced melting conditions resulted in ferroan and magnesian granitoids, respectively. The typical petrographic characteristic is alkali feldspar megacrysts set in a medium-grained matrix. Orogeny was driven by flat-slab subduction of the paleo-Pacific Plate. Thermal relaxation caused dehydration melting and water-fluxed melting, depending on the availability of fluids from the oceanic plate. The fluids and melts from the oceanic plate metasomatised the overriding lower continental crust and continental lithospheric mantle; however, such effects are only significant in regions adjacent to the continental margin (Zhejiang, Fujian and Jiangxi Provinces).

The second stage (Early–Middle Jurassic) of granitoids in South China is made up of post-orogenic ferroan granitoids. The main rock types are syenogranite, quartz syenite and syenite. These granitoids were formed at high temperature with low water contents and low oxygen fugacities. They were formed during contemporaneous underplating of reduced intraplate basalts following the break-off of the paleo-Pacific Plate. The continental crust had not started to attenuate at this stage.

The third stage (Middle Jurassic–Early Cretaceous) of granitoids in South China is composed of post-orogenic magnesian granitoids. Most of them are granodioritic porphyries that were generated from water-fluxed melting or fractionated from hydrous basaltic magmas in a still thick, lower continental crust. They have high oxygen fugacities, high water contents and were formed at low temperatures. The water was derived from hydrous metasomatic continental lithospheric mantle and/or the foundering oceanic slab.

The fourth stage (Late Jurassic–Cretaceous) of granitoids in South China consists of anorogenic ferroan granitoids. They are alkali feldspar granite or syenogranite with high silica contents that were generated under low-temperatures as a result of low-pressure dehydration melting processes, with variable redox conditions. They were generated in attenuated continental crust caused by the roll-back of the paleo-Pacific Plate.

The fifth stage (Late Jurassic–Cretaceous) of granitoids in South China consist of anorogenic ferroan granitoids. The main rock types are porphyritic quartz syenite and syenogranite. They have a petrogenesis and tectonic setting similar to the fourth stage, but record higher magma temperatures, lower oxygen fugacities and more depleted Nd-Hf isotopic compositions. It is implied that underplated reduced intraplate basalts were involved in the crustal melting process.

The sixth stage (Late Jurassic–Cretaceous) of granitoids in South China was generated by fractional crystallization of mantle-derived magmas from the enriched continental lithospheric mantle in an anorogenic setting. The main rock types are (quartz) diorite, (quartz) monzonite, granodiorite, monzogranite, (quartz) syenite. They are MME-bearing and oxidized granitoids. For



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the oxidized granitoids, high/low fractionation pressures, generally associated with a thick/thin continental crust, resulted in magnesian/ferroan characteristics. Intrusion of these granitoids caused growth and thickening of the continental crust.



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I-Type Granites from Paranaguá Neoproterozoic Belt.

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The Paranaguá terrane is represented by neoproterozoic units distributed in a NE-SW elongated swath, about 250 km long and 30 km wide, in south-southeastern Brazil, within the states of São Paulo, Paraná and Santa Catarina. This terrane is mainly constituted by an igneous complex, represented by the Morro Inglês, Rio do Poço and Canavieiras-Estrela suites. The country rocks of these *l.s.* granites are gnaissic and gnaissic-migmatitic rocks of the São Francisco do Sul complex and metasedimentary rocks of the Rio das Cobras sequence.

The Morro Inglês suite is the most expressive unite in Paranaguá terrane, being mainly represented by leucocratic rocks, with medium to thick-grained porphyritic texture, composed by megacrystals of K-feldspar (2 to 10cm), plagioclase (An12-20), quartz, hornblende ± biotite and accessory phase composed by sphene, apatite, epidote, allanite and zircon. Mafic enclaves with spherical to angular shapes are often observed, in most composed by diorites and amphibolites with fine-grained equigranular texture. Lithochemical signatures are compatible with arc magmatic-generated granitic rocks, with high-K to shoshonitic calc-alkaline character and relatively high contents of Ba, Nb, Zr, Rb, Sr, Th and K₂O. This pattern resembles the one observed in sin- to late-collisional environments related to mature magmatic arcs, with sources modified by crustal contamination.

The Canavieiras suite outcrops along shear zones in the western section, showing leucocratic rocks, with medium to fine-grained inequigranular texture, that usually exhibit deformation features characterized by cataclastic and mylonitic therns. The mineralogy is compose by K-feldspar , plagioclase, quartz and biotite, with sphene, allanite and zircon as accessories. The Morro Inglês suite rocks present higher values of K₂O and smaller values of Na₂O than the rocks of the Canavieiras-Estrela suite. Both suites show important variations of Ba and Sr, high values of Rb and Zr, and medium-to-high values of Nb and Y.

The Rio do Poço suite outcrops as restricted bodies along the Paranaguá terrane, in most represented by leucocratic and hololeucocratic rocks with medium to fine-grained equigranular texture, frequently foliated as magmatic flow. It is compose by K-feldspar, quartz, plagioclase (An8-15), biotite ± muscovite and accessories represented by apatite (with dimensions about 1 -1,5mm), allanite, epidote and zircon. The geochemical data allows recognized a sub-alkaline signature with a peraluminous association. The REEs patterns of Rio do Poço and Morro Inglês suites are quite similar, denoting an enrichment of all elements in this suite, which present a marginally peraluminous character, with HREE-depleted rocks, without an Eu negative anomaly.

U-Pb (zircon) ages of these suites are very close and does not allow a clear separation of them. A high concentration of ages between 600-580 Ma represent the main magmatic period of the Paranaguá terrane. Although less frequent, older ages between 620-610 Ma were obtained in the three suites, suggesting the presence of a relatively early magmatism in this terrane's evolution. However, U-Pb (zircon) ages obtained in crystals rims of leucorgranitic rocks are distributed between 560-480 Ma, suggesting late tectonothermal events. These ages must be related with important thermotectonic events of the cambro-ordovician Buzios orogeny.



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Ediacaran extensional magmatism in the Borborema Province, NE Brazil: Insights into the mineral chemistry, geochemistry and petrology of Serra Branca Pluton

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The Serra Branca Pluton (SBP) intrudes Archean to Paleoproterozoic orthogneisses and migmatites in the Central domain of the Borborema Province. This intrusion is associated with the synchronous movement of both the E-W-trending dextral Coxixola and the sinistral NE-SW-trending shear zones, which was responsible for spectacular flux-like structure recorded in the SBP granites. The SBP comprises leucocratic biotite syenogranite to monzogranite, including localized enclaves of porphyritic granites, diorites, and country rocks. U-Pb zircon SHRIMP data defined a crystallization age of 560 ± 5 Ma for the SBP granites. The biotite compositions range from Fe-biotite to siderofilite crossing the buffers ($\text{FeSiO}_4\text{-SiO}_2\text{-Fe}_3\text{O}_4$) and (Ni-NiO) close to Fe^{2+} , suggesting crystallization under intermediate $f\text{O}_2$ conditions. The oxides are Mn-rich Fe-ilmenite, with titanomagnetite in the rim. Magma crystallization temperatures, based on zircon saturation, range within the $783^\circ\text{C}\text{-}843^\circ\text{C}$ interval. The studied granites have high SiO_2 (>70 wt.%) and K_2O contents, and are slightly peraluminous. The SBP has high MALI plotting in the alkali-calcic field at high SiO_2 as most A-type granites. They show positive trends to Na_2O and Al_2O_3 and negative trends to P_2O_5 K_2O , and no trends to Sr and Ba in the Harker diagrams. The REE patterns are characterized by deep negative Eu anomalies. The chondrite normalized spidergram patterns show trough at Nb, Ta, Sr, P and Ti. The high SiO_2 and K_2O contents associated to K-feldspar rich composition and coarsely perthitic alkali feldspars suggest fractionation at low pressures. In major elements correlations diagrams, the studied granites plot in the limit between the fields of melts generated by melting of metagreywackers and amphibolite, involving mixing processes and/or crystal fractionation. The La vs. La/Yb correlation diagram for the SBP granites suggests evolution through partial melting process while Cr vs. SiO_2 correlation suggests fractional crystallization. The trends recorded in the Harker diagrams suggest biotite, apatite and zircon fractionation, and absence of K-feldspar fractionation during the magma evolution. The SBP granites show low Dy/Dy* [$\text{Dy}_\text{N}/(\text{La}^{4/13}_\text{N}/\text{Yb}^{9/13}_\text{N})$] values and high Dy/Yb ratios. The low Dy/Dy* and Ti/Ti* ratios and negative trend recorded in the SBP granites reflect later fractional crystallization of Ti-oxides and/or amphibole residual. The $\epsilon\text{Nd}^{(560\text{Ma})}$ values are very low (-21,06 to -21,78) and the T_{DM} model ages range from 2.35 to 2.49Ga. The geochemical and isotopic data suggest that the SBP granites magma was generated by partial melting of a Paleoproterozoic to Archean crust, leaving plagioclase and/or amphibole in the residue. It explains the negative Eu anomalies and high $(\text{Ce}/\text{Yb})_\text{N}$ recorded in the REE patterns. The generated magma evolved through fractional crystallization of biotite, apatite and zircon at shallow level in an extensional environment. The presence of enclaves of diorite and porphyritic granite, not cogenetic with the SBP, as well as enclaves of the country rocks, suggest some degree of contamination during the magma emplacement.



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A2-type granites intruded along the Remigio - Pocinhos shear zone, Borborema Province, NE Brazil: Pilõezinhos Pluton

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The Pilõezinhos Pluton constitutes an ENE-WSW elongated intrusion, 30 km long by 4km width, limited to the north by the dextral, ENE-WSW trending, Remigio - Pocinhos Shear Zone (RPSZ). The RPSZ comprises the east branch of the continental scale Patos Shear Zone. The Pilõezinhos Pluton is intruded into Brasiliano metasediments and Tonian orthogneisses along the limit between the Central and North domains of the Borborema Province. In this work, we present new mineralogical, geochemical and geochronological data for the granites from the Pilõezinhos Pluton in order to compare it with others granites from the Borborema Province. U–Th–Pb laser ablation data from seventeen zircon grains of a porphyritic granitic sample, yielded an age of 566 ± 3 Ma (MSWD=0.88), which is interpreted as the crystallization age. Two main petrographic facies were observed: 1) porphyritic syenogranite to monzogranite, containing rare dioritic enclaves, and 2) fine-grained, equigranular leucocratic syenogranites. The biotites from the studied granites are Fe-rich, with Fe/(Fe+Mg) ratios ranging from 0.72 to 0.82. The biotites from the enclaves have Fe/(Fe+Mg) ratios ranging from 0.49 to 0.50. The composition of amphiboles from studied granites range from hastingsite to ferro-tschermakite, with Fe/(Fe+Mg) ratios within the 0.80 - 0.89 interval. The plagioclases show compositions ranging from oligoclase to andesine. Alkali feldspar are mainly microcline, with Or content ranging from 84 to 92. The analyzed opaque minerals are Fe-Ti oxides, with TiO₂ content ranging from 52% to 54% and FeO content ranging from 45 to 46%, which are values typical of ilmenite. Magnetite was recorded in small amount. The chemical compositions of the mafic mineral phases of the studied granites are similar to those recorded in mafic mineral phases of A₂-type granites described in the Central Domain of the Borborema Province. The studied granites have SiO₂ contents ranging from 64wt% to 72wt%, high FeO/(FeO+MgO) ratios (0.8 to 0.8) and MALI values within the 3 – 8 interval. The REE patterns are characterized by (Ce/Yb)_N ratio ranging from 15.8 to 68.2, and negative Eu anomalies, with Eu/Eu* ratios ranging from 0.21 to 0.77. The enclaves have lower total REE compared to the host granites. The multi element, chondrite normalized plots show patterns characterized by trough at Ba, Nb, Ta, Sr, P and Ti, which are similar to those recorded in A-type granites. The recorded troughs at Nb and Ta are probably inherited from the source. The Y and Nb contents range respectively from 20.6 ppm and 22.2 ppm in the fine grained granites to 70.2 ppm and 52.2 ppm in the porphyritic granites. These Y and Nb contents classified the studied granites as A₂-type. The mineral compositions recorded in the studied granites are consistent with crystallization under low fO₂ conditions. The granites from the Pilõezinhos Pluton are alkali-calcic, A₂-type ferroan granites, which are commonly thought to be derived from the subcontinental lithosphere or lower crust. Granites with similar composition and crystallization age are recorded intruded along the EW-trending Coxixola Shear Zone, the Marinho Pluton, in the Central Domain of the Borborema Province.



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The discovery of ca. 3400 Ma TTG orthogneiss from the Porteirinha Complex discloses a protracted crustal evolution from 3.4 to 0.6 Ga at the eastern margin of the São Francisco Craton (SFC), SE Brazil

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This geochronological, isotopic and chemical study is focused on the Archean-Rhyacian southern segment of the São Francisco Craton (SSFC), the Porteirinha Domain (PTD), state of Minas Gerais, SE Brazil. It is the first geochronological study carried out in this domain. The main target is the TTG gneisses of the Porteirinha Complex (Sample 1). The gneiss dated at 3371 ± 6 Ma unraveled an intricate, polycyclic (polymetamorphic) evolution characterized by two metamorphic overprinting episodes dated respectively at 3146 ± 24 Ma (M_1) and ca. 600 Ma (M_2). The former (M_1) is so far, the most reliable (robust) evidence of the oldest (hidden) metamorphic episode ever dated in Brazil. The latter (M_2), in turn, is endemic in most of the exposed eastern cratonic margin. Whole-rock Sm-Nd analysis from the gneiss provided a slightly negative $\epsilon Nd_{(t=3370)} = -0.78$ value, and a depleted mantle model (T_{DM}) age of 3.5 Ga, indicating that it derives mainly from the (re)melting of a ca. 3.5 Ga tholeiitic oceanic source. Sample 2, a K-rich ortholeucogneiss from the Rio Itacambiricu Complex, was dated at 2657 ± 25 Ma and also presents the M_2 overprinting age of ca. 600 Ma. These M_2 Ediacaran overprinting ages from both Archean gneisses are ascribed to the NW-directed overthrusting of the W segment of the Araçuaí Orogen (i.e. the Araçuaí-West Congo Orogen AWCO), during the amalgamation of the SW sector of the Gondwana Supercontinent, from ca. 590-540 Ma. The other three analyses were obtained from Rhyacian granitoids. Sample 3 from a syn-collisional, S-type leucogranitic Tingui Complex which was re-melted at 2140 ± 14 Ma. It is interpreted as a northern extension of the Mineiro Belt, from the southernmost Rhyacian cratonic envelop, also overprinted by the Ediacaran, SW Gondwana amalgamation. Samples 4 and 5 belong to a post-orogenic (post-collisional), mixed-source, per-alkaline, Rhyacian-Orosiran A₁-type suite, with crystallization ages of 2067 ± 20 Ma and 2039 ± 8 Ma, respectively. Samples 3 and 4 also present evidences of partial opening of the isotopic systems during the M_2 Ediacaran episode also responsible for the overprinting of the Archean gneisses. In order to understand this intricate evolution in a wider regional scale, we have compiled, tabulated and contextualized the totality of the published U-Pb geochronological data from the SW and NW segments of SFC (225 analyses), covering the magmatic evolution from Early Paleoproterozoic to Rhyacian times, as well as the Ediacaran overprinting effects on these reworked cratonic domains. The regional contextualization of the databank indicates that during the Ediacaran Period most of the eastern margin of the SSFC behaved neither as a craton s.s. nor as an orogenic belt, similarly to data reported from the basement of the Trans-Saharan Belt in Africa. Due to the intensive Pan-African overprinting event, this belt is currently designated as metacraton. In contrast to the partially “metacratonized” SSFC, the NW and NE cratonic segments from the SFC in Bahia state were not affected by the Ediacaran event, remaining stable up to the opening of the Atlantic Ocean and giving rise to the so-called “Bahia-Gabon Bridge”.



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The Rhyacian granitogenesis of Bacajá domain, Transamazonas Province, northern Brazil.

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The Bacajá domain (SE Amazon craton) is composed of minor Archean granite-greenstone remnants, Siderian greenstone belts and Rhyacian intermediate to acid granitoids. These Rhyacian plutons were emplaced during at least three different pulses and occur as elongate batholiths (WNW) between Pacajá and Anapu villages. The older intrusive suite (Bacajaí complex) comprises metaquartz diorites, metagranodiorites and metamonzogranites emplaced around 2110 Ma. These rocks may present magmatic foliation, or granoblastic texture or even mylonitic deformation. In rocks with weak granoblastic texture it is remarkable secondary overgrowth of sericite to muscovite within plagioclase in response to thermal effects caused by the subsequent intrusions. Reddish biotite and metamorphic clinopyroxene are described in rocks with strong granoblastic texture. The metagranitoids of the Bacajaí complex display low-K and medium-K calc-alkaline signature. The rare-earth elements (REE) patterns of these granitoids is marked by fractionated patterns ($(La/Lu)_N = 4$ to 36) and low values of heavy REE. Tonalites and granodiorites from the Arapari intrusive suite and monzogranites from the João Jorge intrusive suite show igneous layering, magmatic folds and synmagmatic deformation pointing to synkinematic emplacement. Both suites have medium to high calc-alkaline signature and represent the orogenic granitogenesis that occurred between 2086 Ma and 2069 Ma. Syenites and monzonites from the João Jorge intrusive suite are weakly foliated and present shoshonitic to peralkaline affinity. Mantle sources and deep vertical discontinuities would have controlled the origin and emplacement of these syenites and monzonites which crystallized around 2076 Ma, lately in the orogenesis evolution of the Bacajá domain.



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Geology, geochronology and petrogenesis of a Neoproterozoic, syntectonic sillimanite-muscovite-biotite granite from southernmost Brazil

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The Butiá Granite (BG) is a NNW- elongate intrusion of foliated sillimanite-muscovite-biotite granite emplaced during dextral shearing within a post-collisional transcurrent shear zone in southernmost Brazil. Textural relations indicate that sillimanite is mostly a liquidus phase, although the possibility of some restitic crystals can not be ruled out. The host rocks are granulite-facies ortho and paragneisses (peak metamorphism at *ca.* 650 Ma), as well as syntectonic intrusive syenites (*ca.* 640 Ma). Host-rock xenoliths are abundant and may reach up to several metres in diameter. Leucogranites from the inner part of the intrusion are coarser grained and weakly foliated, whilst at the borders they are finer grained and more strongly mylonitic. Foliation is marked mainly by biotite and muscovite, with subordinate prismatic sillimanite, and elongate aggregates of equant quartz and feldspar. The U-Pb ID-TIMS age determined in monazites from these leucogranites is 629.2 ± 6.8 Ma. This value is in accordance with two rim zircon spots of ~ 629 Ma obtained by LA-MC-ICP-MS, and is interpreted to be the crystallization age. The Butiá Granite is peraluminous, with A/CNK varying from 1.1 to 1.4 independently of SiO₂ increase, and shows high contents of K₂O (4.5 to 6 wt%), which allows it to be included in the group of cordierite-bearing peraluminous granites (CPG). The trace element composition is similar to those of syncollisional peraluminous granites such as those from Tibet, Yunnan, and Cornwall. The compositional variations within the Butiá Granite were modeled for major elements and explained as controlled by magmatic-flow segregation and fractionation of assemblages dominated by biotite + plagioclase + zircon. Saturation curves suggest that zircon crystallization started at about 750-760°C. It is proposed that the Butia granite mineral assembly - sillimanite + biotite + muscovite + plagioclase + K feldspar + quartz - correspond to crystallization of metapelite-derived melts at temperatures under 850°C and pressures about 10 kbar, which explains the absence of cordierite and garnet commonly found in such compositions. The BG isotopic dataset is rather homogeneous. It consists of whole-rock - ⁸⁷Sr/⁸⁶Sr_(i) (0.7178 to 0.7297), εNd_(t) (-11 to -17), and Pb-Pb in K-feldspar - ²⁰⁶Pb/²⁰⁴Pb_i = 17.5 - 19.3; ²⁰⁷Pb/²⁰⁴Pb_i = 15.4 - 15.7; ²⁰⁵Pb/²⁰⁴Pb_i = 37.8 - 39.2), all of them pointing to crustal sources. The model age of 2.00-2.03 Ga is compatible with inheritance LA-MC-ICP-MS age data of *ca.* 2.2 Ga obtained from zircon. The regularity and consistency of such dataset, together with the narrow range of isotopes and inheritance values for this granite points to a crustal source of high Rb/Sr and Sm/Nd ratios. This is reflected mainly in high initial ratios, strongly negative εNd_(t) and high TDM age values. The elevated Pb/Pb ratio values are in agreement with crustal values, and together with the remaining isotope and geochronological data point towards recycling of an old and homogeneous crust.



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Orosirian post-collisional magmatism of the Setuva Antiform: geochemistry, Nd model age and U-Pb zircon age

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The Setuva Antiform is situated in the Ribeira Fold Belt, between the Apiaí and Curitiba terranes at the Parana State, Brazil. It has been designated as gneiss-migmatites of the Atuba complex after geochronological works without detailed mapping to discriminate these granitoids. This Antiform is an E-NE striking elliptical structure separated from the Açungui Group by thrust to transcurrent zones and divided in core and marginal zones. Its marginal, Santana-Bocaina Sequence, consists of mylonites-phyllonites and quartz veins. In the core, Neo-Archaean *porphyritic biotite granodiorites* (*PBG*) are cut by the Orosirian Água Comprida granites, and foliated mafic rocks. The *PBG*, the basement for Água Comprida granite, occurs in the core's southern and also as xenoliths in the *Água Comprida granite*. *PBG* is monzogranite to granodiorite composed of feldspar porphyroclasts in a heterogranular fine grained matrix. The main foliation marked by feldspar orientation is folded and a second foliation has a mylonitic character. There are evidences of feldspar recrystallization inferring a amphibolite facies metamorphism. *PBG* is a magnesian granite, medium to high K calc-alkaline, meta to peraluminous with K_2O/Na_2O ratio between 0,47 to 1,0. *BPM* presents discordant zircons with and upper intercept discordia age of 2952 ± 35 Ma. The Nd model age is very close to the crystallization age (ca. 2.9 Ga), suggesting a Neoproterozoic granite. The Água Comprida granite comprises three facies. Foliated, coarse-grained *porphyritic biotite syenogranite* (*PBS*) is dominant and locally pass into a foliated *porphyritic amphibole syenogranite* (*PAS*). Tabular bodies of fine-grained *equigranular biotite syenogranite* (*EBS*) cut the *PBS* with diffuse and sinuous to lobate contacts. The *PBS* is composed of feldspar megacrysts, mainly perthite in a coarse grained matrix. Megacrysts and mafic aggregates mark the main foliation. Ductile shear zones mark the second deformation event. Both *PBS* and *EBS* display solid-state deformation, and have biotite as mafic phase; titanite, allanite, apatite and zircon as accessory phases. The *PAS* has sodic-amphibole and biotite as mafic minerals and a higher content of allanite and titanite. A parallel alignment of biotite schlieren marks a *PAS* shape foliation variably developed. The main foliation is tectonic and marked by deformed K-feldspar and plagioclase. Regarding $FeO/(FeO + MgO)$ ratio, *PBS* are ferroan to magnesian granites, while *EBS* and *PAS* are ferroan granites. In the K_2O/SiO_2 diagram the Água Comprida granite is high K calc-alkaline, but in the $FeO/(FeO + MgO) \times Al_2O_3$ diagram *PBS* has a trend from calc-alkaline to A-type granites, while *EBS* and *PAS* has an A-type trend. All three are slightly peralkaline to metaluminous with A/NK close to 1. In diagrams for tectonic discrimination ($Nb+Y/Rb$), a trend from syn – post collision (*PBS* and *EBS*) to intraplate granite (*PAS*) is observed. The *PBS* zircons yield concordant ages of 2165 ± 16 Ma and 2186 ± 11 Ma. The Água Comprida granite is part of the Paleoproterozoic pos-collisional granitic intrusions, the dominant stratigraphic unit of the Setuva Antiform, and have TDM ages and eNd (for $t = 2.16$ Ga) values between 2.40 and 2.43 Ga and -0.58 and -2.63. The geochemistry and age data of the Agua Comprida granite suggests that only the *PBG* is part of the Atuba complex.



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Neoproterozoic and Late Paleozoic granitoids of Wrangel Island and Central Chukotka: age, composition and setting in the structure of Arctic region

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Neoproterozoic granitoids are associated with metamorphic basement exposed on the Wrangel Island. Metamorphic basement is represented by stratified Wrangel complex, composed of dislocated metavolcanic, metavolcaniclastic and metasedimentary rocks. In the lower part of metamorphic rocks of this complex there are conformable tabular bodies of foliated granitoids.

U-Pb SHRIMP zircon datings of granitoids are: 702±3 ìa (N=20), 707±4 ìa (N=25), 682±2 ìa (N=60). They indicate Neoproterozoic (Cryogenian) age of granitoids. Some zircons contain inherited cores, for which following datings were obtained: 1.2, 1.01; 1.17; 1.44; >2.6 Ga. This data allow supposing the presence of Neoproterozoic–Mesoproterozoic rocks in the basement of Wrangel Island and their participation in the melting process during granite magmas formation.

Recently Paleozoic age of part of Central Chukotka granitoids was established for granite-gneisses in the uplift structures (granite-metamorphic domes) of Anyui-Chukotka fold system.

We carried out geochronological studies of granitoids of Kibera massif, Kuul Uplift and Kuekvun' massif of the same name uplift of Anyui-Chukotka fold system. Kuul Uplift is stretched in WNW direction along the East-Siberian Sea coast on 110 km with 15-30 km wide. In the central part of uplift terrigenous Devonian and terrigenous-carbonate Lower-Middle Carboniferous deposits are located. They are overlain with stratigraphical unconformity by terrigenous deposits of P₂-T.

Granitoids of Kibera massif intrude Devonian deposits. U-Pb SHRIMP zircon datings are obtained for granites of Kibera massif (357±4 Ma), granite-porphyre (352±4 Ma) and biotite granites from conglomerate pebbles at the base of C deposits (359±3 Ma).

Kuekvun' Uplift is stretched in latitudinal direction on 90 km and is 25 km wide. In the centre of uplift metamorphosed D-C₂ deposits are located. They are framed with stratigraphical contact by terrigenous deposits of P₂-T₁. Metamorphic rocks include small (up to several tens of metres) bodies of light-coloured granitoids, transformed in augen gneisses or granite-gneisses with "augens" of potassium feldspar, plagioclase, quartz. Quartz syenites of Kuekvun massif have concordant age is 352±6 Ma (U-Pb TIMS).

Affinity of granitoids of Kibera and Kuekvun' massifs with I-type granites, their calc-alkalic and alkali-calcic character, Nb-Ta minimum on spidergrams allow supposing their supra-subduction (continental margin) origin.

Stated data confirm the existence of Late Paleozoic granitoid activity within Chukotka. Granitoid complexes of D–C₁ age are continued on the territory of Arctic Alaska, Yukon and Arctic Canada. D-C boundary corresponds to the age of tectonic events of Ellesmerian orogeny in Arctic region. Structural studies on Wrangell Island allowed establishing Ellesmerian deformations. All data indicate the community of geological history in the framework of single block Chukotka-Arctic Alaska, transported from the Arctic Canada region according to rotation hypothesis.

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NEW WHOLE-ROCK Nd ISOTOPE DATA FOR THE PALEOPROTEROZOIC A-TYPE GRANITES (1.88 GA) FROM CARAJAS PROVINCE, EASTERN AMAZONIAN CRATON, BRAZIL

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Three 1.88–1.86 Ga A-type granite suites are present in the Carajás province the major Archean crustal segment of the Amazonian craton: Jamon (Rio Maria Domain), Velho Guilherme (Xingu region), and Serra dos Carajás (Carajás Domain). These are anorogenic batholiths and stocks with geochemical and petrological affinities with Mesoproterozoic rapakivi granite suites of Laurentia-Baltica. Besides these three suites, in the northern part of the Rio Maria domain, the Seringa and São João (both ~ 1.89 Ga old) granites were recently described. They are essentially composed of moderately reduced monzogranites to reduced syenogranites, have A-type geochemical signature and display more similarity with the granites of the Serra dos Carajás suite. However it is not defined yet if these granites belong to the Serra dos Carajás suite or constitute an independent suite. In order to compare the Seringa and São João granites with the Paleoproterozoic suites of Carajás, and verify possible differences in their sources, we have made Nd whole-rock analyses of representative samples from the main facies of these granites. The Seringa batholith has Nd concentrations varying between 60.09 and 83.89 ppm, and Sm contents of 10.25 to 12.99 ppm, show little variation in ¹⁴⁷Sm/¹⁴⁴Nd (0.093583 to 0.103112), T_{DM} model ages varying from 2.86 to 2.91 Ga, and negative ε_{Nd} (at 1880 Ma) values of -10.3 to -10.8. In the São João pluton, the Nd concentrations are of 50.27 to 50.36 ppm, and Sm contents of 8.91 to 8.96 ppm. Variation in ¹⁴⁷Sm/¹⁴⁴Nd (0.102908 to 0.107698) is also limited. The T_{DM} model ages are slightly older (2.89 to 2.98 Ga) and ε_{Nd} (at 1880 Ma) values show a larger range (-9.4 to -11.3) compared to Seringa granite. These data indicate that the Seringa and São João magmas were derived from a Mesoarchean source. Both the granites show strongly unradiogenic initial Nd isotopic compositions indicating a long period of crustal residence time for the sources of these rocks. These A-type granites show Nd isotope composition compatible with those of other Paleoproterozoic suites from Carajás (T_{DM} model ages 3.35 to 2.60 Ga; ε_{Nd} values -12 to -8 at 1880 Ma). However, the Nd model ages of the Seringa and São João granites (2.86 to 2.98 Ga) approach more those of Jamon (2.59 to 3.0 Ga) and Serra dos Carajás suites (2.61 to 3.23 Ga), and tend to be younger than those of the Velho Guilherme suite (3.2 to 3.0 Ga). The ε_{Nd} values for the studied granites are strongly negative and constitute evidence that they derived from the Mesoarchean units of the Carajás province in a similar way to the other anorogenic suites. This preliminary interpretation will be better evaluated in the following by the refinement of U-Pb zircon ages using SHRIMP and acquisition of Lu-Hf isotopic data in zircon, not only in the Seringa and São João granites but also in the three anorogenic suites of the Carajás Province.



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Florianópolis Batholith – the roots of an Ediacaran magmatic arc generated during the Gondwana amalgamation, Dom Feliciano Belt, Santa Catarina State, South Brazil.

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The 1200km long Granite Belt (GB) represents the roots of a Neoproterozoic magmatic arc that occupies the entire south-eastern portion of Brazil and Uruguay, comprising the granitic batholiths that occur at SSE of Major Gercino (SC) - Cordilheira (RS) - Sierra Ballena (UY) Suture Zone. The Granite Belt is the petroTECTONIC Internal Domain of the Dom Feliciano Belt being composed of Florianópolis (SC) and Pelotas (RS) batholiths in south Brazil and Aiguá in Uruguay. Rouf pendants of metasedimentary rocks are observed along the entire belt. The Florianópolis Batholith is made up of three major unities: Aguas Mornas – strongly deformed orthomigmatites with basic-intermediate mesosomes and felsic leucosomes; São Pedro de Alcantara – slightly foliated biotite (hornblende) granodiorites to monzogranites with amphibolite to dioritic mafic enclaves; Pedras Grandes – non deformed equigranular to porphyritic pink syeno to monzogranites and felsic volcanics representing the youngest igneous rocks related to the magmatic arc evolution. U-Pb zircon ages (SHRIMP+LAICPMS) spans in the 640-590Ma interval with most close to 600 Ma. ⁸⁷Sr/⁸⁶Sr(i) around 0.710, moderately negative epsilon Nd values (-2 to -8) and zircon negative epsilon Hf values characterize the involvement of the continental crust in the generation of Florianópolis Batholith. Positive zircon epsilon Hf values are restricted to the Laguna Granite of the Pedras Grandes Suite being the first indication of Neoproterozoic juvenile accretion in the entire Granite Belt. Sr, Nd and Hf isotopic values of the Florianópolis Batholith points out a different signature when compared to the other domains of the Dom Feliciano Belt. Similar conclusion can also be reached when the detrital zircon age pattern of its metasedimentary cover, where 1.0-1.2 Ga zircon ages predominates, is compared with the regional supracrustal successions of the Central Domain of the DFB (Brusque Belt). On the other hand considering the similarities between the Granite Belt in South America and the western domain of Kaoko Belt (Skeleton Coast) in Africa, a correlation between these domains can be made. It is proposed here that the Granite Belt has been developed in the active margin of Angola and Kalahari cratons as a result of the eastward subduction of the Adamastor Ocean oceanic crust. The resulting magmatic arc (Granite Belt) would be associated with the evolution of the Kaoko, Gariiep and Saldania belts of Southwestern Africa. Only during the Ediacaran period the Granite Belt collided against the “South America” becoming part of the Dom Feliciano Belt.



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Petrogenesis of the Permian-Early Triassic granitoids of the northeastern sector of the North Patagonian Massif

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Permian–Early Triassic granitoids cropping out between the villages of Nahuel Niyeu to the east and Yaminué to the west, northeastern North Patagonian Massif can be separated into two groups: the oldest at 280 Ma, the Early Permian Granitoids (EPG) and the youngest the 255- 245 Ma Late Permian- Early Triassic Granitoids (LPETG) that are made up by several igneous complexes. The EPG, restricted to the east of the area, are mostly undeformed and intrude a low grade basement. The LPETG are, in the east, mostly undeformed and intrude Cambrian granites and in the west syn-kinematic sheeted intrusion concordantly emplaced in medium grade metaclastic rocks of probably Devonian age or variably deformed granites intruding either the sheeted granitoids or, the youngest, a very low grade metaclastic unit (López de Luchi et al. 2010, *Tectonophysics* 494: 118-137, Rapalini et al. 2013 *Terra Nova* doi: 10.1111/ter.12043.). These granitoids are slightly metaluminous to weakly peraluminous (ASI 0.95-1.07) and I-type, being EPG medium K calc-alkaline and LPETG high K calc-alkaline to alkalic-calcic. An overlap in the wide concentration ranges of oxides, such as SiO₂, CaO, MgO, Fe₂O₃ and TiO₂ for EPG and LPETG, with no discernable differentiation trends on Harker variation diagram, precludes the derivation of one group from the other by differentiation following emplacement. At SiO₂ 65% EPG show higher concentration of Na, Sr, Zr, lower Rb/Sr and a less pronounced Eu anomaly than the LPETG. Chondrite normalized REE patterns varies from rather flat to moderately fractionated except for one sample of the LPETG but there is an overall flattening towards more evolved granites. In petrotectonic plots both EPG and LPETG are located in the volcanic arc field but the latter is closer to or either in the syn-collisional the late orogenic fields. Significant differences appear when considering isotopic data (Martínez Dopico et al 2011, *JSAES*, 31:324-341, Pankhurst et al. 2014, *JGSL* 171, 313-328). EPG exhibit homogeneous composition, i. e. ⁸⁷Sr/⁸⁶Sr_i 0.704, T_{DM} 1.2 Ga and epsilon Nd -3 whereas LPETG exhibit an ampler range of ⁸⁷Sr/⁸⁶Sr_i from 0.7074 to 0.7097, T_{DM} 1.4-1.5 Ga and epsilon Nd from -4.9 to -8.6. Major differences in Sr-Nd isotopic composition and the great difference in Sr content suggest reworked basic sources (pre-Early Permian oceanic lithosphere terranes) or mixing of basic magmas with crustal components for EPG based on the low ⁸⁷Sr/⁸⁶Sr_i and slightly negative epsilon Nd. Coeval basic magmas are represented by dioritic to monzodioritic enclaves or late stage very scarce dykes. LPETG source is rather uniform for all the studied rocks. On the other hand the relatively low Rb/Sr, negative epsilon Nd and ⁸⁷Sr/⁸⁶Sr_i from 0.7074 to 0.7097 suggest a depleted lower crustal source. Therefore there is a major change in the source at ca 255 Ma. In the interval between 250-245 Ma a decrease in Sr, increase of the Eu anomaly and an overall flattening of the REE patterns may suggest shallowing of the sources.



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The post-tectonic granites of the Gavião Block: the example of Salininha Monzogranite, Brumado, Bahia, Brazil.

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Gavião Block is one of the four Archean crustal segments that collided during the Paleoproterozoic. There are post-tectonic granitoids associated with this Block and one of these is Salininha Monzogranite, object of this work. This granitic body is located at approximately 50 kilometers NW of the city of Brumado, state of Bahia, Brazil. In order to understand how the crustal evolution of the southern portion of the Gavião Block occurred, the study of this rock's mineralogy, litho-geochemistry and geochronology becomes necessary.

This rock's color varies from light to dark gray; it is homogeneous and does not show deformational structures. It shows an abrupt, rectilinear contact with the gneissic enclosing rock and xenoliths of this gneiss can be found in the granitic body.

This rock is composed by quartz, plagioclase, K-feldspar and biotite, all these primary, as main minerals and muscovite, epidote, zircon and opaques as accessories. The litho-geochemical studies for major, minor, trace and rare earth elements revealed that this monzogranite is peraluminous and also shows a strong negative Eu anomaly, indicating that the source of the magma that generated this rock is, now, poor in plagioclase. These data were also used to help determining the tectonic environment of formation of this igneous body as post-collisional.

The U-Pb (ID-TIMS) preliminary age of 1943 ± 5 Ma, measured on zircon crystals, indicates that this monzogranite was formed after the paleoproterozoic collision and this can be noticed by the absence of deformational structures at the outcrops of this granitic body. Detailed geochemical and geochronological studies will give a more precise idea about how the crustal evolution of this portion of the São Francisco Craton occurred.



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Petrogenesis of the syn-orogenic calc-alkaline magmatism in the Agudos Grandes Batholith, SE Brazil

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The Agudos Grandes Batholith is a result of voluminous and long-lived (>615-565 Ma) granite magmatism developed in the Apiaí Domain of the Ribeira Belt in SE Brazil. The largest volume of granite was emplaced during the “syn-orogenic” period and is largely dominated by foliated metaluminous high-K calc-alkaline granites (610±2 Ma; Ibiúna-type), with subordinate peraluminous leucogranites (610±1 Ma; Turvo-type) and allanite and titanite-rich biotite granites (608±5 Ma; Itapevi-type).

The Ibiúna-type hornblende-biotite granites span a wide range of SiO₂ (63-73 wt.%) and are characterized by high Mg# (usually, 40-50) and high Ba and Sr contents. REE patterns are fractionated (La_N/Yb_N= 16-62); low Rb/Sr and U/Th ratios and the Sr-Nd-Pb isotope signature are indicative of significant contribution from old lower crust. Their signature strongly contrasts with the Turvo-type muscovite-biotite leucogranites, which intrude them and are have high SiO₂ (73-75 wt.%), high U/Th, and low Zr and LREE.

The Itapevi-type is fine-to medium-grained, equigranular to porphyritic biotite granites with abundant allanite and titanite. These granites span a similarly large compositional range (60-74 wt.% SiO₂), but differ from the Ibiúna-type by their consistently lower Mg# (25-40) and Sr, and higher Ba/Sr, Zr, Hf, LREE and Th at a given silica content. They have fractionated REE patterns, with a mafic equigranular sub-type enriched in HREE (La_N/Yb_N= 25-96) when compared with a felsic sub-type (La_N/Yb_N= 7-37). A porphyritic sub-type is petrographically similar to the Ibiúna type, and is distinguished by its lower CI (~8).

Major-element geochemical modeling shows that the felsic Itapevi cannot be derived from the mafic Itapevi variety by fractional crystallization; the results show that fractionated melts do not reach high values of SiO₂ as observed in the Itapevi-felsic. A better fit is achieved by fractional crystallization of a magma akin to Ibiúna-type and up to 18% assimilation of a metapelite; the presence of inherited zircons with ~1.8 and 2.1 Ga is consistent with the budget of detrital sources in the Apiaí Domain.

The Itapevi mafic and porphyritic sub-types, which show evidences of interaction with a mafic magma (e.g., mafic enclaves), can be modeled as resulting from mixing between the Itapevi felsic sub-type and a basalt magma.

Heat flux provided by the intrusion of the Ibiúna granites resulted in low-degree (F~ 0.07-0.37) partial melting of more fertile protoliths (metawackes) at shallower crustal levels generating the anatectic peraluminous Turvo-type leucogranites.



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THE SERRA DOS ÓRGÃOS BATHOLITH IN THE RIBEIRA BELT, RIO DE JANEIRO, BRAZIL

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The Serra dos Órgãos batholith in Rio de Janeiro occupies about 5,000 km². Its exact age is still uncertain, but it was probably intruded at about 570Ma during an extensional episode, part of the series of events which comprise the Brasiliano Orogeny in SE Brazil, and which include later deformation, metamorphism and granite intrusion during the interval between 630 and 480Ma. The main rock types are biotite-hornblende monzogranite, and biotite leucogranite which may contain hornblende. Small quantities of quartz diorite (mainly as enclaves), tonalite, granodiorite, aplite and pegmatite are also present. The chemical compositions of the main facies are sub-alkaline (calcic and slightly tholeiitic to mafic rocks and calc-alkaline to granitoids), medium- to high-K, and slightly to moderately peraluminous. In detail, a number of chemical facies are separated on the basis of Rb and Ti+Zr+P contents. The rocks are isotopically heterogeneous, as shown by Sr and Nd compositions which indicate that crustal reworking of late Paleoproterozoic rocks was the dominant petrogenetic process, while juvenile contributions were at most, very restricted. Geothermometry and geobarometry suggest that most of the batholith solidified in the middle crust at about 750°C and between 5 and 5.5 kb. Based on our data, these rocks should not be considered as part of the Rio Negro juvenile magmatic arc. On the contrary, they are considered as recycling of older crustal material (Paleoproterozoic), as indicated by isotopes of Sr and Nd.



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"A-type" Neoproterozoic magmatism of the Graciosa Province, S-SE Brazil: a review

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Neoproterozoic "A-type" silicic provinces are widespread in continental Brazil. They were emplaced during extensional regimes related to Gondwana amalgamation events. Specific petrological features attest the recognition of two coeval "post-collisional" provinces in southeastern Brazil: Itu and Graciosa Provinces. In the Graciosa Province, granites and syenites build several isolated plutons, plutonic and volcano-plutonic complexes, emplaced in low crustal levels during a relatively short time interval, close to ca. 580 Ma.

Contemporaneous high-K gabbro-dioritic and dioritic rocks as well as some basic and silicic volcanics occur in small proportions. A poorly known charnockitic-like rock occurs in at least one pluton. The main granitic and syenitic series crystallized from high-T melts and are grouped in the alkaline and aluminous petrographic associations.

The aluminous association is made mainly of metaluminous to slightly peraluminous biotite (\pm hornblende) monzo- and syenogranites formed under variable oxi-red conditions.

Relatively oxidizing varieties (f_{O_2} close to the TMQAI buffer) bearing allanite, titanite, magnetite and ilmenite are largely dominant over relatively reduced varieties (f_{O_2} close to the QFM) with allanite and ilmenite. *Hypersolvus* metaluminous alkali-feldspar syenites, quartz syenites, and peralkaline alkali-feldspar granites constitute the alkaline association, crystallized in relatively reduced environments ($f_{O_2} \gg$ QFM). Syenites present fayalite, Ca-pyroxenes and Ca- and Na-Ca amphiboles while Na-pyroxenes and Na- and Na-Ca amphiboles are the main mafic minerals in the peralkaline rocks. Chevkinite and ilmenite (\pm magnetite, titanite) are typical accessory minerals.

Late, contrasted hydrothermal alteration environments, styles and products characterize these magmatic series. In general the late- to post magmatic crystallization stages in both associations followed increasing oxidation trends and the late-formed minerals fill in mirolitic cavities and fractures as well as appear interstitial to or substituting the primary phases. Typically, evolved peralkaline alkali-feldspar granites develop an exotic "agpaitic" late- to post-magmatic HFSE- and REE-rich mineral assemblage, while albite granites and a variety of greisens, some of them cassiterite-bearing, are related to biotite granites, mainly of the relatively reduced types.

The main geochemical features of the Graciosa Province are akin to A-type provinces elsewhere. All series are rich in alkalis; the relatively oxidized rocks of the aluminous series evolve from slightly magnesian to typical ferroan while the alkaline series as well as the relatively reduced aluminous series are highly ferroan and Ca-, Sr-, and Ba-poor. As expected, the alkaline series are relatively enriched in the HFS and RE elements; a remarkable positive correlation does exist between these elements and the Agpaitic Index. Available and incoming isotopic data (Sr-Nd-Pb-Hf) of typical rocks from the province point towards contributions from sources relatively evolved. Even the gabbro-diorites and the *hypersolvus* rocks from the alkaline association present crustal-like isotopic signatures and



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older, archean to paleoproterozoic, Nd- and Hf-model ages. A “typical” mantle component has been characterized only in some $^{18}\text{O}/^{16}\text{O}$ ratios measured in zircon crystals from samples of the alkaline association.

Although both OIB-like mantle- and crustal-sources must have contributed to the building of the province, the details of the petrological processes, as well as the tectonics involved, are not clear enough and need further improvements.



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Timing and sources of granite magmatism in the Ribeira Belt, SE Brazil: insights from zircon in situ U-Pb dating and Hf isotope geochemistry in granites from the São Roque Domain

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Eight new in situ U-Pb zircon age determinations by Shrimp and MC-LA-ICPMS reveal that the main granite magmatism in the São Roque Domain, which is largely dominated by high-K calc-alkaline monzogranites with subordinate peraluminous leucogranites, occurred between 603±4 and 591±4 Ma. Importantly, this small temporal range is ca. 20-30 Ma younger than previously admitted based on U-Pb TIMS dates from literature, some of which obtained in the same occurrences now dated. The observed discrepancy seems related to the presence of small Paleoproterozoic inherited cores in part of the zircon populations used for TIMS dating, which could also respond for the unusually high (up to 10 Ma) uncertainty associated with most of these ages. The younger age range now identified for the São Roque granite magmatism has important implications for the evolution of the Ribeira Fold Belt. Whilst previously admitted ages ca. 620-630 Ma substantiated correlations with the widespread and intensely foliated high-K calc-alkaline granitoid rocks of the neighbor Socorro-Guaxupé Thrust Nappe (potentially associated with an accretionary continental margin), the ~ 600-590 Ma interval seems more consistent with a late deformation tectonic setting. Strongly negative $\epsilon_{\text{Hf}}(t)$ characterize the magmatic zircons from the São Roque Domain granites. An eastward increase from -22 in the São Roque Granite to -11 in the Cantareira Granite and neighboring stocks suggests an across-domain shift in granite sources. Such eastward younging of sources, also indicated by Sm-Nd isotope data from granites and supracrustal sequences in neighboring domains, is suggestive that some of the first-order limits and discontinuities in this belt are not defined by the strike-slip fault systems traditionally taken to separate distinct domains. Although the negative $\epsilon_{\text{Hf}}(t)$ and $\epsilon_{\text{Nd}}(t)$ indicate sources with long crustal residence for all studied granite plutons, the observed range is more radiogenic than the values calculated at 600 Ma for both the Mesoproterozoic (1.5-1.8 Ga) passive-margin metavolcano-sedimentary sequences of the São Roque Domain and their inferred Archean to Paleoproterozoic continental sources. Therefore, a contribution from sources with less negative $\epsilon_{\text{Hf}}(t)$ and $\epsilon_{\text{Nd}}(t)$ is required to explain the observed range.



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Characterization of the Rio Capivari Complex, basement of the Embu Terrane: Geochemical and Geochronological constraints

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The Embu Terrane outcrops in the central Ribeira Belt, which is part of the Mantiqueira Province in the southeastern of Brazil. The Terrane is characterized by a framework of basement orthogneisses (Rio Capivari Complex) and meta-supracrustal rocks, intruded by old orthogneisses (0.82 Ga) and voluminous granite occurrences (mainly in the interval 630-580).

Basement rocks are predominantly migmatitic with relict igneous textures and variable deformation and partial melting degrees, with structure varying from gneissic to protomylonitic and leucosome remobilizations associated with stromatic to diatexitic features.

Combined whole rock geochemistry, isotope, and U-Pb zircon geochronology results from basement selected samples reveal a Paleoproterozoic sector defined by a magmatic event at ≈ 2.16 Ga, followed by partial melting and metamorphism at 590-620 Ma, therefore synchronous to the main magmatic event in the Embu Terrane, which might indicate that basement rocks contributed as a source component to the granite magmatism. Rocks range from tonalite and granodiorite to granite (*TTGs*), with minor intrusions of gabbros. They exhibit Magnesian signatures and are predominantly Alkali-calcic to Calc-alkaline and metaluminous.

Nd isotopes indicate that migmatites were produced via reworking of Archean crust (T_{DM} from 2.49 to 3.31 Ga), with the youngest component representing newly accreted, juvenile crust, as suggested not only by the proximity between T_{DM} and radiometric U-Pb zircon ages of a mesocratic tonalitic gneiss (2.49 and 2.43 Ga, respectively) but also by its markedly positive $\epsilon Nd(t)$ (+3.4) and $\epsilon Hf(t)$ (+4.6). More felsic migmatites have Rhyacian ages (from 2.05 to 2.19 Ga) and show $\epsilon Nd(t)$ ranging from -7.4 to -2.5 which combined with $\epsilon Hf(t)$ in the interval -48.1 to +4.2, suggests that these represent reworked crustal sources of prolonged residence times. Amphibolites occur as boudins and represent intrusive basaltic dykes, since T_{DM} are much younger, ranging from calymmian (1.50 Ga - Mesoproterozoic) to tonian (0.99 Ga - Neoproterozoic).

Chondrite normalized zircon chemistry reveals enrichment in light REE for rocks bearing larger proportions of felsic neosome. Th/U ratios are higher for magmatic cores (0.07-1.59, with predominance of higher values) compared to metamorphic overgrowths (mainly in the interval 0.007-0.049). All samples are enriched in HREE in respect to LREE. However, magmatic zircons show progressively steeper profiles compared to inherited and metamorphic crystals, as also denoted Lu/Sm_N ratios average of 82, 34, 14, respectively. Chemical data suggest a complex evolutionary path, involving either the preservation of Archean relict zircons during high-pressure anatexis or the entrapment of zircon xenocrysts from the overlying rocks during the ascent of deep magmas.

Metamorphic overgrowths register a shallower process as indicated by lower Lu/Sm_N and higher oxidation (Eu/Eu* between 0.16 and 0.50, against 0.22-0.84, and 0.32- 0.72 observed for magmatic and inherited zircons, respectively).

These results identify a relatively pristine Siderian rock suite that holds the potential for future investigation into the early evolution of continental crust in the Ribeira Belt.



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Petrology of the Glória Norte Massif, Sergipano Orogenic System, NE Brazil

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In the northern portion of the *Sergipano* Orogenic System the Neoproterozoic is characterized by a widespread granitic plutonism. The studied granite occur in the *Macururé* Domain which is built up mostly by garnet micaschists with minor marble and quartzites. On field, the *Glória Norte* Massif (GNM, 42 km²) truncates regional structures, and is composed of two main facies of hornblende-biotite-quartz-monzonites, distinguished by the presence of porphyritic texture. The porphyritic rocks predominate. Magmatic structures - such as feldspar and mica flow orientation - are preserved. There is no significant evidence of solid-state deformation in the studied rocks. Mineral assemblages show conditions of increasing fluid content in the magma during cooling (diopside, green hornblende and brown biotite, followed by feldspar and quartz). The late-magmatic stage is represented by a fluid phase that changed biotite into chlorite, formed white mica and carbonate, and changed feldspars in clay minerals. At this same stage the recrystallization developed myrmecitic and perthitic textures, both commonly observed in the porphyritic quartz monzonite. Mafic microgranular enclaves (MME) are abundant, showing different sizes and shapes. Ellipsoidal enclaves are oriented according to the magmatic foliation. Many magma mixture features are observed as - for example - crystals corrosion and dissolution, compositional zoning of feldspars and agglomerates of mafic minerals. The fine granulation of the enclaves indicates a rapid cooling of mafic magma bubbles due to temperature contrast with the host felsic magma. In thin section, textures confirm the rapid cooling of the enclaves, such as apatite crystals with acicular morphology that occur near the MME edges, marking the enclave interface bound with the host rock. Geochemical data revealed that the GNM composition ranges from monzonite to granite, with shoshonitic affinity. Enclave's compositions range from monzogabros to monzonites, and may be correlated to the ultrapotassic suits (MgO > 3 wt. %, K₂O > 3 wt. %). Trace elements diagrams show the enrichment of LREE relative to HREE, and strong negative anomalies of Ta, Nb, Ti, P, Sr, and Eu, mostly in the enclaves. The average temperature calculated by Zr thermometers indicates that the onset of MGN crystallization initiated between 810°C and 784 °C, and finished at 730°C - 700°C. The zircon U-Pb SHRIMP age of 588 ± 5.2 Ma, places these magmas in the Ediacaran Period. These rocks are not significantly affected by tectonic events and this age marks the occurrence of these alkaline magmas in the *Sergipano* Orogenic System between 588 and 571 Ma. In the Pearce's diagrams, the GNM rocks are positioned in the field of post-collisional granites. However, we also observed a volcanic arc signature in these same samples. The MMEs and minettes are associated with volcanic arc and syn-collisional signatures, respectively. [Acknowledgments: CNPq/ FAPITEC/PRONEX].



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FERROAN GRANITES AND CHARNOCKITES (1.39-1.30 Ga) IN THE RONDONIA TIN PROVINCE RELATED TO THE EVOLUTION OF THE RONDONIAN-SAN IGNACIO OROGENIC SYSTEM, SW AMAZONIAN CRATON, BRAZIL

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The Rondonian-San Ignacio Province (RSIP: 1.56-1.30 Ga) is a composite orogen in Brazil (south Rondônia and northwest Mato Grosso states) – Bolivia boundary constituted by successive accretions of oceanic and continental arcs (1.56-1.34 Ga), microcontinent-continent collision (1.35-1.34 Ga), and a post-collisional stage (1.34-1.32 Ga). 1.39-1.30 Ga non-deformed ferroan granites and charnockites temporally related to the development of the RSIP are recognized in the Rondônia Tin Province: 1) 1.39 to 1.34 Ga: an older calc-alkalic and ferroan quartz-monzodioritic charnockite, and a younger metaluminous to slightly peraluminous, potassic, alkali-calcic, ferroan granitoids and granitic charnockite of the Alto Candeias Intrusive Suite (ACIS); 2) 1.38 to 1.37 Ga: metaluminous, hypersolvus, alkalic, ferroan granitoids and associated rocks (syenites, monzonites, monzodiorites, and diorites) of the Teotônio Intrusive Suite (TIS); and metaluminous to slightly peraluminous, potassic, alkali-calcic, ferroan granitoids and associated rocks (quartz monzonites, monzodiorites, diorites, and hybrid rocks) of the Santo Antônio Intrusive Suite (SAIS); and 3) 1.32 to 1.30 Ga: metaluminous to peraluminous, potassic, alkali-calcic, ferroan granitoids and associated gabbro of the São Lourenço-Caripunas Intrusive Suite (SLCIS). The geochemical data indicate that the granitoids of all suites are typically A-type and within-plate granites (ACIS: A₂ group and reduced; TIS: A₁ group and reduced; SAIS: A₂ group and oxidized; SLCIS: A₂ group and reduced and oxidized). These suites are interpreted to be related to episodic underplating of mafic, iron-rich, mantle-derived magmas in an extensional regime and within-plate tectonic setting. This view is supported by the presence of associated rocks such as diorites, monzodiorites, diabase, and gabbros as enclaves, dikes, minor intrusions and mingled and mixing rocks, as well as by the Nd composition values of granitoids ($\epsilon_{Nd} = +0.14$ to $+2.56$) at least in the TIS, SAIS and SLCIS. The alkalic metaluminous granitoids and related rocks of the TIS were formed by fractional crystallization of ferro-basalt parent magma, whereas the alkali-calcic metaluminous granitoids of the SAIS, ACIS, and SLCIS were crystallized from anatectic melts derived from quartzo-feldspathic sources in response to mafic underplating. The anatectic melts included important mantle source components at least in the TIS, SAIS, and SLCIS.



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Mesozoic Magmatism and the Evolution of Crust-Mantle Structures in the Eastern Part of Sino-Korean Craton

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A variety of types of data indicate that the subcontinental lithospheric mantle of the eastern part of Sino-Korean Craton (SKC) has been dramatically thinned or lost during the Mesozoic. Here I propose a comprehensive model to explain the reactivation of the eastern SKC during Mesozoic. During the Late Triassic to the Early Jurassic, several alkaline and granitoid plutons intruded into the southern and northern margins of the SKC. They represent the post-collision magmatism related to the continental collisions. In the Middle and Late Jurassic, intensive compressional deformation and widespread syn-kinematic and post-kinematic magmatism occurred in the eastern and northern margins of the SKC. The thrusting and magmatic activities in the eastern margin were related to the subduction of the Paleo-Pacific plate. The Middle and Late Jurassic contractional tectonism and extensive magmatism occurred in the northern margin, and the acid magma with adakite-like geochemical feature intruded in the southeastern and northern margins indicates the existence of over-thickened crust in these regions.

The widespread magmatism occurred both in the margins and interior of the SKC during the early stage of Early Cretaceous. The extensive acid magmatism with A2-type granite feature in the south, southeastern and northern margins of the SKC suggests that the over-thickened crust had been fully heated. The alkaline and/or high-Mg rocks intruded in the interior of the eastern SKC manifested the decompression melting of the lithospheric mantle. The thinning of lithospheric mantle in the interior of the eastern SKC was related to the contractional deformation along the margins, because the shortening of lithosphere in the margin of a continent plate can trigger laterally flow and thinning of the lithospheric mantle beneath the plate's interior. After *ca.*125 Ma, the metamorphic core complex (MCC) with southeast-northwest-direction shearing sense developed simultaneously in the southern, northern and eastern margins of the SKC. The mantle-derived high-K magmas occurred in these margins exhibit Sr-Nd-Pb isotopic signatures of the SKC's lithospheric mantle. The simultaneously developing of MCCs indicated the gravity collapse of the over-thickened crusts, and was related to the retreat of the subducted Paleo-Pacific plate.

Based on these observations, a tectonic model of circum-craton collision driving is proposed for the magmatism, tectonism and lithospheric thinning in the eastern portion of the SKC. The key points include that, (1) the contraction along the margins of the SKC is the driving mechanism of the thinning of craton's lithospheric mantle; (2) the Mesozoic lithospheric thinning and transformation beneath the eastern SKC developed gradually from its margins into the interior; (3) the Jurassic subduction of Paleo-Pacific plate strongly influenced the lithospheric evolution of the eastern SKC, dehydration reactions in the slab released fluids that significantly hydrated the root of the eastern SKC, changing the rheology of the lithospheric mantle and causing significant hydration-related weakening; (4) the hydro-weakening caused by pre-Triassic subduction of the Tethyan and the Paleo-Asian oceans only influences the mantle beneath the southern and northern margin of the SKC, respectively, and did not trigger the wholesale lithospheric thinning or loss in the SKC.



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Generation of Continental Crust in the Borborema Province, Northeastern Brazil

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This work deals with the origin and evolution of magmatic rocks in the area north of the Patos Lineament in the Borborema Province (BP) of northeastern Brazil. Archaean rocks cover ca. 4.4% of the exposed terrain. They were emplaced over a period of 700 Ma, with at least seven events of magma generation, at 3.41, 3.36, 3.33, 3.19, 3.12, 3.03, and 2.69 Ga. The rocks are subalkaline to slightly alkaline, with affinity to I- and M-type magmas; they follow trondhjemitic or potassium calc-alkaline differentiation trends. They have epsilon Nd(t) of +3.36 to -6.18 and negative anomalies for Ta-Nb, P and Ti, consistent with a convergent tectonic setting. Both subducted oceanic crust and upper mantle (depleted or metasomatised) served as sources of the magmas. After a time lapse of about 350 m.y., large-scale emplacement of Paleoproterozoic units took place. These rocks cover about 47.3% of the region. Their geochemistry indicates juvenile magmatism with a minor contribution from crustal sources. These rocks also exhibit potassic calc-alkaline differentiation trends, again akin to I- and M-type magmas, and show negative anomalies for Ta-Nb, Ti and P. Metasomatised mantle, resulting from interaction with adakitic or trondhjemitic melts in a subduction zone setting, is interpreted to be the source of the magmas. U-Pb ages indicate generation of plutonic rocks at 2.24-2.22 Ga (in some places at about 2.4-2.3 Ga) and 2.13-2.11 Ga, and andesitic volcanism at 2.15 Ga. Isotopic evidence indicates juvenile magmatism (epsilon Nd(t) of +2.9 to -2.9). After a time lapse of about 200 m.y. a period of within-plate magmatic activity followed, with acidic volcanism (1.79 Ga) in Orós, granitic plutonism (1.74 Ga) in the Seridó region, anorthosites (1.70 Ga) and A-type granites (1.6 Ga) in the Transverse Zone (TZ). Early Neoproterozoic volcanism at 1091 Ma, and A-type plutonism, from 920 to 775 Ma, mark the intraplate magmatism in the TZ. In the Seridó Domain, the Late Neoproterozoic registers several events of plutonism, at 600-591 / 575 / 560 / 543 / 525 and 515-510 Ma (pegmatites). These rocks cover ca 15.8% of the area. The most important magmatic event is that at 575 Ma. It coincides with the peak of widespread transpression and synchronous high temperature metamorphism. The Neoproterozoic rocks are mostly calc-alkaline or transitional to alkaline. Inherited Archean and Palaeoproterozoic zircons and Nd model ages, as well as moderate to strongly negative (-21 to -9) epsilon Nd, and persistent negative anomalies for Ta-Nb, Ti and P indicate significant crustal contributions in their genesis. While a convergent setting (subduction zone) could explain the Archaean and Palaeoproterozoic units, this is not so for the Neoproterozoic rocks, since the latter mimic the geochemical and isotopic features of the older sources. In the study area the peak of juvenile accretion (mantle derived magmas) took place in the Archaean (3.4-2.7 Ga) and Palaeoproterozoic (2.4-2.11 Ga), whereas crustal recycling predominated in the Neoproterozoic.



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Lower crust-derived shoshonitic magma: an example from NE Brazil

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The Guarany pluton in the Pernambuco-Alagoas Domain, northeastern Brazil, is an example of shoshonitic granite crystallized from remelting of mafic lower crust. This pluton consists of unfoliated hornblende monzodiorite to biotite granite intrusive into orthogneisses, a few km south of the Pernambuco shear zone, and is cut by diorite dikes and enclaves with field relationships suggesting that they are co-magmatic with host granite. The granite contains biotite, amphibole, titanite, apatite, zircon, magnetite, allanite and magmatic epidote as mafic phases, while the diorite contains amphibole, biotite and epidote. UPb SHRIMP zircon ages are the same for the host granite and a diorite dike (573 ± 4 Ma) confirming they are coeval. The rocks are rich in K (average $K_2O = 5.1\%$), Ba (average 1384 ppm), Sr (average 451 ppm), and present low TiO_2 (average 0.9%). Rb/Sr ranges from 0.19 to 1.1 and Th/U ratios range from 5 to 16. Chondrite-normalized REE patterns and primitive mantle-normalized incompatible element diagram are overlap for the two rock types. The latter shows strong enrichment in LILE, depletion in HFSE, and negative spikes at U, Sr, P, Ti and Ta-Nb.

Magmatic epidote, amphibole chemistry, and zircon and apatite saturation geothermometers indicate magma emplacement at high P (~7 kbar) and T (~900°C) conditions. Co-magmatic granites and diorite have chemical and isotopic characteristics of crustal melts, such as enrichment in incompatible elements, high back calculated initial $^{87}Sr/^{86}Sr$ (average 0.71253), and negative $\epsilon Nd(0.57Ga)$ values (average -14.58). Values of $\delta^{18}O(zircon)$ from the granites are high and variable (~9- 11‰), show positive correlation with whole-rock silica contents, which together with a hyperbolic curve formed by granite and diorite in initial $^{87}Sr/^{86}Sr$ and Sr concentration space, are suggestive of hybridization between a lower crust melt and intermediate crustal rocks, concomitant with its during fractional crystallization. Altogether, the geochemistry and isotopic behavior are consistent with the hypothesis that the granite was formed by partial melting of quartz-poor, long-term crustal residence (1.9-2.2 Ga) mafic lower crustal rocks, probably triggered by decompression due to movements of deep shear zones, likely enhanced by underplating of mantle-derived mafic magma.



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Mixing between granites and diatexites in an anatectic terrane, Kangaroo Island, South Australia

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Hybridisation processes such as mingling and mixing of magmas, or assimilation of crustal material by an intrusive magma, are key processes controlling the evolution of granitoids. The literature has focused on the interaction between mafic and felsic magmas, with only little research on the interaction between different felsic magmas. Here, we report features from the ~500Ma Delamerian Orogeny on the south coast of Kangaroo Island where turbidites of the Kanmantoo Group have undergone extensive anatexis. We show evidence for hybridization between intrusive granite sheets and *in source* products of turbidite melting, mostly diatexites. Muscovite breakdown assisted by water-fluxed melting of the turbidites resulted in a fine-grained, grey, granitic magma, which forms a schollen-rich diatexite. These are intruded and by leucocratic, coarse-grained, K-feldspar megacrystic granites. Structures suggest that the megacrystic granite intruded when the diatexite was still molten, and both become hybridized as they were sheared together as magmas by oblique-dextral-thrust shear sense. The combination between multiple intrusion events and shearing create multiple and different opportunities for hybridization, explaining the extreme variability of magmatic rocks types. The most recognizable feature of the process is the transfer of solids between the two end-member magmas: megacrysts from the granite are transferred to the fine-grained diatexite, and schollen and schlieren from the diatexite are transferred to the megacrystic granites. We envisage a general process where a partial melted region forms a low-viscosity trap, impeding the passage of external magmas. These intrude the anatectic zone, where they raise the temperature and water content, triggering further *in situ* melting, and mix with the locally produced anatectic melts. On Kangaroo Island, the protolith of both magmas is the Kanmantoo Group, the diatexites being roughly *in situ* and the intrusive megacrystic magma being derived from deeper sources. This process is possibly typical of crustal anatectic zone and could be equivalent to regions where juvenile, mafic magmas intrude crustal migmatites. The outcrops on Kangaroo Island essentially record a MASH zone, such as envisaged by Hildreth and Moorbath, with the difference that melting, assimilation, storage, and homogenization involves only continental crustal magmas.