UNIVERSIDADE DE SÃO PAULO
INSTITUTO DE GEOCIÊNCIAS

**Serra do Barro Branco orthogneiss: untimely record of the West Gondwana amalgamation in the
São Roque Domain**

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Orientador: Prof. Dr. Mario da Costa Campos Neto

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Às mulheres na ciência.

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ABSTRACT

Large volumes of high-K calc-alkaline metaluminous to peraluminous granitoids are intrusive in south-eastern Brazil. In particular, the high-K geochemical affinity extends from the batholiths of the Socorro-Guaxupé Nappe to smaller intrusions in the São Roque Domain. The fault-bounded São Roque Domain is a relatively small crustal block that comprises two metavolcano-sedimentary sequences of Statherian maximum depositional age. Detrital zircon provenance points to a Rhyacian (2.17 Ga) proximal source area with patterns matching the southern portion of the Socorro-Guaxupé Nappe. The domain records magmatic activity initiated at *ca.* 685 Ma with the crystallisation of the Barro Branco biotite orthogneiss of intermediate SiO₂ composition. Unprecedented zircon ages around 740 and 800-900 Ma found in a metavolcaniclastic rock suggest older magmatism also might have taken place. The Barro Branco orthogneiss has an inequigranular facies dated at *ca.* 625 Ma of more “evolved” peraluminous affinity. The Moinho is a (hornblende)-biotite granodiorite emplaced at *ca.* 620 Ma with more “primitive” SiO₂ range, typically metaluminous. The most voluminous Ediacaran magmatism occurred within 610-590 Ma represented by several circumscribed biotite granites. All granitoids have high Sr/Y and LREE, low Nb and Ti and lack negative Eu anomaly that suggest a deep lower crustal source with residual garnet ($\pm$ amphibole $\pm$ rutile). Whereas the Socorro-Guaxupé arc rocks have intermediate Sr/Y and moderate to absent, negative Eu anomalies but share the trace-elemental imprints of subduction zones. Nd and Hf isotopes indicate that the Barro Branco orthogneiss carries a significant juvenile component while the inequigranular orthogneiss and Moinho granodiorite have typically crustal signatures that seem to partially originate from the country metasedimentary rocks. During the temporal gap between the Barro Branco emplacement and the magmatism that followed from *ca.* 635 Ma on, the mantle beneath the São Roque Domain might have been fertilized by crustal additions. Enriched mantle and low-degree partial melting probably produced high-K enriched melts. Thus, we propose the São Roque Domain developed on the Paranapanema active margin and records the initiation of subduction in the retro-arc domain. The magmatic “shut-down” of *ca.* 35 m.y. could result from a slab retreat that caused magmatism to migrate northwards in the Socorro-Guaxupé arc domain. Magmatism followed at *ca.* 635 Ma with crustal signatures that support mantle enrichment from the last-longing subduction beneath the Paranapanema. A metasedimentary rock with monazite age of *ca.* 600 Ma and two cores of *ca.* 630 Ma may be evidence of an ongoing thermal episode in the São Roque Domain, overlapping the metamorphism in the neighbour Socorro-Guaxupé Nappe.

RESUMO

Grandes volumes de granitoides calcioalcalinos de alto-K são intrusivos no sudeste do Brasil. Afinidades geoquímicas de alto-K estendem-se dos batólitos da *Nappe* Socorro-Guaxupé a pequenas intrusões no Domínio São Roque. O Domínio São Roque é uma pequena porção crustal limitada por zonas de cisalhamento que compreende duas sequências metavulcanossedimentares com idade máxima deposicional Estateriana. Proveniência de zircões detríticos relata uma área-fonte proximal de idade Riaciana (2.17 Ga) com padrões detríticos similares à porção sul da *Nappe* Socorro-Guaxupé. O domínio registra início do magmatismo em *ca.* 685 Ma com a cristalização do biotita ortognaisse Barro Branco, de composição intermediária. Idades de zircão inéditas por volta de 740 e 800-900 Ma de uma rocha metavulcanoclástica sugerem possível vulcanismo prévio. O ortognaisse Barro Branco possui uma fácies inequigranular de *ca.* 625 Ma de composição "evoluída" peraluminosa. O Moinho é um (hornblenda)-biotita granodiorito de 620 Ma de composição mais "primitiva" e tipicamente metaluminoso. O magmatismo Ediacarano mais volumoso ocorreu dentre 610-590 Ma representado por diversos biotita granitos circunscritos. Todos os granitoides possuem alto Sr/Y e ETR leves, baixo Nb e Ti e carecem da anomalia negativa de Eu, sugerindo uma fonte crustal profunda com granada residual ($\pm$ anfíbólio $\pm$ rutilo). Enquanto as rochas da *Nappe* Socorro-Guaxupé tem Sr/Y intermediário e anomalias negativas de Eu moderadas a ausentes, porém todos partilham das assinaturas de elementos-traço típicos de zona de subducção. Isótopos de Nd e Hf indicam que o Barro Branco possui um importante componente juvenil enquanto o ortognaisse inequigranular e o Moinho possuem assinaturas tipicamente crustais que derivam em parte dos metassedimentos encaixantes. Entre a intrusão do Barro Branco e o magmatismo que seguiu em 635 Ma, adições crustais possivelmente fertilizaram o manto sob o Domínio São Roque. O enriquecimento do manto e fusão parcial de baixo grau podem ter sido responsáveis pelos *melts* enriquecidos de alto-K. Sendo assim, propomos que o Domínio São Roque se desenvolveu na margem ativa do bloco Paranapanema e representa as fases iniciais de subducção em domínio de retroarco. A interrupção do magmatismo de ~35 m.a. possivelmente resultou do recuo da placa subductante fazendo com que este migrasse para norte, no domínio de arco Socorro-Guaxupé. O magmatismo seguiu em *ca.* 635 Ma com assinaturas isotópicas radiogênicas que refletem o efeito da duradoura subducção sob o Paranapanema. Idade de monazita concordante a *ca.* 600 Ma e dois núcleos de *ca.* 630 Ma de uma rocha metassedimentar podem ser evidência de um longo episódio termal no Domínio São Roque, coincidindo com o período de metamorfismo no domínio vizinho Socorro-Guaxupé.

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Structure of the dissertation

The dissertation is divided in: (1) a general introduction; (2) a detailed geological background; (3) detailed methodology; (4) results; (5) discussion and (6) conclusions. This research yielded a paper (submitted to Precambrian Research on 16/01/2020 and accepted on 17/08/2020: <https://doi.org/10.1016/j.precamres.2020.105913>), thus, we present the first half of the paper (Title and Abstract, 1- Introduction, 2- Geological Setting, 3- Methodology, 4- Results) under the “Results” chapter. The paper encompasses condensed versions of the Introduction, Geological setting and Methodology from the dissertation. Since the “Discussion” and “Conclusions” topics of the paper correspond to those of the dissertation, we separated them into individual chapters.

Considering the content was aimed for a scientific paper, to make the reading more fluid and straightforward, we chose to present the results of whole-rock geochemistry in a joint text that gives a general picture of the analysed rocks and highlights respective relevant features. Alternatively, in Appendix-III the reader can find a thorough geochemical description of each unit.

1. INTRODUCTION

In ocean-continent subduction zone settings leading to continental collision, the transition from collisional to late stages of arc evolution is marked by the emplacement of calc-alkaline batholiths and high-K to shoshonitic volcanics. The origin of high-K magmatism is frequently attributed to mantle enriched by previous subductions and triggered by processes such as slab break-off or lower crustal delamination. Alternatively, studies have shown several batches of low-degree partial melting are able of producing such geochemical trends (e.g., Stern et al., 1988; Putirka and Busby, 2007; Wang et al., 2017). Therefore, high-K contents might be produced by several processes that are not necessarily related to the late-or post-orogenic stages of continental evolution and thus linked to magmatism that is contemporaneous to activity in the arc front (e.g., Stern, 1988).

High-K calc-alkaline granitoids are widespread in the Socorro-Guaxupé arc domain (pre- and syn-collisional) and the southern neighbour São Roque Domain. These granitoids carry subduction-related signatures and evidences for coeval mafic magmatism (e.g., Haddad, 1995; Ragatky, 1998; Vinagre et al., 2014; Janasi et al., 2016). The Socorro-Guaxupé Nappe comprises clear evidence of pre-, syn- and late-orogenic arc magmatism and the collisional phase relates to an ultra-high temperature metamorphism (Rocha et al., 2017; Tedeschi et al., 2017). However, the tectonic meaning of the São Roque Domain remains unclear. A correlation of both domains had been suggested in terms of the metasedimentary record (Campos Neto, 2000) and supported by detrital zircon provenance studies on the São Roque Domain (Henrique-Pinto et al., 2015b).

The scope of this study is to provide insights on whether the massive São Roque Domain magmatism was related to the convergence between the Paranapanema and São Francisco paleoplates that led to the development of the Socorro-Guaxupé Nappe. We conducted LA-ICP-MS U-Pb determinations in zircon and monazite, LA-ICP-MS Hf in zircon, whole-rock Sm-Nd and whole-rock geochemistry. The data give unprecedented information on the timing of magmatism and petrogenesis that show the generation of the Socorro-Guaxupé Nappe and São Roque Domain granitoids was potentially co-related and further provide implications on their tectonic evolution.

2. GEOLOGICAL SETTING

2.1. Socorro-Guaxupé Nappe

The Socorro-Guaxupé Nappe is a high-grade, arc-derived terrane of exposed, deep Neoproterozoic crust (magmatic arc roots), generated during the convergence between active margin of the Paranapanema and the passive margin of the São Francisco paleoplates, as part of the Southern Brasília Orogen (Brito Neves et al., 1999; Campos Neto, 2000) during the diachronic West Gondwana amalgamation. The magmatic arc remnants are stacked over the passive margin basement and covers (Carrancas and Lima Duarte nappe systems) and the kyanite-bearing granulites (Três Pontas-Varginha nappe) which is thrust over a metasedimentary pile with eclogitic occurrences (Liberdade nappe) thus forming a package of flat-lying, east-verging thick-skinned nappes (Campos Neto and Caby, 1999; Trouw et al., 2000; Campos Neto et al., 2010, 2011).

The pre-collisional magmatic arc, developed on the active margin of the Paranapanema plate, is divided into three units of the SGN, from base to top: (i) garnet± orthopyroxene-bearing enderbitic granulites topped by amphibolite-facies (biotite)-hornblende tonalite to granodiorite gneisses; (ii) hornblende-biotite-(clinopyroxene)-bearing stromatic and nebulitic migmatites that transition to porphyritic hornblende-biotite granite batholiths, and (iii) garnet± sillimanite gneisses with biotite-garnet-bearing that grade to peraluminous muscovite-bearing leucosomes (Campos Neto and Caby, 2000).

Charnockite and high-K calc-alkaline suites of hornblende-biotite-quartz monzonites-monzogranites with mafic enclaves (Janasi and Ulbrich, 1991; Haddad, 1995; Janasi, 1999; Mora et al., 2014) and subordinate monzodiorites, tonalites and granodiorites intrude the package. They are partially coeval to a prolonged high to ultra-high temperature metamorphism (up to ~1000°C) recently estimated at ca. 630-590 Ma (Rocha et al., 2017) or ca. 670-590 Ma (Tedeschi et al., 2018).

2.2. São Roque Domain

Two major dextral shear zones delimit the São Roque Domain. The Jundiuvira shear zone to the north separates it from the Socorro-Guaxupé nappe, whereas the Taxaquara shear zone to the south marks the boundary with the Embu Terrane (Campanha et al., 2019). It comprises two main metavolcano-sedimentary sequences whose relation and stratigraphic positions are still controversial, the Serra do Itaberaba Group and São Roque Group *stricto sensu* (Juliani and Beljavskis, 1995 and references therein; Juliani et al., 2000), formerly described as a single

São Roque unit (Hasui, 1975). These sequences are massively intruded by Neoproterozoic granitoids. Age constraints for these two groups are scarce and difficult to interpret due to the complex intercalations and discontinuities across the domain.

2.2.1. Paleoproterozoic (to Mesoproterozoic?) metavolcano-sedimentary sequences

The Serra do Itaberaba Group is a metavolcano-sedimentary sequence that records medium-grade metamorphism (Juliani et al., 1986) that was thought to be basal to the São Roque Group (e.g., Coutinho et al., 1982). It comprises units from base to top that intercalate metamafic, metapelitic, calc-silicate and metavolcanic rocks and banded iron formations (Morro da Pedra Preta Formation), Fe-Mg- and Ca-rich pelites with carbonate lenses, metatuffs, metabasalts and metarhyolites to upper rhythmic schists (Nhanguçu Formation;) and the Pirucaia Formation, a quartzitic unit, that is possibly chrono-correlative to the former (Juliani et al., 2000). The basal metapelitic rocks of the Serra do Itaberaba Group present medium- to even high-grade assemblages with garnet, staurolite, kyanite, sillimanite and cordierite porphyroblasts and, rarely, K-feldspar while the Pirucaia Formation grades into quartz-rich ($\pm$ biotite)-garnet-sillimanite schists ($\sim$ turbidites). A minimum depositional age of ca. 1395 ± 10 Ma was obtained from a metandesite above a MORB-like metamafic unit after which basaltic eruptions would have succeeded in oceanic ridge environment (Juliani, 1993; Giuliani et al., 2000 and references therein).

The São Roque Group (Juliani et al., 1986, 2000) comprises a sequence of low-grade rocks represented by feldspathic metarythmites (*metawackes*) with intercalations of phyllites, slate, metarenite, metarkose and metamafic rocks underlain by metaconglomerates and metabreccias (basal units). In the Pirapora do Bom Jesus region, Bergmann (1988) organized the lithostratigraphy into the basal Pirapora do Bom Jesus Formation (basic metavolcanic rocks, tuffs, pyroclastic rocks with carbonates), the superior Estrada dos Romeiros Formation (basal metarenites and upper metapelites) and upper Boturuna Formation (volcanic rocks intercalated with metarkoses, overlain by basaltic effusions and orthoquartzites). In the Serra do Itaberaba region, the Piragibu Formation is a low-grade metapelitic unit that could represent the distal facies of the Estrada dos Romeiros Formation (Juliani and Beljavskis, 1995), therefore being the uppermost unit in this location. Some authors claim the São Roque Group represented a Neoproterozoic back-arc basin (e.g., Hackspacher et al., 2000; Giuliani et al., 2000) while others suggested a continental rift basin in passive margin (Bergmann, 1988) with deposition around ~ 1.75 - 1.79 Ga (Van Schmus et al., 1986; Henrique-Pinto et al., 2018) from the age of an interlayered metarhyodacite (Morro do Polvilho).

Recent U-Pb detrital zircon data of metasandstones and metarkoses from the central São Roque Domain advocated for Statherian (~1.75 Ga) and Calymmian (~1.4 Ga) depositional ages at most, consisting of a lower rift sequence (Boturuna Formation), an intermediate volcano-sedimentary sequence (Serra do Itaberaba Group and possibly the Pirapora do Bom Jesus Formation) and upper platform turbidites (Piragibu Formation; Henrique-Pinto et al., 2015b). In this scenario, the authors suggested the few Neoproterozoic ages obtained indicate metamorphic overgrowths. The São Roque Domain quartzites are potentially correlated to the quartzites and schists from the Serra do Japi region in the southernmost Socorro-Guaxupé Nappe (Campos Neto, 2000), as shown by the highly similar detrital zircon patterns (Henrique-Pinto et al., 2015b).

2.2.2. Neoproterozoic magmatism

A voluminous Neoproterozoic granitic magmatism intruded the São Roque Domain characterized by numerous circumscribed stocks and small batholiths often associated to the NE-SW shear zones. The I-type magmatism is typically high-K calc-alkaline with relatively high Sr/Y, Ba and Sr, dominated by porphyritic biotite monzogranites to quartz-monzonites of intermediate composition and predominantly metaluminous character (Janasi and Ulbrich, 1991). It was potentially generated at deep crustal levels due to instability of plagioclase (Janasi et al., 2016; Lamoso and Janasi, 2019) with contribution from coeval mafic magmatism (as suggested by the presence of mafic microgranular enclaves) and probably from the country metasedimentary rocks. These I-type granitoids were considered to represent syn- to late-collisional emplacements (Campos Neto et al., 1983, 1988; Janasi and Ulbrich, 1991; Ragatky, 1998). There are also subordinate, post-orogenic sub-alkaline occurrences of A-type affinity (Janasi and Ulbrich, 1991).

In the central São Roque Domain, Janasi et al. (2016) constrained the granitic magmatism within a short interval of ~20-30 m.y., (*ca.* 605-590 Ma) and re-examined the reliability of previous works that reported older crystallisation ages (Tassinari, 1988; Töpfner, 1996), arguing for a possible mixture of inherited Paleoproterozoic zircon domains due to method limitations (TIMS U-Pb_(Zr)). Janasi et al. (2016) showed that Hf and Nd systems define nearly parallel trends indicative of an eastward shift to less radiogenic signatures that could be explained by juvenile contribution from an enriched mantle during the Neoproterozoic, that also becomes more voluminous in this direction. The authors suggested the isotopic signatures are product of the reworking of a 2.4-2.5 Ga-old juvenile protolith at 2.2-2.1 Ga. In their interpretation, the São Roque Domain magmatism might be related to convergence east of the Ribeira domain.

Our study area is located in the eastern São Roque Domain (Figure 2-1) where age constraints and isotopic studies are scarcer. Recent U-Pb data concerning the late-orogenic plutons point to an equally short interval of magma generation (*ca.* 606-589 Ma; Lamoso and Janasi, 2019). The Serra do Barro Branco orthogneiss (Figure 2-2) is one of the largest occurrences with structural and textural framework indicative of syn-orogenic setting (Campos Neto et al., 1988) also suggested by chemical data, a TIMS U-Pb zircon age of *ca.* 629 Ma and an isochronic Rb/Sr age of 673 Ma (Ragatky, 1998). Likewise, the small Moinho granodiorite, immediately south of the Barro Branco intrusion, was dated at *ca.* 620 Ma (SHRIMP U-Pb zircon; Tassinari et al., 2004) indicating a younger emplacement compared to the Barro Branco (Campos Neto et al., 1988; Ragatky, 1998). Ragatky (1998) argued for reworking of a deep, long-lived crustal source (Nd T_{DM} model ages $\sim$ 1.7-2.0 Ga) to generate older granitoids with possible juvenile accretions later on (Nd T_{DM} $\sim$ 1.6-1.4 Ga) for the younger, less radiogenic granitoids.

Figure 2-1: a- Tectonic sketch of Western Gondwana (1- Phanerozoic basins; 2- Proterozoic covers; 3- Neoproterozoic System of Orogens; 4- Basement of the cratons; 5- Covered old blocks; 6-South boundary of São Francisco craton, Cioffi et al., 2016b). b- Tectonic map of the southern orogenic systems surrounding the São Francisco craton. The black square marks the area of study in the São Roque Domain.

2.2.3. Structural framework of the study area (eastern SRD)

Numerous shear zones with lateral displacement compose the inner São Roque Domain as well as its northern and southern limits. The strike-slip system is observed in the eastern margin of the São Francisco craton and south to the terranes that make up the Ribeira Belt and is correlated to the emplacement of the granitic magmatism. The easternmost São Roque Domain is constrained within the Jundiuvira and Buquira-Rio Jaguari shear zones that delimit respectively the Socorro-Guaxupé Nappe and the Embu Terrane while the area is also crosscut by the Sertãozinho shear zone.

The general framework of the study area (Figure 2-2) describes a mylonitic, anastomosing foliation formed by sinistral kinematics (post-main metamorphism) and overprinted by dextral movements (Garcia and Campos Neto, 1997). The cross-section and structural elements in Figure 2-2 show that the main metamorphic foliation is pervasive in the Barro Branco orthogneiss (and its inequigranular association) and parallelizes its tectonic contact with the country metasediments. The Barro Branco orthogneiss is mainly accommodated between the Jundiuvira and Sertãozinho shear zones, producing a strong protomylonitic foliation and the NE-elongated shape of the main intrusion and minor bodies. The Ediacaran granites (Serra da Boa Vista and Morro Azul) are slightly foliated closer to the mylonitic zones. The S_2 foliation shifts from NW to SE-dipping associated to a sub-vertical axial-plan cleavage and gently plunging NE fold axes (β), that altogether characterize a cylindrical west-verging fold. The stretching lineation is marked by feldspar porphyroclasts orientation with E-NE direction and gently-to-moderately plunging, that re-orientated the fold axes and supports the ductile strike-slip top-to-SW shear zone regime.

Figure 2-2: Detailed geological map of the study area (modified from Campos Neto et al., 1988) and NW-SE cross-section with stereograms of the structural features..

3. ANALYTICAL METHODS

3.1. U-Th-Pb geochronology in zircon and monazite (LA-ICP-MS)

Sample preparation and U-Pb dating via LA-ICPMS of detrital and igneous zircon and monazite were performed at the Centro de Pesquisas Geocronológicas (CPGeo) facility, Instituto de Geociências, Universidade de São Paulo (IGc-USP). Five samples (IGT-04C, IGT-04D, BB-04C, BB-06C and BB-09) were used for zircon separation and sample IGT-04D also yielded a monazite-rich fraction.

Following the routine used in CPGeo (Sato et al., 2008), raw samples were manually crushed using hammers and hydraulic press to achieve a suitable size for use of the steel-jaw breaker that reduced the fragments to 1-2 cm. These fragments were milled with a disc mill coupled to a set of sieves for granulometric segregation using 100-250 and <250 mesh. The heavy minerals (fractions 100-250 mesh) were primarily separated on a Wiffley table, hand-magnet and subsequently a Frantz-type electromagnetic separator (0.4 A). The non-magnetic fractions were decanted in bromoform ($d = 2.85 \text{ g/cm}^3$) and methylene iodide ($d = 3.32 \text{ g/cm}^3$) and once more underwent magnetic separation to concentrate zircon (1.8 A). The heavy magnetic fraction separated at 0.5 A concentrated monazite. A total of one-hundred zircon grains and two-hundred monazite grains were hand-picked per sample always avoiding fractures, inclusions or associated mineral phases, organized in eight per eight layouts under a Leitz binocular stereo magnifier, mounted on double-sided tape and embedded in epoxy-type resin. The mounts were polished to expose the grain surface and up to 40-50% of their width.

To determine the spot positions, the internal crystal structures were analysed via scanning electron microscopy generating cathodoluminescence (CL) images of the zircon grains at the Laboratório de Microscopia Eletrônica de Varredura (IGc-USP) and back-scatter electron (BSE) images of the monazite grains at the Laboratório de Caracterização Tecnológica, Escola Politécnica (USP). For CL-imaging the mounts were gold-coated (2-3 μm) and processed in a Quanta 250 spectrometer (FEI Company) with high voltage 15-20 kV, 17 mm distance, PMD detector and magnification range of 100-260x. The BSE-imaging of carbon-coated (2-3 μm) mounts was generated in a Quanta 650 FEG (FEI Company) operating at high vacuum with BSED detector, high voltage 20 kV, 14 mm distance and magnification range of 580-819x (2973x for one particular grain).

The LA-ICP-MS U-Pb data were acquired utilizing the Excimer Laser Ablation 193 μm system (Photon Machines) coupled to the Thermo-Neptune multicollector inductively coupled plasma mass spectrometer (MC-ICP-MS). The laser ablation system operated at a repetition

rate of 6-7 Hz, an applied energy of 6 mJ, a 25-32 μm spot diameter (monazite and zircon, respectively) and approximately 40-60 s ablation per spot analysis. The carrier gas He (6.0% purity) transports the ablated material under 0.7 L/min through a “Tygon”-tube to the mass spectrometer. The MC-ICP-MS was set to a mixed cup configuration (Faraday and MIC) resulting in simultaneous readings of $L_3=^{206}\text{Pb}$ (V), $L_1=^{208}\text{Pb}$ (V), $H_2=^{232}\text{Th}$ (V), $H_4=^{238}\text{U}$ (V), $IC_2=^{202}\text{Hg}$ (cps), $IC_4=^{204}\text{Hg}+^{204}\text{Pb}$ (cps) and $IC_5=^{207}\text{Pb}$ (cps) and operated at a radio frequency power of 1100 W, a refrigeration Ar flux rate of 15 L/min, an auxiliary Ar flux rate of 0.7 L/min and a sample gas flux of 0.6 L/min.

In order to correct for instrumental isotopic fractionation of $^{206}\text{Pb}/^{238}\text{U}$ and ^{204}Pb , the procedure includes four blank analyses, four NIST-612 (Woodhead and Hergt, 2001), five standard (GJ-1 zircon reference material 600 Ma - Elhlou et al., 2006); or Monazite-44069 reference material – Aleinikoff et al., 2006) and thirteen unknown sample measurements, that complete one spreadsheet every 50 minutes of analyses. Initial Pb (^{204}Pb) was corrected according to Stacey and Kramers (1975). The analysed data were reduced and corrected in R-based Python software (Siqueira et al., 2014) and exported as Excel spreadsheets. The Excel-compatible software *Isoplot* v.4.15 (Ludwig, 2003) provided the probability density plots and Concordia diagrams for interpretation. The detrital zircon dataset was analysed also using Macro-Excel spreadsheets from the Arizona LaserChron Center. Data reduction was based on the following criteria: (i) common Pb < 6 ppm, (ii) relatively low U (ppm), (iii) relatively small 2σ uncertainties and (iv) $^{206}\text{Pb}/^{207}\text{Pb}$ dates within $100 \pm 10\%$ of concordance (provenance study).

3.2. Whole rock and trace-element geochemistry

Twenty-three samples were used for quantitative analysis of major, minor and some trace elements via X-ray fluorescence at the Laboratório de Fluorescência de Raios-X – NAP-Geoanalítica facility (IGc-USP), according to the routine described in Mori et al. (1999), using a Phillips-PW2400 XRF spectrometer. The sample preparation involved the fragmentation of large samples to centimetric pieces by hammers, hydraulic press and then a steel-jaw breaker. These fragments were split into sub-samples of 100-150 g using a cross-type Jones splitter and were finally milled using a Pulverisette-type agate mill until reaching less than 200 mesh of particle size. Major and minor elements were measured with the use of fused pellets of <200 mesh which were prepared mixing 1 ± 0.0001 g of sample powder and 9 ± 0.0003 g of flux (lithium tetra and metaborate mixture) in a Pt-Au crucible heated at 1100-1200°C in a Claisse fusion instrument. Trace-elements were measured in pressed powder pellets produced by mixing 7 ± 0.005 g of sample powder with 1.4 ± 0.005 g of Hoechst microgranular binding wax

and pressed in a Herzog powder tungsten carbide platen pellet machine for 60 seconds at 30 kPa. Analytical quality was controlled using duplicated samples and JB-1a and JG-1a (a granite from the Geological Survey of Japan) as reference standards.

Rare Earth and additional trace elements were measured for twenty samples via ICP-MS, at the Laboratório de Química e ICP – NAP-Geoanalítica facility (IGc-USP), following the procedures described by Navarro et al. (2008). Aliquots containing 40 mg of sample powders (<200 mesh) were placed in a Teflon container (mixed to 2 ml of 14 mol/L HNO₃ and 6 ml of 40% v/v HF) into a Paar bomb and inserted into a furnace for five days at constant 200°C. The solution was heated until complete dryness and loss of HF, followed by repeated additions of nitric acid and evaporation until complete dissolution of the residue. Analytical quality was controlled using JG-3 (granite) and JR-1 (rhyolite) reference materials. The PerkinElmer ICP-MS model ELAN 6100 DRC operated at the following conditions: nebuliser gas flow of 0.9 L/min, auxiliary gas flow of 1.2 L/min, plasma gas flow of 15 L/min, lens voltage of 9.25 V, radio frequency power of 1100 W, analogue stage voltage detector of 1900 V and digital stage voltage detector of 1300 V.

Chemical plots and spidergrams of the whole-rock and trace-element data were generated with the GCDKit 4.1 R-based software (Janoušek et al., 2006) using classification schemes available therein (e.g., Shand, 1943; Peccerillo and Taylor, 1976; Frost et al., 2001; among others). Trace and rare Earth elements were chondrite-normalized according to McDonough and Sun (1995).

3.3. Isotope geochemistry

3.3.1. Whole-rock Sm-Nd isotopes

Nd isotope determinations were held at CPGeo facility, at the Instituto de Geociências (IGc-USP) and performed in a Thermo-Neptune ICP-MS. Sample preparation involved total dissolution in HF and HNO₃ until complete evaporation in Paar bombs at 200°C, followed by 6N HCl washes and overnight evaporation. Samarium and Neodymium were retrieved using ion-exchange columns. REE were first extracted in 250 µL of RE-resin with 3 ml 1N and 1.2 ml 0.05N HNO₃. Sm and Nd were separated in LN-resin with several washes of 0.26N HCl for Nd and 0.55N HCl for Sm. Analytical blank analysis was 29 pg.

¹⁴³Nd/¹⁴⁴Nd isotopic ratios were normalized to ¹⁴⁶Nd/¹⁴⁴Nd = 0.7219 (DePaolo, 1981) and ¹⁴³Nd/¹⁴⁴Nd = 0.512103 (JNDi-1 – average laboratory value of the last twelve months). The

$\epsilon\text{Nd}_{(0)}$ was calculated using the equation $[(^{143}\text{Nd}/^{144}\text{Nd})_{\text{sample}}/0.512638]-1$, where 0.512638 was taken from Hamilton et al. (1983).

3.3.2. Lu-Hf in zircon

Hf isotope determinations were performed at the CPGeo facility (Instituto de Geociências - USP) via LA-ICP-MS. Sample preparation is detailed in item 3.1 and the same zircon mounts were used for Hf analyses. The LA-ICP-MS Hf data were acquired using the laser ablation system coupled to a Thermo-Neptune multicollector mass spectrometer previously described in section 3.1 and operated under the same conditions of those employed for the U-Pb system, however with a spot diameter of 47 μm , a He flux rate of 0.25 L/min plus a N_2 flux rate of 1.2 mL/min to reduce oxide formation in the plasma, instead. The MC-ICP-MS cup configuration was set to L4 = ^{171}Yb , L3 = ^{173}Yb , L2 = ^{174}Hf , L1 = ^{175}Lu , C = $^{176}\text{Hf} + ^{176}\text{Lu} + ^{176}\text{Yb}$, H1 = ^{177}Hf , H2 = ^{178}Hf , H3 = ^{179}Hf and H4 = ^{181}Ta . The analysis routine involved blank and four GJ1-82C standard (zircon reference material – Elhlou et al., 2006) and mud tank measurements by the end of every thirteen analyses. The acquired data were reduced using an in-house Excel spreadsheet considering ^{176}Lu decay constant = 1.867e^{-11} (Söderlund et al., 2004), present-day $^{176}\text{Hf}/^{177}\text{Hf}$ of 0.28325 (DM) and 0.282785 (CHUR) and $^{176}\text{Lu}/^{177}\text{Hf}$ of 0.0384 (DM) and 0.0336 (CHUR) (Griffin et al., 2002; Bouvier et al., 2008).

3.4. Monazite chemistry

Wavelength-dispersive spectrometry analyses (WDS) in monazite grain mount were held at the NAP Geoanalítica Laboratory (Instituto de Geociências-USP), performed with a JEOL JXA- 8530F Field Emission Electron Probe Microanalyzer (FE-EPMA) operating at 20 kV and 50 nA current with 5 μm focused beam. The applied standards were natural minerals (fluorapatite, albite, diopside, hornblende, fayalite, wollastonite, microcline, zircon, ilmenite, rutile), REE (and Y)-phosphates (Sm, Gd, Dy, Yb, La, Ce, Pr, Nd) and oxides (Sr, Ba, Th, U). The analysed points for REE, Si, Y, P, Th and U were as follows: L β_2 (LIFL) for Sm, Gd, Dy; L α_2 (LIFL) for Yb; K α_3 (PETJ) for Si; L α_3 (PETJ) for Y; L α_4 (LIFL) for La, Ce; L β_4 (LIFL) for Pr, Nd; K α_5 (PETH) for P; M α_5 (PETH) for Th and M β_5 (PETH) for U.

4. RESULTS

Serra do Barro Branco orthogneiss: an untimely record of Western Gondwana amalgamation in the São Roque Domain

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Abstract

Large volumes of high-K calc-alkaline metaluminous to peraluminous granitoids are intrusive in south-eastern Brazil. This particular geochemical affinity extends from the batholiths of the Socorro-Guaxupé Nappe (SGN) to smaller intrusions in the São Roque Domain (SRD). The fault-bounded SRD comprises two metavolcano-sedimentary sequences of Statherian maximum depositional age. Detrital zircon provenance points to a Rhyacian (2.17 Ga) proximal source area matching the southern portion of the SGN. The domain records magmatic activity initiated at ca. 685 Ma with the crystallisation of the Barro Branco biotite orthogneiss of intermediate SiO₂ composition. Unprecedented zircon ages also suggest older activities around 740 and 800-900 Ma recorded in a metavolcaniclastic rock. The Barro Branco has an inequigranular facies dated at ca. 625 Ma of “evolved” peraluminous affinity. The Moinho is a “primitive” metaluminous granodiorite emplaced at ca. 620 Ma. The most voluminous magmatism occurred within 610-590 Ma represented by several circumscribed biotite granites. All granitoids have high Sr/Y and LREE, low Nb and Ti and lack negative Eu anomaly suggesting a deep lower crustal source with residual garnet ($\pm$ amphibole $\pm$ rutile). Whereas the Socorro-Guaxupé arc rocks have intermediate Sr/Y and moderate-to-absent, negative Eu anomalies but share the trace-elemental imprints of subduction zones. Nd and Hf isotopes indicate Barro Branco carries a significant juvenile component while the inequigranular orthogneiss and Moinho granodiorite have crustal signatures that seem to partially originate from the country metasedimentary rocks. During the temporal gap between the Barro Branco emplacement and subsequent magmatism, the mantle beneath the SRD might have been fertilized by crustal additions. Enriched mantle and low-degree partial melting probably produced high-K enriched melts. Thus, we propose the SRD developed on the Paranapanema active margin recording the initiation of subduction in a retro-arc domain. The “shut-down” of ca. 35 m.y. could result from a slab retreat causing magmatism to migrate northwards in the Socorro-Guaxupé arc domain. Magmatism followed at ca. 635 Ma with crustal signatures supplied by the last-longing subduction. A metasedimentary rock with monazite age of 600 Ma (to 630 Ma) may be evidence of a thermal episode in the SRD, overlapping metamorphism in the neighbour SGN.

4.1. Introduction

In subduction settings, the transition from collisional to late stages of arc evolution is marked by the emplacement of calc-alkaline batholiths and high-K to shoshonitic volcanics. The origin of high-K magmatism is frequently attributed to mantle enriched by previous subductions and triggered by processes such as slab break-off or lower crustal delamination. Alternatively, studies have shown several batches of low-degree partial melting are able of producing such geochemical trends (e.g., Putirka and Busby, 2007; Stern, 1988; Wang et al., 2017). Therefore, high-K contents might be produced by several processes that are not necessarily related to the late-or post-orogenic stages of continental evolution.

High-K calc-alkaline granitoids are widespread in the Socorro-Guaxupé arc domain and the southern neighbour São Roque Domain. These granitoids carry subduction-related signatures and evidences for coeval mafic magmatism (e.g. Haddad, 1995; Vinagre et al., 2014; Ragatky, 1998; Janasi et al., 2016). A correlation of both domains has been suggested in terms of the metasedimentary record (Campos Neto, 2000) and supported by provenance studies on the São Roque Domain (Henrique-Pinto et al., 2015b).

The scope of this paper is to provide insights on whether the massive São Roque Domain magmatism was related to the convergence between the Paranapanema and São Francisco paleoplates, which led to the development of the Socorro-Guaxupé Nappe. We present new U-Pb age constraints, Lu-Hf in zircon and whole-rock Sm-Nd as well as geochemical data of the Barro Branco orthogneiss (target of this study) and associated occurrences. The data give unprecedented information on the timing of magmatism and petrogenesis that show the generation of the Socorro-Guaxupé Nappe and São Roque Domain granitoids was potentially co-related and further provide implications on their tectonic evolution.

4.2. Geological Setting

4.2.1. Socorro-Guaxupé Nappe

The Socorro-Guaxupé Nappe (SGN) is a high-grade, arc-derived terrane of exposed, deep Neoproterozoic crust (magmatic arc roots), generated during the convergence between active margin of the Paranapanema and the passive margin of the São Francisco paleoplates, as part of the Southern Brasília Orogen (Brito Neves et al., 1999; Campos Neto, 2000) during the diachronic West Gondwana amalgamation. The magmatic arc remnants are stacked over the passive margin basement and covers (Carrancas and Lima Duarte nappe systems) and the kyanite-bearing granulites (Três Pontas-Varginha nappe) which is thrust over a metasedimentary pile with eclogitic occurrences (Liberdade nappe) thus forming a package of

flat-lying, east-verging thick-skinned nappes (Campos Neto and Caby, 1999; Trouw et al., 2000; Campos Neto et al., 2010, 2011).

The pre-collisional magmatic arc, developed on the active margin of the Paranapanema plate, is divided into three units of the Socorro-Guaxupé Nappe, from base to top: (i) garnet± orthopyroxene-bearing enderbitic granulites topped by amphibolite-facies (biotite)-hornblende tonalite to granodiorite gneisses; (ii) hornblende-biotite-(clinopyroxene)-bearing stromatic and nebulitic migmatites that transition to porphyritic hornblende-biotite granite batholiths, and (iii) garnet± sillimanite gneisses with biotite-garnet-bearing that grade to peraluminous muscovite-bearing leucosomes (Campos Neto and Caby, 2000).

Charnockite and high-K calc-alkaline suites of hornblende-biotite-quartz monzonites-monzogranites with mafic enclaves (Janasi and Ulbrich, 1991; Haddad, 1995; Janasi, 1999; Mora et al., 2014) and subordinate monzodiorites, tonalites and granodiorites intrude the package. They are partially coeval to a prolonged high to ultra-high temperature metamorphism (up to ~1000°C) recently estimated at *ca.* 630-590 Ma (Rocha et al., 2017) or *ca.* 670-590 Ma (Tedeschi et al., 2018).

4.2.2. São Roque Domain

Two major dextral shear zones delimit the São Roque Domain. The Jundiuvira shear zone to the north separates it from the Socorro-Guaxupé Nappe, whereas the Taxaquara shear zone to the south marks the boundary with the Embu Terrane (Campanha et al., 2019). It comprises two main metavolcano-sedimentary sequences whose relation and stratigraphic positions are still controversial, the Serra do Itaberaba Group and São Roque Group *stricto sensu* (Juliani and Beljavskis, 1995 and references therein; Juliani et al., 2000), formerly described as a single São Roque unit (Hasui, 1975). These sequences are massively intruded by Neoproterozoic granitoids. Age constraints are scarce and difficult to interpret due to the complex intercalations and discontinuities across the domain.

4.2.3. Paleoproterozoic (to Mesoproterozoic?) metavolcano-sedimentary sequences

The Serra do Itaberaba Group is a metavolcano-sedimentary sequence that records medium-grade metamorphism (Juliani et al., 1986) that was thought to be basal to the SRG (e.g. Coutinho et al., 1982). It comprises units from base to top that intercalate metamafic, metapelitic, calc-silicate and metavolcanic rocks and banded iron formations, Fe-Mg- and Ca-rich pelites with carbonate lenses, metatuffs, metabasalts and metarhyolites to upper rhythmic schists and a quartzitic unit, that is possibly chrono-correlative to the former (Juliani et al.,

2000). The basal metapelitic rocks present medium- to high-grade assemblages with garnet, staurolite, kyanite, sillimanite and cordierite porphyroblasts and, rarely, K-feldspar while the quartzitic unit grades into quartz-rich ($\pm$ biotite)-garnet-sillimanite schists ($\sim$ turbidites). A minimum depositional age of $ca. 1395 \pm 10$ Ma was obtained from a metandesite above a MORB-like metamafic unit after which basaltic eruptions would have succeeded in an oceanic ridge environment (Juliani, 1993; Giuliani et al., 2000 and references therein).

The São Roque Group (Juliani et al., 1986; 2000) comprises a sequence of low-grade rocks represented by feldspathic metarythmites (metawackes) with intercalations of phyllites, slate, metarenite, metarkose and metamafic rocks underlain by metaconglomerates and metabreccias (basal units). To the south (Pirapora do Bom Jesus region), Bergmann (1988) organized the lithostratigraphy from base to top into (i) basic metavolcanic rocks, tuffs, pyroclastic rocks with carbonates), (ii) basal metarenites and upper metapelites and (iii) volcanic rocks intercalated with metarkoses, overlain by basaltic effusions and orthoquartzites. The intermediate unit extends to the north (Serra do Itaberaba region) as an upper low-grade metapelite (Juliani and Beljavskis, 1995). Some authors claim the São Roque Group represented a Neoproterozoic back-arc basin (e.g., Hackspacher et al., 2000; Giuliani et al., 2000) while others suggested a continental rift basin in passive margin (Bergmann, 1988) with deposition around ~ 1.75 - 1.79 Ga (Van Schmus et al., 1986; Henrique-Pinto et al., 2018) from the age of an interlayered metarhyodacite.

Recent U-Pb detrital zircon data of metasandstones and metarkoses from the central São Roque Domain advocated for Statherian (~ 1.75 Ga) and Calymmian (~ 1.4 Ga) depositional ages at most, consisting of a lower rift sequence, an intermediate volcano-sedimentary sequence (mainly the Serra do Itaberaba Group) and upper platform turbidites (Henrique-Pinto et al., 2015a). In this scenario, the authors suggested the few Neoproterozoic ages obtained indicate metamorphic overgrowths. The São Roque Domain quartzites are potentially correlated to the quartzites and schists in the southernmost Socorro-Guaxupé Nappe (Serra do Japi region, Campos Neto, 2000), as shown by the highly similar detrital zircon patterns (Henrique-Pinto et al., 2015b).

4.2.4. *Neoproterozoic magmatism*

A voluminous Neoproterozoic granitic magmatism invaded the São Roque Domain expressed by numerous circumscribed stocks and small batholiths often associated to the NE shear zones. The I-type magmatism is typically high-K calc-alkaline with relatively high Sr/Y, Ba and Sr, dominated by porphyritic biotite monzogranites to quartz-monzonites of intermediate composition and predominantly metaluminous character (Janasi and Ulbrich,

1991). It was potentially generated at deep crustal levels due to instability of plagioclase (Janasi et al., 2016; Lamoso and Janasi, 2019) with contribution from coeval mafic magmatism (as suggested by the presence of mafic microgranular enclaves) and probably from the country metasedimentary rocks. These I-type granitoids were considered to represent syn- to late-collisional emplacements (Campos Neto et al., 1983, 1988; Janasi and Ulbrich, 1991; Ragatky, 1998). There are also subordinate, post-orogenic sub-alkaline occurrences of A-type affinity (Janasi and Ulbrich, 1991).

In the central São Roque Domain domain, Janasi et al. (2016) constrained the granitic magmatism within a short interval of ~20-30 m.y., ranging 605-590 Ma, which refute previous works that reported older crystallisation ages (Tassinari, 1988; Töpfner, 1996), arguing for a possible mixture of inherited Paleoproterozoic zircon domains due to method limitations (TIMS U-Pb_(Zr)). Janasi et al. (2016) showed that Hf and Nd systems define nearly parallel trends indicative of an eastward shift to less radiogenic signatures that could be explained by juvenile contribution from an enriched mantle during the Neoproterozoic that also becomes more voluminous in this direction. The authors suggested the isotopic signatures are product of the reworking of a 2.4-2.5 Ga-old juvenile protolith at 2.2-2.1 Ga. In their interpretation, the São Roque Domain magmatism might be related to convergence east of the Ribeira domain.

Our study area is located in the eastern São Roque Domain (Figure 4-1) where age constraints and isotopic studies are scarcer. Recent U-Pb data concerning the late-orogenic plutons point to an equally short interval of magma generation (606-589 Ma; Lamoso and Janasi, 2019). The Serra do Barro Branco orthogneiss (Figure 4-2) is one of the largest occurrences with structural and textural framework indicative of syn-orogenic setting (Campos Neto et al., 1988) also suggested by chemical data, a TIMS U-Pb zircon age of *ca.* 629 Ma and an isochronic Rb/Sr age of 673 Ma (Ragatky, 1998). Likewise, the small Moinho granodiorite, immediately south of the Barro Branco intrusion, was dated at *ca.* 620 Ma (SHRIMP U-Pb zircon age; Tassinari et al., 2004) indicating a younger emplacement compared to the Barro Branco (Campos Neto et al., 1988; Ragatky, 1998). Ragatky (1998) argued for reworking of a deep, long-lived crustal source (Nd T_{DM} model ages ~1.7-2.0 Ga) to generate older granitoids with possible juvenile accretions later on (Nd T_{DM} ~1.6-1.4 Ga) for the younger, less radiogenic granitoids.

Figure 4-1 a- Tectonic sketch of the reconstruction of Western Gondwana. (1- Phanerozoic basins; 2- Proterozoic covers; 3- Neoproterozoic System of Orogens; 4- Basement of the cratons; 5- Covered old blocks; 6-South boundary of São Francisco craton). b-Tectonic map of the orogenic systems that surround the São Francisco craton in southeastern Brazil denoting the study area.

4.2.5. Structural framework of the study area

Numerous shear zones with lateral displacement compose the inner São Roque Domain as well as its northern and southern limits. The strike-slip system is observed in the eastern margin of the São Francisco craton and south to the terranes that make up the Ribeira Belt and is correlated to the emplacement of the granitic magmatism. The easternmost São Roque Domain is constrained within the Jundiuvira and Buquira-Rio Jaguari shear zones that delimit respectively the Socorro-Guaxupé Nappe and the Embu Terrane while the area is also crosscut by the Sertãozinho shear zone.

The general framework of the study area describes a mylonitic, anastomosing foliation formed by sinistral kinematics (post-main metamorphism) and overprinted by dextral movements (Garcia and Campos Neto, 1997). The cross-section and structural elements in Figure 4-2 show that the main metamorphic foliation is pervasive in the Barro Branco orthogneiss (and its inequigranular association) and parallelizes its tectonic contact with the country metasediments. The Barro Branco orthogneiss is mainly accommodated between the Jundiuvira and Sertãozinho shear zones, producing a strong protomylonitic foliation and the

NE-elongated shape of the main intrusion and minor bodies. The Ediacaran granites are slightly foliated closer to the mylonitic zones. The S_2 foliation shifts from NW to SE-dipping associated to a sub-vertical axial-plan cleavage and gently plunging NE fold axes (β), that altogether characterize a cylindrical west-verging fold. The stretching lineation is marked by feldspar porphyroclasts orientation with E-NE direction and gently-to-moderately plunging, that re-orientated the fold axes and supports the ductile top-to-SW shear zone regime.

Figure 4-2: Detailed map of the study area and E-W cross-section with structural elements plotted in stereograms.

4.3. Methodology

4.3.1. U-Th-Pb geochronology (LA-ICP-MS) in zircon and monazite

Sample preparation and U-Pb dating via LA-ICPMS of zircon and monazite were performed at the Centro de Pesquisas Geocronológicas (CPGeo) facility, Instituto de Geociências, Universidade de São Paulo (IGc-USP) and followed the routine of Sato et al. (2008). Cathodoluminescence imaging (CL) of zircon was performed at the Laboratório de Microscopia Eletrônica de Varredura (IGc-USP) using a Quanta 250 FEI spectrometer with high voltage 15-20 kV, 17 mm distance, PMD detector and magnification range of 100-260x. Back-scatter electron imaging (BSE) of monazite was performed at the Laboratório de Caracterização Tecnológica, Escola Politécnica (USP) using a Quanta 650 FEG operating at high vacuum with BSED detector, high voltage 20 kV, 14 mm distance and magnification range of 580-819x. The imaging techniques assessed crystal typology and spot positioning.

The LA-ICP-MS U-Pb data were acquired utilizing the Excimer Laser Ablation 193nm system (Photon Machines) coupled to the Thermo-Neptune multicollector inductively coupled plasma mass spectrometer (MC-ICP-MS). The laser ablation system operated at a repetition rate of 6-7 Hz, an applied energy of 6 mJ, a 25-32 μm spot diameter (monazite and zircon, respectively) and approximately 40-60 s ablation per spot analysis. The carrier gas He (6.0% purity) transports the ablated material under 0.7 L/min through a “Tygon”-tube to the mass spectrometer. The MC-ICP-MS was set to a mixed cup configuration (Faraday and MIC) of simultaneous readings of $L_3=^{206}\text{Pb}$ (V), $L_1=^{208}\text{Pb}$ (V), $H_2=^{232}\text{Th}$ (V), $H_4=^{238}\text{U}$ (V), $IC_2=^{202}\text{Hg}$ (cps), $IC_4=^{204}\text{Hg}+^{204}\text{Pb}$ (cps) and $IC_5=^{207}\text{Pb}$ (cps) and operated at a radio frequency power of 1100 W, a refrigeration Ar flux rate of 15 L/min, an auxiliary Ar flux rate of 0.7 L/min and a sample gas flux of 0.6 L/min. In order to correct for instrumental isotopic fractionation of $^{206}\text{Pb}/^{238}\text{U}$ and ^{204}Pb , the procedure included four blank analyses, four NIST-612 (Woodhead and Hergt, 2001), five standard (GJ-1 zircon reference material 600 Ma - Elhlou et al., 2006; or Monazite-44069 reference material – Aleinikoff et al., 2006) and thirteen unknown sample measurements, that complete one spreadsheet, every 50 minutes of analyses. Initial Pb (^{204}Pb) was corrected according to Stacey and Kramers (1975). Data were reduced and corrected using in-house software (Siqueira et al., 2014) and exported as spreadsheets. *Isoplot* v.4.15 (Ludwig, 2009) provided the probability density plots and Concordia diagrams for interpretation. The detrital zircon dataset was also analysed using Macro-Excel spreadsheets from the Arizona LaserChron Center. Data reduction was based on the following criteria: (i) common Pb < 6 ppm, (ii) relatively low U (ppm), (iii) relatively small 2σ uncertainties and (iv) $^{206}\text{Pb}/^{207}\text{Pb}$ dates within $100 \pm 10\%$ of concordance (provenance).

4.3.2. Whole rock and trace-element geochemistry

Quantitative analysis of major, minor and some trace elements via X-ray fluorescence were performed at the Laboratório de Fluorescência de Raios-X – NAP-Geoanalítica facility (IGc-USP), using a Phillips-PW2400 XRF spectrometer. Sample preparation followed the routine described in Mori et al. (1999). Analytical quality was controlled using duplicated samples and JB-1a and JG-1a (a granite from the Geological Survey of Japan) as reference standards.

Rare Earth and additional trace elements were measured via ICP-MS, at the Laboratório de Química e ICP – NAP-Geoanalítica facility (IGc-USP), following the procedures described by Navarro et al. (2008). Analytical quality was controlled using JG-3 (granite) and JR-1 (rhyolite) reference materials. The PerkinElmer ICP-MS model ELAN 6100 DRC operated at the following conditions: nebuliser gas flow of 0.9 L/min, auxiliary gas flow of 1.2 L/min, plasma gas flow of 15 L/min, lens voltage of 9.25 V, radio frequency power of 1100 W, analogue stage voltage detector of 1900 V and digital stage voltage detector of 1300 V.

Excel and GCDKit 4.1 (Janoušek et al., 2006) were used to generate binary plots and spidergrams.

4.3.3. Isotope geochemistry

4.3.4. *Whole-rock Sm-Nd isotopes*

Nd isotope determinations were held at CPGeo facility, at the Instituto de Geociências (IGc-USP) and performed in a Thermo-Neptune ICP-MS. Sample preparation involved total dissolution in HF and HNO₃ until complete evaporation in Paar bombs at 200°C, followed by 6N HCl washes and overnight evaporation. Samarium and Neodymium were retrieved using ion-exchange columns. REE were first extracted in 250 µL of RE-resin with 3 ml 1N and 1.2 ml 0.05N HNO₃. Sm and Nd were separated in LN-resin with several washes of 0.26N HCl for Nd and 0.55N HCl for Sm. Analytical blank analysis was 29 pg.

¹⁴³Nd/¹⁴⁴Nd isotopic ratios were normalized to ¹⁴⁶Nd/¹⁴⁴Nd = 0.7219 (DePaolo, 1981) and ¹⁴³Nd/¹⁴⁴Nd = 0.512103 (JNDi-1 – average laboratory value of the last twelve months). The εNd(0) was calculated using the equation [(¹⁴³Nd/¹⁴⁴Nd)_{sample}/0.512638]-1, where 0.512638 was taken from Hamilton et al. (1983).

4.3.5. *Lu-Hf in zircon via laser ablation (LA-ICP-MS)*

Hf isotope determinations were performed at the CPGeo facility (Instituto de Geociências - USP) via LA-ICP-MS. The same zircon mounts were used for Hf analyses. The LA-ICP-MS Hf operated under the same conditions of those employed for the U-Pb system, however, with

a larger spot of 47 μm , a He flux rate of 0.25 L/min plus a N₂ flux rate of 1.2 mL/min to reduce oxide formation in the plasma. The MC-ICP-MS cup configuration was set to L4 = ¹⁷¹Yb, L3 = ¹⁷³Yb, L2 = ¹⁷⁴Hf, L1 = ¹⁷⁵Lu, C = ¹⁷⁶Hf + ¹⁷⁶Lu + ¹⁷⁶Yb, H1 = ¹⁷⁷Hf, H2 = ¹⁷⁸Hf, H3 = ¹⁷⁹Hf and H4 = ¹⁸¹Ta. The analysis routine involved blank and four GJ1-82C standard (zircon reference material – Elhlou et al., 2006) and mud tank measurements by the end of every thirteen analyses. The acquired data were reduced using in-house spreadsheet that considered ¹⁷⁶Lu decay constant = 1.867e^{-11} (Söderlund et al., 2004), present-day ¹⁷⁶Hf/¹⁷⁷Hf of 0.28325 (DM) and 0.282785 (CHUR) and ¹⁷⁶Lu/¹⁷⁷Hf of 0.0384 (DM) and 0.0336 (CHUR) (Griffin et al., 2002; Bouvier et al., 2008).

4.3.6. EPMA-monazite chemistry

Wavelength-dispersive spectrometry analyses (WDS) in monazite grain mount were held at the NAP Geoanalítica Laboratory (Instituto de Geociências-USP), performed with a JEOL JXA- 8530F Field Emission Electron Probe Microanalyzer (FE-EPMA) operating at 20 kV and 50 nA current with 5 μm focused beam. The applied standards were natural minerals (fluorapatite, albite, diopside, hornblende, fayalite, wollastonite, microcline, zircon, ilmenite, rutile), REE (and Y)-phosphates (Sm, Gd, Dy, Yb, La, Ce, Pr, Nd) and oxides (Sr, Ba, Th, U). The analysed points for REE, Si, Y, P, Th and U were as follows: L β_2 (LIFL) for Sm, Gd, Dy; L α_2 (LIFL) for Yb; K α_3 (PETJ) for Si; L α_3 (PETJ) for Y; L α_4 (LIFL) for La, Ce; L β_4 (LIFL) for Pr, Nd; K α_5 (PETH) for P; M α_5 (PETH) for Th and M β_5 (PETH) for U.

4.4. Results

4.4.1. Petrography and sampling

The studied granitoids are elongated bodies intrusive in metavolcano-sedimentary rocks of the Serra do Itaberaba Group confined between two local shear zones (Jundiuvira and Sertãozinho) that condition the mylonitic aspect of the gneisses. Sampling is representative of map- and sample-scale variations in composition and fabric of all granitoids. Sample coordinates are enlisted in Table 1 and modal composition in Table 2 (Appendix).

The Barro Branco orthogneiss (Figure 4-3a-d) is one of the largest manifestations represented by a main sheet-like folded body alongside other smaller elongated sheets. It is a grey to slightly pink gneiss whose composition varies within tonalite-granodiorite-monzogranite with porphyroblastic texture (~2 cm) and a fine-grained inequigranular matrix (≤ 1 mm) that develops to a typical mylonitic foliation (Figure 4-4a) depending on the shear zone influence. It is mainly composed of quartz, plagioclase (oligoclase-andesine), K-feldspar

(microcline $\pm$ orthoclase) and biotite as the mafic phase, accessory assemblage comprehends titanite, metamict allanite, epidote, magnetite, apatite, zircon and – rarely – monazite. The orthogneiss has an anastomosing S_2 -foliation defined by a green-brownish biotite concentrated in lepidoblastic layers; the foliation moulds feldspar porphyroclasts with high-T ductile shapes (δ - and σ -type and “fish”-shaped) and transitions to brittle antithetic fractures (Figure 4-4b) and recrystallised biotite and quartz strain shadows. The granoblastic bands are coarser, comprising microcline and plagioclase porphyroclasts intertwined with quartz-ribbons of interlobate contacts (grain boundary migration). The feldspar porphyroclasts have corroded rims replaced by recrystallised sub-grains or consist of entirely recrystallised pseudomorphs. Myrmekitic and perthitic (flame or granular intergrowths) textures are common. The accessory phases are frequently associated to the foliation, apatite being the most abundant accessory mineral. Titanite and allanite possibly represent magmatic phases, with the later showing dark rims that likely grew during metamorphism. Epidote occurs in allanite pseudomorphs and associated to magnetite and plagioclase. Muscovite and chlorite are secondary phases as products of alteration. Some of the samples are titanite-free and, in such cases, biotite shifts to a brown-reddish shade where we observe a distinctive coronitic texture composed of microgranular epidote + allanite corona, inner apatite corona and a -rarely preserved- monazite core.

There is a non-porphyritic occurrence associated to the Barro Branco intrusion that is represented by an inequigranular (0.4-1.6 mm) biotite orthogneiss. It is a monzogranite with quartz, plagioclase (oligoclase), microcline and biotite and accessory phases such as metamict allanite, apatite, zircon and monazite whereas titanite is xenoblastic and much less voluminous in comparison with the porphyritic facies. Sericite and chlorite are products of alteration of feldspars and biotite. The biotite has a brown-reddish colour such as the titanite-free Barro Branco samples and marks the S_2 -foliation. The coronal epidote+allanite+apatite($\pm$ monazite) association is also frequent (Figure 4-4c), further described. This inequigranular occurrence is also mentioned in Ragatky (1998) where it was sampled as the main Barro Branco orthogneiss.

Figure 4-3: (a-d) Outcrop BB-41 of the Barro Branco biotite orthogneiss displaying the mylonitic foliation along with the distinctive compositional layers; (e-f) Outcrop BB-50 of the Moinho granodiorite exhibiting a subtle foliation and a coarse-grained porphyritic texture; (g) Outcrop BB-21 of a quartz-rich biotite paragneiss intruded by several quartzitic veins; (h-i) Outcrop IGT-04: (1) fine-grained biotite paragneiss (IGT-04D); (2) a mafic gneiss composed of biotite-rich (IGT-04H) and hornblende-rich (IGT-04E) levels; (3) a deformed quartz+feldspar+biotite granitoid displaying compositional layers, with fold interference and axial plane-foliation, also marked by extensional features in the hinge.

Figure 4-4: (a) Sample BB-01A of the Barro Branco orthogneiss showing a protomylonitic foliation with feldspar porphyroclasts enfolded by a green-brownish biotite; (b) A σ -type feldspar porphyroclast showing an antithetic fracture from sample BB-03 (Barro Branco); (c) The coronitic texture that is common to the inequigranular orthogneiss (sample BB-09), note that only epidote was preserved in the core; (d) The most common association observed in the foliation of the Moinho granodiorite comprises hornblende + biotite + epidote + apatite (sample BB-44A); (e) A fine-grained biotite gneiss referred to as metavolcaniclastic rock crosscut by a coarse granitic vein (sample IGT-04C); (f) A fine-grained biotite paragneiss (the metasedimentary rock – sample IGT-04D) with lenses of concentrated reddish biotite containing numerous monazite and zircon inclusions. Mineral abbreviations as in Kretz (1983).

The Moinho Granite outcrops to the south of the Barro Branco intrusion (Figure 4-3e-f) and defines a much smaller body (6000 per 750 m – Tassinari et al., 2004) of a (hornblende)-biotite gneiss. The main facies is a dark grey to slightly pink granodiorite (few samples are monzogranites) with a porphyritic texture intertwined with a subtle foliation. This foliation is

marked by a greenish biotite $\pm$ hornblende and moulds feldspar (microcline and plagioclase) and flame-like perthite phenocrysts (≤ 1 cm). The inequigranular matrix (0.4-1.8 mm) is composed of interlobate quartz, plagioclase (oligoclase-andesine), microcline and perthites where granophyric texture is common, and the grain boundaries are filled with recrystallised quartz and feldspar sub-grains. The accessory phases are titanite, abundant apatite, metamict allanite, magnetite, epidote and zircon. Most samples of the Moinho have trace occurrences of hornblende or none, however, one single sample (BB-44AI) presented up to 10% sub-idioblastic oriented hornblende within the foliation (Figure 4-4d).

East of the Moinho and Barro Branco, the IGT-04 outcrop (Figure 4-3h-i) exposed along a roadcut of the Dom Pedro I highway presents a complex relation between gneisses that differ in granulation, structure and composition. The outcrop comprises a light-grey and fine-grained biotite gneiss (interpreted as a metavolcaniclastic rock – IGT-04 C) found at the base of the exposure in which lepidoblastic layers of biotite needles mark the S_2 -foliation and enfold feldspar porphyroclasts alternating with discontinuous granoblastic lenses of quartz and, subordinate, plagioclase and microcline with interlobate contacts. Accessory phases are magnetite, apatite, metamict allanite and zircon. Occasionally granitic veins with coarse granulation and sinuous boundaries intersect the tectonic foliation; these veins are composed of quartz, microcline, plagioclase and trace occurrences of biotite, white mica and carbonate (Figure 4-4e). The metavolcaniclastic gneiss is obliquely cut by a dark-grey gneiss of hornblende-rich (IGT-04F) and biotite-rich (IGT-04H) levels with very abundant titanite that alternate thin tonalitic bands. The amphibolitic gneiss is in contact with a light-grey biotite paragneiss composed of thick micaceous lenses (muscovite + biotite) and “fish” feldspar porphyroclasts, alternating quartz *ribbons*, with accessory phases such as epidote, zircon, apatite and expressive monazite. A *boudinaged* calc-silicate band occurs subordinately with phaneritic inequigranular texture (slightly oriented), composed of quartz, plagioclase, biotite, titanite, magnetite and trace occurrences of hornblende, epidote, zircon and apatite.

The metasedimentary rocks that are intruded by the studied granitoids are mica-schists cut by numerous quartzitic and leucogranitic veins. The two-mica schist and paragneiss are banded with prevailing coarse-grained muscovite+biotite-lenses rich in monazite and zircon inclusions that define the S_2 -foliation (Figure 4-4f); second-generation micas also occur oblique to the foliation. The anastomosed foliation moulds feldspar porphyroclasts and pseudomorphs of recrystallized quartz + feldspar with features of sub-grain rotation and grain boundary migration. Subordinate granoblastic bands are very fine-grained composed of quartz + alkaline feldspar + plagioclase with irregular contacts.

The Igaratá gneisses are scattered elongated bodies of biotite gneisses similar to the inequigranular facies of the Barro Branco orthogneiss, mostly occurring between the Sertãozinho and Buquira shear zones (Figure 4-2). The foliation varies from subtle to moderate, marked by a reddish biotite that, unlike the inequigranular orthogneiss, occurs associated with titanite. These gneisses are monzogranites comprising a matrix of inequigranular intergrown quartz + plagioclase + microcline that locally develop porphyroblasts. Substitution of biotite by chlorite and white mica (sericite) altering feldspars are frequent features. Accessory phases are titanite, metamict allanite, epidote, zircon and apatite.

The biotite granites are small circumscribed plutons with phaneritic inequigranular texture, at times slightly oriented. The fabric is defined by irregular and polygonised contacts, composed of quartz, microcline, plagioclase and biotite with accessory phases such as titanite, allanite, epidote, apatite, magnetite and zircon. Quartz displays undulose extinction and grain boundary migration, related to sub-idiomorphic microcline and plagioclase. Chlorite occurs often related to biotite (substitution) and titanite.

4.4.2. *Coronal textures of apatite-allanite-epidote*

The inequigranular orthogneiss and a few samples of the biotite granites present a remarkable coronal texture composed of allanite + epidote + apatite. Although there is not a pattern concerning inward composition of each corona, the ubiquitous feature is an external yellow-brownish rim of allanite + epidote fine aggregates (hybrid zone).

Figure 4-5 lists a handful of textures observed in the same sample (BB-09 of the inequigranular orthogneiss). The hybrid zone contains some sparse prismatic crystals that could be allanite and more rarely occur zircon crystals. We note that magnetite and biotite are frequently associated to the coronas, mostly outside the texture in contact with the external rim, whereas plagioclase is always present. The contact relations between apatite, epidote and monazite (or zircon, whenever present) are complex. Zones are generally irregular in that mid-coronas do not necessarily form a complete ring leaving direct contacts between core and external rim (Figure 4-5a,b). In many cases, mid-rims are absent, the hybrid zones involve apatite or epidote. Monazite is observed at the core of the coronas or as a small corroded remnant (Figure 4-5c-f).

Figure 4-5: Examples of the variety of coronal textures observed in sample BB-09 of the inequigranular orthogneiss. (a-b) Idiomorphic apatite is found in the core of the texture, involved by a mid-rim of epidote and an outer hybrid rim (allanite+epidote). The epidote mid-rim contains zircon inclusions and the outer rim is in contact with magnetite. (c) Idiomorphic polygonal apatite bigger than the coronal texture is observed in direct contact with the external allanite+epidote rim whereas pure apatite mid-rim is absent. Epidote is predominant and there is a potentially monazite remnant. (d) One of the rare cases in which monazite was preserved, followed by an apatite rim filled with impurities and outer allanite+epidote. (e-f) The coronal textures intimately relate to biotite, magnetite and plagioclase.

4.4.3. Whole-rock and trace-element geochemistry

Harker plots for all sampled rocks (Figure 4-6) describe a steep negative correlation of TiO_2 , $\text{Fe}_2\text{O}_{3(\text{t})}$, MgO , CaO , Al_2O_3 and P_2O_5 concentrations towards the more evolved members while K_2O increases with silica content. Major, minor and trace-element compositions are enlisted in Table 3. Rocks with granitic composition are products of a high-K calc-alkaline magmatism with SiO_2 ranging from 57 to 70% and K_2O varying from 3.5 to 6.3%, except for a calc-alkaline metavolcanic sample with distinctively low K_2O (2.7%) and higher SiO_2 (75%). Molar fractions $A/(N+K)$ and $A/(C+N+K)$ range 0.93-1.1 and 1.08-1.5, respectively, with samples straddling along the metaluminous/peraluminous boundary. According to the Frost et

al. (2001) scheme, the granitoids are magnesian to slightly ferroan and mostly alkali-calcic (Figure 4-7).

Figure 4-6: Harker plots of the major elements and mg number of all sampled rocks. Black arrows indicate fractionation trends. Grey symbols represent data from literature: (i) SRD: 610-580 Ma granites (Ragatky, 1998; Janasi et al., 2016; Lamoso and Janasi, 2019) and granitoids in the eastern SRD that include the Barro Branco and Moinho (Campos Neto et al., 1988; Lamoso and Janasi, 2019); (ii) SGN: hbl-bt orthogneisses (Janasi, 1999), Pinhal-Ipuina batholith (Haddad, 1995), Serra da Água Limpa batholith (Vinagre et al., 2014), Pinhal and São José do Rio Pardo diatexites, granulites and metatexites (Mora et al., 2014) and metatexitic orthogneisses (Gengo, 2014); (iii) metavolcanic sequence from eastern SRD, inferred as SIG (Campos Neto et al., 1988).

The Barro Branco orthogneiss presents the most scattered dataset ranging from primitive to evolved SiO_2 compositions (57-68%) that overlap with the primitive Moinho granodiorite (59-65%) and the more evolved inequigranular orthogneiss (66-70%) and biotite granites (67-70%). The amphibolitic gneiss and metavolcaniclastic rock act mostly as compositional end-members classified, according to the TAS diagram (Middlemost, 1994), as andesite-trachyandesite (57 wt.% SiO_2) and rhyolite (75 wt.% SiO_2), respectively. The dataset describes

a negative correlation of SiO_2 versus TiO_2 , Al_2O_3 , P_2O_5 , $\text{Fe}_2\text{O}_{3\text{T}}$, MgO and CaO . The TiO_2 is low in the Moinho granodiorite when compared to the primitive samples (amphibolitic gneiss and Barro Branco orthogneiss) and thus detached from the main trend. The CaO , $\text{Fe}_2\text{O}_{3\text{T}}$ and MgO plots clearly describe differentiation trends with inflection at approximately 60% SiO_2 , whereas Al_2O_3 and P_2O_5 mark a shift from strongly to moderately negative slopes. The biotite paragneiss comprehends the lowest Na_2O (2.4 wt.%), P_2O_5 (0.08 wt.%) and CaO (0.8 wt.%) concentrations. The mg# parameter on the other hand describes a discrete negative correlation with SiO_2 within a narrow range (37-43) while, interestingly, the peraluminous and evolved samples scatter most, from values higher than the primitive ones (46) to the lowest of the dataset (25).

Figure 4-7: Classification schemes according to Frost et al. (2001), Peccerillo and Taylor (1976) and Shand (1943) of the sampled granitoids. Symbols as in Figure 4-6.

As observed in Figure 4-8, most rocks present high Ba (1308-2210 ppm) and Sr, the latter being more abundant in the Barro Branco orthogneiss (809-1079 ppm) and Moinho granodiorite (858-1032 ppm) than the evolved members (456-994 ppm). The Zr budget is relatively low (190-665 ppm) and the trend suggests the magmas reached saturation around ~62 wt.% SiO_2 . V shows a straightforward negative correlation with SiO_2 , with the amphibolitic gneiss and metavolcaniclastic rock marking the highest (123 ppm) and lowest (15 ppm) values,

respectively. The samples present low Y (4-26 ppm) and variations are more expressive in the inequigranular orthogneiss and biotite granites, producing some extreme Sr/Y ratios (as further discussed in section 5.2). The amphibolitic gneiss has the highest Nb (36 ppm), V (123 ppm) and Y (26 ppm) concentrations probably due to abundant hornblende while the biotite paragneiss is remarkably enriched in Rb (279 ppm) and depleted in Sr (246 ppm).

Figure 4-8: (a-g) Trace-elements (ppm) plots and (h-i) REE chondrite-normalized (McDonough and Sun, 1995) ratios of all samples. Symbols as in Fig 5. *Plot (h): garnet and amphibole fractionation patterns from Davidson et al. (2007); black dashed arrow refers to all granitoids (Barro Branco + Moinho + inequigranular orthogneiss + biotite granites); light grey dashed arrow refers to SRD samples; dark grey dashed arrow corresponds to SGN samples.

Chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns (Figure 4-9) have overall discrete negative slopes with near-flat HREE and absent or weakly negative Eu anomalies. The Barro Branco orthogneiss and Moinho granodiorite lack the negative Eu anomaly (both vary ~0.9-1.0) whereas the evolved granitoids (inequigranular orthogneiss and biotite granites) present few pronounced anomalies (around ~0.7). REE fractionation is stronger in the inequigranular orthogneiss [(La/Lu)N=59-160] and the biotite granites [(La/Lu)N=15-189] mostly due to LREE enrichment [(La/Eu)N=13-14 and 4-16, respectively] and a slight depletion in HREE. On a counterpart, the Barro Branco and Moinho have straight negative

trends with weak HREE fractionation. The metavolcaniclastic rock and the biotite paragneiss present the most pronounced negative Eu anomalies, the latter having a slightly concave-upward HREE pattern. The amphibolitic gneiss is enriched in both LREE and HREE while lacking Eu anomaly. The dataset in Ragatky (1998) describes positive Gd and negative Tm anomalies that are not reproduced in our samples and may be linked to analytical issues.

Figure 4-9: Chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns of all samples with detailed spiderplots. Fields represent data from literature: (i) SRD (Ragatky, 1998; Janasi et al., 2016) and (ii) SGN (Haddad, 1995; Janasi, 1999; Gengo, 2014; Vinagre et al., 2014; Mora et al., 2014). *The Barro Branco samples from Ragatky (1998) refer to the fine-grained inequigranular facies, herein named inequigranular orthogneiss, thus we compare these data with both the Barro Branco and inequigranular orthogneisses from this study.

4.4.4. Zircon typology, U-Pb ages and Hf isotope determinations

4.4.5. *Barro Branco orthogneiss*

BB-04C zircon crystals are prismatic, subhedral to euhedral with 100-300 μm in the longer axis. Crystals with oscillatory zoning predominate locally resorbed and recrystallised, but sector zoning also occurs in a lesser extent (Figure 4-10, see Appendix V). Note that we use recrystallisation and reworking to denote disturbed zoning textures. Two main groups were identified for the Neoproterozoic zircons: (i) oscillatory-zoned with aspect ratio 4:1 and bright luminescent cores surrounded by a darker domain and (ii) more elongated (6:1) sector-zoned with darker cores and resorbed brighter rims. Sub-rounded (2:1) oscillatory-zoned zircons ($n=2$) have relict Paleoproterozoic cores with recrystallized medium- to dark-CL response. All grains present dark narrow rims. Th/U ratios range ~ 0.3 -2.7 with no apparent age correlation nor texture/disturbance (the two inherited zircons were not considered).

The younger set ($n=4$; 510-620 Ma) and the relict cores ($n=2$; 1881 and 2398 Ma) were rejected from the age calculation (hollow ellipses). The $^{206}\text{Pb}/^{238}\text{U}$ dates (736-636 Ma, Table 4) yielded a Concordia age of 684.5 ± 9.6 Ma ($n=15$; MSWD= 0.44; probability of concordance= 0.51) which we interpret as the crystallisation age of the magmatic protolith (Figure 4-11).

The *in situ* Hf analyses (Table 5) yielded ϵHf from -8 to +1.2 and average -4.4 ± 1.4 (2σ) and $^{176}\text{Lu}/^{177}\text{Hf}$ ratios from 0.0004 to 0.0019, the latter being the highest value of the dataset. The broad range of radiogenic signatures is probably related to mixing of distinct zircon domains and imply an important unradiogenic component at ~ 700 Ma. Although in the same textural context of U-Pb determinations, the Hf signatures do not vary accordingly to U-Pb age. Xenocrystic zircon cores tend to be more radiogenic than apparently undisturbed oscillatory zoning and homogeneous cores. Yet homogeneous cores that are nearly as radiogenic as the oscillatory rims could signify that the time period of zircon crystallisation corresponds to that of the magmatic protolith and the small range of $^{176}\text{Hf}/^{177}\text{Hf}(t)$ ratios (0.282129-0.282381) discards the hypothesis of isotopic disturbance.

Figure 4-10: Cathodoluminescence images of zircon grains from samples of granitoids (BB-04, BB-09), a metavolcaniclastic rock (IGT-04C) and metasedimentary rocks (BB-06, IGT-04D). First three samples also feature Hf determinations (LA-ICPMS).

4.4.6. *Inequigranular orthogneiss*

BB-09 zircon crystals are petrographically heterogeneous. They are predominantly prismatic with 100-250 µm in the long axis but also occur as sub-rounded grains. In general, the zoning pattern is not clearly marked. Elongated crystals (aspect ratios from 3:1 to 5:1) are weakly oscillatory- or sector-zoned with bright to medium luminescence, others have a

medium-CL nearly homogeneous texture that yielded the youngest U-Pb ages. Low-CL response is predominantly observed in the smaller prismatic (2:1) and sub-rounded (1:1), inherited Paleoproterozoic zircons with weak oscillatory zoning. Most grains have dark narrow rims and no age distinction was observed for grains without such dark rims (see Figure 4-10).

The $^{206}\text{Pb}/^{238}\text{U}$ dates (Table 4) of the prismatic zircons with zoning and homogeneous texture range from 694 to 584 Ma with resulting Concordia age at 624 ± 10.6 Ma ($n=16$; MSWD=0.066; 2σ ; probability of concordance=0.80; Figure 4-11) interpreted to represent the crystallisation time. Rejected data (hollow ellipses) consist of the oldest inherited cluster and a grain of ~689 Ma interpreted as an antecryst (in the sense of Miller et al., 2007) with remarkably low $^{176}\text{Hf}/^{177}\text{Hf}(t)=0.281772$ and $\text{Th}/\text{U}=0.19$, dissonant from the overall range (0.282024-0.282140; 0.47-2.28, respectively). Zircons with Th/U close to the antecryst are found in samples BB-04C and IGT-04C around the same ages but no BB-04C zircons have such low $^{176}\text{Hf}/^{177}\text{Hf}(t)$.

In situ Hf analyses (Table 5) yielded $\epsilon\text{Hf}t=-12.6$ to -7.9 and average -10.4 ± 1.6 (2σ) that only overlap with the most radiogenic Barro Branco values whereas the zircon antecryst presented the most radiogenic value (-20.5). The $^{176}\text{Lu}/^{177}\text{Hf}$ ratios systematically decrease with younger ages describing a continuous trend of 0.00008-0.0005 (lowest range of the dataset).

4.4.7. Metavolcaniclastic rock

Zircon crystals from sample IGT-04C yielded a complex set of scattered dates (Table 4, Figure 4-11c). They are divided into two main groups. The younger set (~800-500 Ma) is mostly bright-CL homogeneous to weakly sector- or oscillatory-zoned prismatic zircons (aspect ratios 4:1 to 5:1) with 80-200 μm in the long axis, sometimes reworked (Figure 4-10, see also Appendix V). Many grains are fragmented and contain inclusions. The vast majority also presents dark-CL rims. Dark oscillatory-zoned zircons also occur and often overgrow bright Paleoproterozoic-Archean relict cores, one of which presented a 755 Ma-old dark rim with low Th/U (0.002), probably metamorphic. According to the Th/U ratios, most zircons <1 Ga overlap with the Barro Branco and inequigranular orthogneiss (0.2-2.8) with the exception of two grains dated at ~900 Ma with low Th/U (~0.02) that seem to have suffered Pb loss (dark-CL) thus resulting in U-Pb aging (Corfu, 2003).

We identified a younger group of $^{206}\text{Pb}/^{238}\text{U}$ dates ($n=10$; 540-620 Ma) that yielded a Concordia age of 609.5 ± 9.8 Ma (MSWD=0.119, probability of concordance=0.73). However, dates <800 Ma (hollow orange ellipses) seem to describe a reverse discordance and cluster around ~700 Ma which yielded a weighted average age of 739 ± 15 Ma ($n=8$; MSWD=1.3; probability=0.26, 2σ) (Figure 4-11d,e).

Figure 4-11: Concordia plots of U-Pb ages (LA-ICP-MS). (a,b) Zircon Concordia ages for the Barro Branco and inequigranular orthogneiss. (c-e) Metavolcaniclastic rock: (c) Concordia plot with all zircon dates except large-error data, (d) Concordia zircon age calculated with the younger cluster, (e) weighted average age calculated with a significant cluster around 700 Ma. (f) Monazite Concordia age of the biotite paragneiss, further discussed in section 4.4.10.

4.4.8. Metasedimentary rocks

BB-06A grains are prismatic, fragmented and/or rounded. Prismatic zircon crystals (150-340 μm) are sector- and oscillatory-zoned (aspect ratio 2:1), frequently carrying relict cores (Figure 4-10, see also Appendix V). Zoning is usually blurry with resorbed rims and reworked cores. The fragmented grains are smaller (130-170 μm) with fir tree zoning and flow structures. Rounded grains (100-150 μm , aspect ratio 1:1) are homogeneous dark. Dark-CL overgrowths are very narrow, up to 50 μm .

IGT-04D grains are prismatic (140-300 μm) with aspect ratios 2:1-3:1. Most grains present oscillatory zoning with dark to medium luminescence and relict cores; few are sector-zoned and brighter (Figure 4-10). Zoning is mostly weak with reworked cores. Overgrowths are dark-CL and narrow, up to 20-40 μm . One zircon is oval (150 μm , 1:1) and sector-zoned with bright relict core and narrow dark rim.

The detrital zircon dataset describes a wide age record from Paleoproterozoic to Archean. The $^{207}\text{Pb}/^{206}\text{Pb}$ dates (Table 4) highlight a main Rhyacian peak at ~ 2.17 Ga (55-62% zircons) and two less important peaks at ~ 2.7 Ga (10-20% Neoarchean zircons) and ~ 2.9 Ga (12-17% Mesoarchean zircons) and one single grain of ~ 1.8 Ga (Figure 4-12). Th/U ratios mostly overlap for both samples (~ 0.01 -2.2), however, IGT-04D has slightly lower values probably due to concurrent crystallization of monazite.

Only sample BB-06A was targeted for *in situ* Hf analyses (Table 5). The detrital dataset presents strongly positive and few negative values of ϵ_{Hf} from -3.7 to +7.2 and an exceptional -6, with average $+2.2 \pm 1.5$ (2σ). The $^{176}\text{Lu}/^{177}\text{Hf}$ ratios roughly increase with older dates. Zircon grains dating ~ 2.1 -2.4 Ga have scattered $^{176}\text{Lu}/^{177}\text{Hf}$ ratios from 0.00028 to 0.00136 while grains older than 2.5 Ga show ratios around 0.0007 ($n=3$) and 0.0014 ($n=1$).

Figure 4-12: Probability density curves of detrital zircon dataset of two metasedimentary rocks (samples BB-06 and IGT-04D) and a metavolcaniclastic rock (sample IGT-04C – grey dashed curve) for comparison, with peak $^{207}\text{Pb}/^{206}\text{Pb}$ ages and respective Th/U ratios. Pie charts describe the zircon population percentages from each period.

4.4.9. Nd isotope geochemistry

The Sm-Nd isotope analyses are enlisted in Table 6. Sample BB-31C of a porphyritic biotite orthogneiss (Barro Branco) yielded the least radiogenic signature with $\epsilon\text{Nd}_{685} = -7.15$ and youngest Nd T_{DM} model age at ~ 1.6 Ga of the dataset. On a counterpart, the younger hornblende-biotite orthogneiss (sample BB-44A, Moinho) is relatively more radiogenic with $\epsilon\text{Nd}_{620} = -12.9$ and yielded older Nd T_{DM} model-age at *ca.* 1.96 Ga. The metavolcaniclastic rock (sample IGT-04C) presented Nd $T_{\text{DM}} \sim 1.8$ Ga and $\epsilon\text{Nd}_{610} = -11.4$, closer to the Moinho signature, whereas ϵNd_{739} yielded a less radiogenic value (-9.7), closer to the Barro Branco

signature. Moreover, the metasedimentary rock (sample IGT-04D) has a nearly juvenile signature at the main Rhyacian peak ($\epsilon\text{Nd}_{2.17\text{ Ga}} = -0.9$) compared to the estimated maximum depositional age ($\epsilon\text{Nd}_{1.81\text{ Ga}} = -5$) and yielded a Nd T_{DM} model age at *ca.* 2.5 Ga.

Ragatky (1998) presented Nd isotope data of the inequigranular orthogneiss that yielded $\epsilon\text{Nd}_{624} = -11.6$ to -11.7 and Nd TDM model ages around 1.75-1.79 Ga. Likewise, compiled Nd isotope data of the Moinho granodiorite (Ragatky, 1998; Tassinari et al., 2004) are similarly radiogenic, with ϵNd_{620} varying from -11.2 to -14.5 . There is a larger spread of the Moinho Nd model ages, from *ca.* 1.88 Ga (Ragatky, 1998) to 2.09-2.13 Ga (Tassinari et al., 2004). Thus, the ϵNd crustal values of the inequigranular orthogneiss and Moinho granodiorite are practically indistinguishable.

The model ages from the acquired data and literature could characterize an event of juvenile accretion at approximately 2.3-2.5 Ga forming a new juvenile crust which was potentially reworked by the magmatism in the São Roque Domain.

4.4.10. Monazite composition and U-Th-Pb age

In thin section, sample IGT-04D presented widespread inclusions of rounded monazite in the foliated metamorphic biotite forming pleochroic halos (Figure 4-4f). The sample provided a monazite-rich fraction of mostly sub-rounded, fragmented and strongly fractured grains, anhedral to subhedral (50-175 μm). BSE imaging shows that the dominant texture is a very discrete patchy zoning with bright- to medium-BSE response, nearly homogeneous. Sector and weak concentric zoning also occur in a lesser extent (see Appendix V).

The $^{206}\text{Pb}/^{238}\text{U}$ dates (Table 4) are uniform within uncertainties and yield a Concordia age of $599.9 \pm 1.9\text{ Ma}$ ($n=36$; $\text{MSWD}=1.8$; 2σ ; probability of concordance=0.18) (Figure 4-11f). Only three monazite grains yielded significantly older $^{206}\text{Pb}/^{238}\text{U}$ dates (618, 629 and 633 Ma), zoned by narrow brighter domains or sectored.

Six monazite grains were analysed for compositional variations (WDS) near the U-Pb spots (LA-ICP-MS, Figure 4-13a). Mineral compositions are enlisted in Table 7. The monazite is typically Ce-rich and chemical variations are mainly controlled by the huttonite exchange $\text{Th}^{4+} + \text{Si}^{4+} = \text{REE}^{3+} + \text{P}^{5+}$ (Linthout, 2007; see Figure 4-13b), as Th contents vary 2.8-6.7 wt.%. The BSE responses seem to be mainly controlled by Th (as well as Si), reaching 0.052-0.071 apfu in the brightest domains, while lower intensities have $\text{Th} < 0.05$ apfu. Other chemical variations were not captured by the BSE imaging. Chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns are uniform, strongly enriched in LREE and linearly decrease towards HREE with only significant variations of Yb (Figure 4-13c).

Figure 4-13: a- BSE images of six monazite grains with U-Pb age spots (LA-ICP-MS) and WDS chemical profiles. b- Cheralite and huttonite substitution vectors of the monazite grains. c- Chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns of monazite.

The concentric zoning is related to chemical variations, thus helping distinguish cores and rims. Rims are often more enriched in HREE+Th compared to cores. Therefore, HREE and Th correlate positively while describing negative slopes against LREE. Although Y and Yb have positive correlation, Y does not have a straightforward behaviour since some cores can be more enriched in this element than rims (Figure 4-14a-c). Intra-grain U-Pb age differences are only relevant in monazite m2 and m22 since the other grains present negligible age differences, uncertainties considered. Monazite m2 and m22 present cores dated around ~630 Ma with relatively low Yb+Th and high LREE while the outermost domains date ~602 Ma with higher Yb+Th and lower LREE.

In Figure 4-14(d-f), we observe that the inferred cores have a lower and narrower range of Th/U ratios (8.4-14). Intermediate regions between cores and rims (namely mid-rims) show a significant increase of Th/U (12-33) whereas the outermost rims have lower values (Th/U < 17), but still higher or close to their cores. This pattern owes mostly to unexpected peaks of Th

and troughs of U that are not correlated to each other. While cores and rims describe basically the same REE patterns, the mid-rims trace a uniform negative slope with no variation of Yb (not shown). This mid-rim pattern either corresponds to resorption zones in the crystals or holds a geological meaning.

Figure 4-14: (a-c) WDS monazite chemical plots categorized into U-Pb age groups. Molar fractions were calculated according to Pyle et al. (2001). (d-f) Chemical monazite profiles for Th/U, Th and U. Spot positions are not in scale (they do not represent actual intra-grain distances), they illustrate variations from inferred cores to rims.

5. DISCUSSION

5.1. Inferences from coronal textures in the granitoids

Coronal structures of apatite, allanite and epidote are reported as reaction products from the break-down of primary monazite (e.g., Broska and Siman, 1998; Finger et al., 1998; Ondrejka et al., 2012). Volume and composition of the products as well as minor associated phases are mostly controlled by the local chemistry and composition of the fluid that mediated the alteration process. These conditions are responsible for a huge variety of coronal patterns. It is important to state that phase stabilities are distinct in granitoid and metapelitic systems. While low-Ca metapelitic rocks grow new monazite from allanite dissolution during prograde metamorphism (Spear and Pyle, 2010), in granitoid lithologies monazite is unstable under amphibolite facies and develops the apatite-allanite-epidote coronas (Finger et al., 1998). The break-down reactions are triggered by a fluid phase that percolates along major grain boundaries and/or cleavage planes and feeds Ca, Al, Fe and Si to the system possibly from plagioclase and biotite (and primary apatite?) as observed in Figure 4-5. The transformation from monazite to allanite (and vice-versa) is mainly controlled by the Ca content of the fluid (either post-magmatic or metamorphic).

In the inequigranular orthogneiss, we mostly observed the complete dissolution of monazite, usually with massive formation of apatite, an epidote rim and the allanite-epidote external zone. Finger et al. (1998) reported textures in which monazite was preserved and apatite formed only a discrete ring due to reduced diffusion rates and restricted REE mobility. Our textures resemble those described in Ondrejka et al. (2012). The authors suggested that destabilization of monazite is not exclusive of high-grade metamorphic conditions and thus derived from post-magmatic fluid activity. Likewise, Vlach (2008) inferred syn-tectonic granites of the Embu Terrane with low-temperature associations (chloritization and sericitization) underwent monazite break-down from fluid activity in the shear zones that deformed them, equivalent to greenschist-facies conditions. We identified biotite substitution by chlorite and newly formed muscovite parallel to the biotite foliation that underpin this hypothesis. Therefore, post-magmatic fluid percolation within the shear zones that accommodate the inequigranular intrusion seems plausible enough to develop the coronal textures. The lack of chemical analyses and age determinations of the coronal aggregates preclude any further assumptions. The metamorphic monazite dated at *ca.* 600 Ma in the biotite

paragneiss implies a thermal event in the São Roque Domain (discussed below, in section 5.6) but more information is needed to support a possible link with the fluid activity here inferred.

5.2. Inferences from whole-rock and trace-element geochemistry

The high-K calc-alkaline ($K_2O > 3.5\%$) granitoids have intermediate compositions from tonalites to monzogranites that describe an evolutionary trend from the most primitive Moinho granodiorite (59-65% SiO_2) to the most evolved inequigranular orthogneiss (69-70% SiO_2). The linear trend of major elements with differentiation indicates that fractional crystallization was the key role mechanism in the evolution of these granitoids, however, other processes might have taken place to explain the high K_2O (K-rich source and/or crustal contamination) and the presence of microgranular mafic enclaves not sampled in this study (magma mixing), also observed in the granites of the central SRD (Janasi et al., 2016). The mg# parameter remains almost uniform throughout the dataset supporting mixing with a basic magma. The TiO_2 vs. SiO_2 plot marks the only exception where the Moinho granodiorite clearly diverges from the general trend. The amphibolitic gneiss and metavolcaniclastic rock commonly act as differentiation end-members (Figure 4-6 and Figure 4-8).

There is a distinct LILE enrichment (Cs, Rb, Ba, Sr, Th) compared to REE (La-Lu) and a moderate depletion in HFSE (Nb, Ti, Zr and P). High Ba (~1100-2200 ppm), Sr (~400-1000 ppm), with exception to the metasedimentary and metavolcaniclastic rocks, coupled to negligible negative Eu anomalies imply plagioclase was not an important fractionating phase in the source (Figure 4-8h-i; e.g. Ragatky, 1998; Janasi et al, 2016; Lamoso and Janasi, 2019). Primitive mantle-normalized spidergrams (Figure 5-1b) describe important peaks of Th, Pb and Nd, troughs of Nb, Ti and P and near-flat HREE (Dy, Yb, Lu) and Y.

In general, Th, U and Pb are enriched relative to other trace elements (Figure 5-1a,b), reflected in high Th/La (~0.1-0.5) and low Ce/Pb (~1-16.5). Such high Th/La ratios are consistent with the bulk continental crust (~0.311, Rudnick and Fountain, 1995) and fractionation of Th and La appears to take place in the lower crust because of abundant apatite, thus, producing low-Th/La residues and high-Th/La melts that rise to the upper crust (Plank, 2005; references therein). Our granitoids show an early apatite saturation given the negative correlation between P_2O_5 and SiO_2 , with saturation temperatures of 940-1060°C (Harrison and Watson, 1984) that probably represent the *liquidus* - although keeping in mind the uncertainty of the method and P over-estimation due to accumulation of the phase. Nevertheless, Zr contents are considerably low (~190-665 ppm) with saturation temperatures 770-910°C around

~60 wt.% SiO₂, that mirror the under-saturated parental magma. These features altogether argue in favour of a lower crustal source.

Figure 5-1: A) Trace-elemental fractionation patterns normalized to lower crust (Weaver and Tarney, 1984) and B) primitive mantle (McDonough and Sun, 1995). Caption as Figure 4-9.

The granitoids have high Sr/Y (30-85) and even some extreme values (110-220) that vary within a narrow MgO range, that several studies have referred to as “adakitic signatures”, also accompanied by high La/Yb (10-80) with few extreme values (155-185). Figure 5-2 shows that La/Yb and Sr/Y are not strictly correlated although the general trend is positive; decoupling seems to occur mainly due to medium and heavy REE fractionating phases in the source. High Sr/Y and La/Yb ratios more likely derive from garnet-bearing sources at pressures where clinopyroxene and amphibole are also stable. The decrease of Dy/Yb with differentiation (Figure 4-8h) indicates fractionation of amphibole (Davidson et al., 2007), however, amphibole alone would probably not alter trace elements in this scale, garnet is more efficient instead (Moyen, 2009). Amphibole fractionation during the latest stages of crystallization might have overprinted the garnet influence in source (Moyen, 2009), since the positive correlation of

Dy/Yb and La/Yb confirms garnet fractionation (not shown, Macpherson et al., 2006). The generation of a parental magma from a garnet ($\pm$ clinopyroxene $\pm$ amphibole)-bearing source is also supported by the spidergrams relative to the lower crust with flattening towards the HREE members (Figure 5-1a) and by the systematic decrease of V and Y with increasing SiO₂ (Figure 4-8).

The variable LILE enrichment coupled to negative Nb anomalies are diagnostic features of subduction-related activity (Tatsumi and Eggins, 1995; references therein) when it comes to basalts, however, the continental crust also carries the Nb-Ta anomaly. Presence of residual rutile (or amphibole) at higher pressures (e.g., Tang et al., 2019) could be responsible for the Nb anomaly and the low TiO₂ contents of the dataset.

Figure 5-2: A) MgO vs. Sr/Y plot of all sampled rocks. Curves were extracted from Chiaradia (2015); note that high-pressure melts of mafic rocks can easily produce high Sr/Y ratios and might have taken part in the evolution of the granitoids and the metavolcanic rock, such as suggested for Archean juvenile crust generation (Chiaradia, 2015). B) La/YbN vs. Sr/Y plot, showing the correlation between these ratios as a tool for crustal thickness estimations in magmatic arcs (Profeta et al., 2015). La/Yb values are chondrite-normalized (McDonough and Sun, 1995).

5.3. Timing of magmatism

The studied I-type granitoids record U-Pb zircon ages that broadly range from the older Barro Branco (684.5 ± 9.6 Ma), with a significant gap of ~ 81 m.y. within uncertainty, to the younger inequigranular (624 ± 11 Ma) orthogneiss and Moinho granodiorite (620 ± 11 Ma; Tassinari et al., 2004). To this moment, there was only one TIMS U-Pb age reported for the Barro Branco of *ca.* 629 ± 10 Ma (Ragatky, 1998) which actually corresponds to the inequigranular facies, therefore consistent with the age determination here presented. The Barro Branco orthogneiss comprises an important data cluster around ~ 640 Ma and such does the related inequigranular orthogneiss, which further supports the multi-intrusive behaviour of the former. It also carries a subordinate cluster of 620-510 Ma ($n=4$) that describes discordance and has little statistical meaning.

The metavolcaniclastic rock comprises a series of inherited ages, some of which have not yet been reported in this domain (~ 900 -800 Ma) and call for further studies. Morphologically similar zircons, younger than 650 Ma, provided an age of *ca.* 609.5 ± 15 Ma which could point to an emplacement contemporaneous to the younger intrusions and the widespread Ediacaran HKCA-magmatism in the SRD (e.g. Janasi et al., 2016), within uncertainty. However, a significant group (including cores) clusters around ~ 700 Ma describing a reverse discordance associated to large errors that could signify the actual (yet disturbed) crystallization time of this rock or an important magmatic event incorporated during magma emplacement with a weighted average age of *ca.* 739 ± 20 Ma.

Nonetheless, dates around ~ 800 -700 Ma are ascribed to the onset of arc magmatism (*ca.* 790 Ma) in the Guaxupé nappe (Tedeschi et al., 2017) while studies on the SGN granulites have argued these clusters consist of xenocrystic cores (Ebert et al., 1996; Vinagre et al., 2014; Rocha et al., 2018) and additional Lu-Hf isotopic constraints should underpin such statement (Rocha et al., 2018; e.g. Whitehouse and Kemp, 2010). South to the Socorro-Guaxupé Nappe, the central and eastern São Roque Domain comprise a younger and narrower main interval of I-type HKCA-magmatism of ~ 30 -20 m.y. (SHRIMP U-Pb *ca.* 610-580 Ma, Janasi et al., 2016; Lamoso and Janasi, 2019). Zircons from these Ediacaran granitoids are typically oscillatory-zoned with 2:1 aspect ratios that distinguish them from the >600 Ma dataset here presented of more elongated grains and darker CL responses. Also, in the central São Roque Domain, studies reported voluminous plutons with zircon cores of >630 Ma that Janasi et al. (2016) interpreted as antecrysts as opposed to previous TIMS determinations of 630-620 Ma dates for syn-tectonic plutonism (Töpfner, 1996). The fact that zircon dates around ~ 700 Ma are commonly observed throughout these domains is noteworthy.

Our data constrain a “short” period of an early HKCA-magmatism from ~690 to ~670 Ma (~20 m.y.) possibly preceded by a Tonian volcanism, at ~740 Ma, in the north-easternmost São Roque Domain. The main magmatic event is therefore roughly synchronous to the pre-collisional stage of the Socorro-Guaxupé Nappe (~670-640 Ma; Ebert et al., 1996; Hackspacher et al., 2003; Vinagre et al., 2014; Mora et al., 2014; Rocha et al., 2017, 2018). The collisional phase that followed marked the onset of an UHT metamorphic event that lasted until ~590 Ma (Tedeschi et al., 2017, Rocha et al., 2017) during which syn- to late-collisional batholiths of very similar geochemical affinities were emplaced (Haddad, 1995; Mora et al., 2014; Gengo, 2014), thus encompassing the inequigranular orthogneiss and Moinho granodiorite around ~635-609 Ma followed by numerous late-collisional stocks until 580 Ma (Janasi et al., 2016).

5.4. Inferences on the source and crustal contributions

The isotopic record of the eastern São Roque Domain is still poorly constrained as most data available concentrate in its central region (e.g. Janasi et al., 2016). Nd-Sr-Pb data available in literature (e.g. Tassinari, 1988; Ragatky, 1998; Tassinari et al., 2004; Henrique-Pinto et al., 2015a) provided important insights on the source rocks of the granitoids as well as sedimentary provenance of the São Roque Group.

Hafnium T_{DM} model ages can vary as much as 300-400 m.y depending on the assumed $^{176}\text{Lu}/^{177}\text{Hf}$ ratio. (e.g. Nebel et al., 2007; Vervoort and Kemp, 2016), thus, we set as parameter the youngest detrital zircon (~1.81 Ga) of our dataset to justify the use of the intermediate crust $^{176}\text{Lu}/^{177}\text{Hf}$ ratio = 0.015 (Griffin et al., 2002). The Hf T_{DM} model ages are slightly older and more scattered than the Nd T_{DM} . Summarizing the model ages, we observe three important periods: ~1.5-2.0 Ga, ~2.1-2.5 Ga and ~2.7-3.0 Ga. The 1.5-2 Ga interval corresponds mainly to the Barro Branco weakly radiogenic signatures ($\epsilon\text{Nd}_{685}=-7.2$; $\epsilon\text{Hf}=-8$ to $+1.2$) at the time of crystallization (*ca.* 684 ± 10 Ma). Despite systematic variations, both Hf and Nd isotope data evidenciate that the Barro Branco parental magma derived from an average ~1.88 Ga crustal reservoir with significant juvenile component suffering minimum crustal contamination. Conversely, the younger Moinho granodiorite (*ca.* 620 ± 11 Ma; Tassinari et al., 2004) and inequigranular orthogneiss (*ca.* 624 ± 11 Ma) probably originated from mixed sources resulting in averaged older model ages and stronger radiogenic signatures ($\epsilon\text{Nd}_{620}=-13$ and $\epsilon\text{Hf}=-20.5$ to -8 , respectively). The ϵNd data from Ragatky (1998) of the inequigranular orthogneiss are also crustal (-10.7 and -10.9). Although we could not establish a precise crystallization date for the metavolcaniclastic rock, the Nd T_{DM} (1.8 Ga) indicates a significant contribution from the ~1.88 Ga crustal source while contamination played an important role (either $\epsilon\text{Nd}_{740}=-9.7$ or

$\epsilon\text{Nd}_{610}=-11.4$) during its ascent, supported by the numerous inherited zircon age clusters (see Figure 4-11). The metasedimentary rocks suggest an important juvenile accretion around ~2.3-2.5 Ga (Hf T_{DM} ~2.3-2.5 Ga; Nd T_{DM} ~2.5 Ga) with strongly positive ϵHf_t (+4.8 to +7.2) and slightly negative ϵNd_{2170} (-0.9) recorded in detrital zircons dating from 2.17 to 2.22 Ga. A subordinate period of ~2.7-3 Ga Hf T_{DM} with positive and negative ϵHf_t (-3.7 to +2.4) recorded in zircons scattered from 2.07 to 2.38 Ga could point to the reworking of an early juvenile crust.

The Hf isotope signatures describe a nearly continuous spread from “juvenile” to “crustal” affinities whereas the Nd isotope evolution shows a gap between the Barro Branco orthogneiss and the rest of the dataset by 4 ϵ units. We suggest the granitoid rocks are cogenetic, produced by several batches of low-degree partial melting (see section 5.2) of a common parental source. Given the significant time span, it is natural to assume the isotopic system of the parental reservoir evolved through time. The inequigranular orthogneiss and Moinho granodiorite are compositionally very distinct rocks whereas isotopically similar (Nd plot - Figure 5-3) and both formed somewhere in-between ~635-610 Ma. The origin of the crustal component is a striking matter for it may involve either contamination from the overlaying metasedimentary rocks of the São Roque Domain and/or a crustal addition to the source, following the up-to-40 m.y. gap since the Barro Branco emplacement. Crustal contamination is a stronger argument for the inequigranular orthogneiss due to its more evolved composition, the fact that it partially overlaps with a few ϵHf signatures of the metasedimentary rock (Figure 5-4) and that it carries a greater amount of inherited zircons (than the Barro Branco orthogneiss, see Figure 4-11). However, it is difficult to make the same assumptions for the Moinho granodiorite which presents a more primitive composition (such as the Barro Branco orthogneiss) but a crustal signature. Thus, we suggest a potential crustal addition of relatively weak-to-intermediate radiogenic signature to the parental source.

Figure 5-3: ϵ_{Nd} vs. age plot of representative samples with Nd data from metamudstones of the São Roque Domain (Henrique-Pinto et al., 2015a).

Figure 5-4: ϵ_{Hf_i} plot of the sampled granitoids (Barro Branco BB-04C and inequigranular orthogneiss BB-09) and the metasedimentary rock (BB-06). Black dashed line is the $^{176}\text{Lu}/^{177}\text{Hf} = 0.015$ crustal evolution (Griffin et al., 2002); “new crust” orange evolution line (Dhuime et al., 2011); grey area is the isotopic evolution of the Morro do Polvilho metarhyolite (Henrique-Pinto et al., 2018); light grey dashed line marks the youngest detrital zircon from sample IGT-04D; the 600-590 Ma SRD data were taken from Janasi et al. (2016). The unpublished detrital zircon array was extracted from Fig. 11 in Janasi et al. (2016) only for visual assessment. Pink area represents metatexites from Mora et al. (2014) and granulites from Tedeschi et al. (2018) in the SGN.

5.5. Zircon provenance and source areas

Detrital zircon crystals from the two metasedimentary samples show predominance of Rhyacian ages marking a ~2.17 Ga peak and one single occurrence of a 1.81 Ga-old zircon, close to the upper sedimentation limit (~1.76 Ma) suggested for the São Roque Group (Henrique-Pinto et al., 2015b, 2018), and subordinate budgets of Late-Orosirian to Siderian and Archean zircons. The metavolcaniclastic rock contains inferences dating from 800 to 900 Ma which do not correlate to any of the São Roque Domain detrital zircon grains. Therefore, their meaning is unknown.

The metasedimentary rocks, a two-mica schist and a biotite paragneiss, are *metawackes* with significant amounts of K-feldspar and plagioclase indicating sediment immaturity. The detrital age peak at ~2.17 Ga is adjacent to the T_{DM} model ages (~2.3-2.5 Ga) with “juvenile” signatures, implying proximity to the source area.

Compared to the detrital zircon dataset of the São Roque Domain (Henrique-Pinto et al., 2015b), the K-S statistical test (Figure 5-5) resulted in high degrees of similarity (P value) between our samples and the metasandstones from Serra do Japi (JP-01), Pico do Jaraguá (PJ-1M) and the Serra do Pirucaia (JP-19). The biotite schist (BB-06) was sampled close to the Jundiuvira Shear Zone and it shows the highest P (0.82) related to the PJ-1M, followed by the JP-01 (P=0.69; sampled north of the JSZ, in the Socorro-Guaxupé domain) and IGT-04D (P=0.53). On the other hand, the biotite paragneiss (IGT-04D) was sampled in the central region of the study area, more distant from the local shear zones and presented greater similarity with JP-19 (0.72), followed by the BB-06 (P=0.53) and JP-01 (P=0.29). The most unlikely source contributions are the ones of the Serra da Viúva and Voturuna metarkoses (VT-03 and VT-04). Still, although low, most P-values are >0.05 and we cannot discard the possibility of contribution (in part) from a common source.

Figure 5-5: Cumulative probability curves for sampled metasedimentary rocks (BB-06 and IGT-04D) compared to a metavolcaniclastic rock with important Paleoproterozoic-Archean inferences (IGT-04C) and metasandstones (PJ-1M, VT-03, VT-04 and JP-19) from the SRD and one sample from the neighbour SGN (JP-01) from Henrique-Pinto et al. (2015b). The K-S test run for the samples results in P-values that measure the degree in which zircon populations are *not* different (Guynn and Gehrels, 2010). Bold values assign all $P > 0.05$ (95% confidence level) and orange boxes indicate the higher P-values for each sample pair.

Henrique-Pinto et al. (2012) identified granitic clasts in metaconglomerates of the SRD and suggested that basement exposures of the Açungui Domain would be ideal candidates of source material, based on Nd T_{DM} ages, detrital zircon age peaks and geographic proximity. However, since these clasts differ compositionally from the basement nuclei of the Açungui Domain, they compared these signatures to the Mineiro Belt, a ~2.2 Ga juvenile crust, thus pointing to the possibility of a southwestward extension of the São Francisco Paleoplate (Henrique-Pinto et al., 2015b). Given the São Francisco paleoplate records “a massive generation of magmatic rocks” during the globally recognized gap of ~2.45-2.22 Ga (Condie et al., 2009; Eriksson and Condie, 2014) with predominantly juvenile signature, Henrique-Pinto et al. (2015b) argue that the São Roque Domain detrital zircon record would thus have a “São Francisco signature”. Meanwhile, this “magmatic gap” has been put to the test with recent

investigations (e.g., Partin et al., 2014) pointing to active-subduction processes between 2.45-2.22 Ga with only few juvenile signatures because great part of this juvenile crust was recycled back into the mantle. Thus, the so-called “São Francisco signatures” would be widespread.

In our view, the São Roque Domain sequences are part of the Paranapanema block, a correlation to the São Francisco paleoplate basement and its passive margin sequences seems unlikely since, based on the plate reconstruction of Merdith et al. (2017), the Paranapanema and São Francisco blocks were not accreted until continental collision around ~670 Ma (Frugis et al., 2018). The Cryogenian and Tonian zircon record (Barro Branco and metavolcaniclastic rock, respectively) of the São Roque Domain agrees with the magmatic arc activity of the Socorro-Guaxupé Nappe. Thus, we argue the Rhyacian source area lies potentially within the Socorro-Guaxupé basement (e.g., Tedeschi et al., 2018). Moreover, the same authors found evidence of Neoarchean components in the Guaxupé Nappe and concluded 2.7 Ga-old crustal material in part contributed to the formation of a granitic leucosome. This occurrence is coherent with the Hf signatures of the 2.7 Ga-old detrital zircon peak in the São Roque Domain (previously discussed in section 5.4).

5.6. Insights on the metamorphism

Metamorphic monazite is usually described in literature as typically patchy because of secondary processes (e.g., fluid interaction and recrystallisation) that affect its texture, rarely preserving any primary zoning. The monazite crystals here presented belong to a metamorphic textural frame as inclusions in orientated biotite, mostly homogeneous or discrete patchy zoning and few sector/concentric-zoned.

Monazite U-Pb dating in this study yielded a Concordia age of *ca.* 600 Ma that we interpret as the record of a metamorphic episode in the São Roque Domain. Peak conditions are unknown since monazite more commonly registers prograde and retrograde paths and the absence of a diagnostic metamorphic assemblage impedes any further supposition. Two oscillatory-zoned monazite grains presented considerable intra-grain age differences, with inner domains around *ca.* 630 Ma to outer rims at *ca.* 600 Ma that could represent crystallisation episodes from an ongoing thermal event. Th contents vary 3-7 wt.%, that interplay within the interval of magmatic and hydrothermal monazite (Catlos, 2013; references therein). Th/U ratios vary in a much larger scale due to high-Th and/or low-U mid-rims. Such phenomenon could be related to simultaneous growth of metamorphic zircon (low Th/U; e.g., Rubatto et al., 2006). Although we did not observe metamorphic zircon rims of such age in our dataset, low-Th/U overgrowths of ~600-560 Ma on detrital zircon from the Serra do Pirucaia were reported in the São Roque

Domain (Henrique-Pinto et al., 2015b). Regardless, this time span coincides with zircon and monazite age determinations of syn-collisional partial melting and last stages of melt crystallisation set for the Socorro-Guaxupé Nappe (Martins et al., 2009; Rocha et al., 2017; Tedeschi et al., 2018).

In the eastern São Roque Domain, the metasedimentary rocks (inferred as the Serra do Itaberaba Group) register metamorphic conditions at the biotite zone imprinted on the main, regional foliation. For low-grade metapelitic rocks, the main sink of Y is allanite and xenotime. Allanite is a common accessory phase throughout our dataset but lacks from the host biotite paragneiss. Thus, allanite, being a common precursor of monazite (e.g., Corrie and Kohn, 2008; Catlos, 2013 and references therein), might have been completely exhausted to form monazite providing significant Y (Spear and Pyle, 2010).

5.7. Tectonic evolution

Based on the above discussions, we propose a model for the tectonic evolution of the eastern São Roque Domain. The metasedimentary record of the São Roque Domain is potentially related to the extension of metasedimentary rocks from the southern portion of the Socorro-Guaxupé Nappe partially hidden by the Jundiuvira Shear Zone (e.g., this study; Henrique-Pinto et al., 2015b), reinforcing the hypothesis of a linked past.

The subduction configuration is the prime reason for the magmatic distribution in space and time. Geochemical affinities between the studied granitoids, especially the Barro Branco, and batholiths throughout the Socorro-Guaxupé Nappe are remarkable, particularly in that they share high K₂O contents within a range of intermediate SiO₂ composition, low MgO, high LREE/HFSE, negative Nb anomalies and weakly radiogenic signatures (Hf-Nd). The magmatism marked by the Barro Branco intrusion (~690-670 Ma) in the São Roque Domain is chrono-correlated to the early arc magmatism of the Socorro-Guaxupé Nappe, although in the paleogeographic hinterland with respect to the southwestern-driven subduction zone. Such ages are related to the early stages of convergence between the Paranapanema and São Francisco paleoplates and corresponding isotopic signatures of both domains show predominantly less radiogenic compositions with a minor crustal component that imply an enriched mantle source. A magmatic inactivity took place in the São Roque Domain until *ca.* 635 Ma (i.e., minimum gap considering Concordia age 624±11 Ma of the Barro Branco II). During this gap, the Socorro-Guaxupé domain recorded extensive, north-northwestward arc-related magmatism from 670 to 590 Ma (e.g., Haddad, 1995; Vinagre et al., 2014; Mora et al., 2014; Gengo, 2014). The resumption of magmatism is marked by the inequigranular orthogneiss (*ca.* 625 Ma),

Moinho granodiorite (*ca.* 620 Ma) and two monazite cores (*ca.* 630 Ma) from a metasedimentary rock presenting relevant shifts in the geochemistry, where stronger radiogenic signatures point to a significant crustal component added to the source and/or during transport and emplacement.

As discussed above (sections 5.2 and 5.4), magmatism in the São Roque Domain potentially derived from a lower crustal source, at conditions where garnet is stable, and plagioclase is not. The petrogenesis is mirrored in trace-elemental ratios such as high Sr/Y and La/Yb. Such ratios have been used to constrain average melting depths and crustal thicknesses for modern arc magmas (e.g., Profeta et al., 2015; Chiaradia, 2015). Both the São Roque and Socorro-Guaxupé domains record high Sr/Y consistent with a thickened crust which was a key factor to developing the calc-alkaline trend of the granitoids (Chiaradia, 2015). The Socorro-Guaxupé domain describes a steady magmatic differentiation along the thick-crustal arc (>30 km). Conversely, the São Roque Domain data show remarkable peak Sr/Y for < 2 wt.% MgO that can be explained by partial melting of a mafic crust, coherent with lower crustal foundering (or, alternatively, slab melting – Chiaradia, 2015 and references therein). The author suggested such geochemical trends are linked to juvenile felsic crust formed in the Archean, which strongly argues in favour of the participation of an old crust in the magmatism of the São Roque Domain.

Moreover, lower Sr/Y values of the São Roque Domain correspond mostly to the 610-590 Ma granitoids and some present higher MgO contents as well (Ragatky, 1998; Lamoso and Janasi, 2019). If we consider the participation of mafic melts as a result of lower crustal delamination, the MgO and Sr/Y values of these younger granitoids are consistent with thinning of the crust and thus prone to juvenile inputs that reflect their less radiogenic signatures (as discussed in Ragatky, 1998; Janasi et al., 2016).

High Sr/Y granitoids in thickened crust can be products of slab failure (Whalen and Hildebrand, 2019). We found that our São Roque Domain dataset as well as the compilation of pre- to -syn-collisional rocks of the Socorro-Guaxupé Nappe did not present coherent results with the proposed discrimination plots (not shown). Although the authors demonstrated the trace-elemental discriminations work well for rocks dating from the Archean to Miocene, there may be some unapproached limitations to the discriminations that should be further investigated. Moreover, our age and isotopic constraints do not fully match this scenario.

Although the São Roque Domain magmatism is subduction-related, its tectonic setting is unclear. High-K₂O magmatism can derive from phlogopite-bearing sources at great depths or a K-enriched lower crust exposed by delamination (e.g., Tatsumi and Eggins, 1995 and references

therein; Feldstein and Lange, 1999), which is more plausible in back-arc domains. Nonetheless, low-degree partial melting of “normal” mantle lithosphere in the Sierra Nevada Batholith was proven enough to produce high-K₂O compositions (e.g. Putirka and Busby, 2007), a similar case was also suggested for the Northern Marianas shoshonites (e.g., Stern, 1988). In addition, an experimental study on the interaction mantle-crust showed that continental sediment inputs in the mantle can generate high-K₂O melts at shallow mantle depths (Wang et al., 2017). Therefore, a delamination-associated late-orogenic setting is not necessary to explain such geochemical trends.

We hypothesize the subduction geometry shifted significantly to produce the *ca.* 35 m.y. magmatic gap in the São Roque Domain (Figure 5-6). The early magmatism during the initiation of subduction (Barro Branco orthogneiss, *ca.* 685 Ma) was probably located in the retroarc domain. Steepening of the subduction angle (slab retreat) is a possible explanation for the interruption of magmatic activity. Magmatism followed at *ca.* 635 Ma through relaxation of the subduction angle, overlapping the collisional phase in the neighbour domain (Rocha et al., 2017; Tedeschi et al., 2018; Frugis et al., 2018). The crustal isotopic signatures recorded in this period are possibly linked to fertilization of the mantle, caused by the last-longing subduction under the Paranapanema active margin (Frugis et al., 2018; Tedeschi et al., 2018). Subduction erosion was feeding material into the mantle, either trench sediments (e.g., Andrelândia schists) and/or forearc crust. As aforementioned, continent-derived additions to the mantle can generate high-K melts that may rise to the base of the crust and relaminate, hence the isotopic crustal component in the source. (e.g., Castro, 2014; Kelemen and Behn, 2016; Ewing et al., 2018).

Figure 5-6: Schematic tectonic model based on the proposed evolution for the São Roque Domain in a retro-arc setting regarding the convergence between the Paranapanema and São Francisco paleoplates. The model is divided into three main stages (a–c) anchored on the geochronological constraints here presented and studies from the surrounding tectonic domains.

Melting and mixing predictions of sedimentary sequences and arc magmas (check for instance Errázuriz-Henao et al., 2019) are beyond the scope of this research and in this case merely hypothetical. However, we use the method proposed by Plank (2005) to assess potential crustal contributions (see Figure 5-7), comparing Th/La of our dataset with the partially subducted trench sediments of the Socorro-Guaxupé Nappe (Andrelândia schists, Frugis et al., 2018) and metasedimentary rocks from the São Roque Domain (Henrique-Pinto et al., 2015a). The following discussion is merely speculative since we are dealing with old arc batholiths that probably do not preserve a straightforward correlation as demonstrated for modern arcs. Note that the Andrelândia schists record maximum depositional age at ~670 Ma (Frugis et al., 2018), therefore, their influence should only be considered for the post-Barro Branco magmatism. The Barro Branco plots in the range of the continental crust signature along with the Andrelândia

schists. The Moinho granodiorite and amphibolitic gneiss record the lowest Th/La of our dataset, closer to the compositions expected for the lower crust, whereas the inequigranular orthogneiss and biotite granites reach up to Th/La~0.3. Both sequences seem fit as crustal additions, although the average Th/La (0.35) of the São Roque Domain metasediments and metamudstones overlaps the upper crust (0.36) and is, therefore, coherent as a potential crustal contaminant for the more evolved granitoids. The Andrelândia schists present a significant spread of Sm/La overlapping values of the Socorro-Guaxupé domain and the lower continental crust that suggest higher degrees of melting of those sediments also might have contributed to the parental source. Another possibility is that recycling of a lower forearc crust was more efficient than melting of the subducting sediments, however, its composition is difficult to predict.

Figure 5-7: (A) Sm/La vs. Th/La plot from Plank (2005) and (B) La/Nb vs. Th/Nb plot. Both plots contain all samples from this study plus metasedimentary rocks from the Andrelândia nappe system (Frugis et al., 2018) and SRD (Henrique-Pinto et al., 2015a). Symbols as in Figure 4-6.

It is noteworthy that most of the Socorro-Guaxupé metatexites and diatexites present low Th/La values (<0.1). However, Th-depletion has been reported as a fluid-mediated process during granulite-facies metamorphism (Plank, 2005 and references therein). The apatite saturation temperatures (Harrison and Watson, 1984) of the Socorro-Guaxupé Nappe (830-1050 °C) and São Roque Domain (section 5.2) rocks are high and present a similar range implying the Th-depletion of the former was indeed caused by the high-grade metamorphism rather than distinct magmatic conditions.

The Socorro-Guaxupé Nappe recorded a high to ultra-high temperature metamorphism that lasted from 630 to 590 Ma. We call attention to the fact that although metamorphic rocks of such conditions are absent in the São Roque Domain, the metamorphic monazite of the biotite paragneiss presented in this study encompasses dates from ca. 630 Ma (two cores) to a Concordia age of ca. 600 Ma that support an ongoing thermal episode.

6. CONCLUSIONS

This research provides unprecedented data concerning the eastern São Roque Domain and proposes a tectonic model based on geochemical and chronological constraints. The widespread subduction-related high-K calc-alkaline magmatism and age correlations throughout the São Roque Domain and neighbour Socorro-Guaxupé Nappe support a joint tectonic evolution. The Barro Branco orthogneiss is a major folded I-type granitoid dated at *ca.* 685 Ma with a strong juvenile component. Associated granitoids formed at *ca.* 625 Ma and 620 Ma with crustal ϵ_{Nd} and ϵ_{Hf} signatures that indicate mixed sources. Geochemistry and isotope Nd-Hf suggest a common parental source derived from the lower crust, yielding high Sr/Y and La/Yb due to residual deep-seated assemblages (e.g., garnet $\pm$ clinopyroxene $\pm$ amphibole). Such conditions result in the typical absence of the negative Eu anomaly, ubiquitous in the granitoids of the São Roque Domain. The presence of mafic microgranular enclaves and high Sr/Y within a narrow range of MgO contents call for the participation of mafic magmatism.

Inherited zircon grains date from Paleoproterozoic to Archean ages. A metavolcaniclastic rock, however, presented a remarkable spread of ages with a significant cluster around 700 Ma and a small group of 800-900 Ma, reported for the first time in this domain. Provenance of detrital zircon in metasedimentary rocks yielded a Rhyacian peak at *ca.* 2.17 Ga (predominantly juvenile) that is consistent with observed patterns in metasandstones of the central São Roque Domain and southern region of the Socorro-Guaxupé, thus, linking their evolution. Monazite U-Pb reported a metamorphic episode at *ca.* 600 Ma, that might have initiated at approximately 630 Ma, concomitant with the 630-590 Ma metamorphism in the Socorro-Guaxupé Nappe.

We propose the Barro Branco orthogneiss records an early magmatism in the retroarc domain during the initiation of subduction beneath the Paranapanema active margin. Magmatism in the São Roque Domain potentially derived from a *ca.* 2.1 Ga juvenile crust that lies within the basement of the Socorro-Guaxupé Nappe. Slab retreat caused the magmatism to migrate northwards resulting in a $\sim$ 35 m.y. magmatic shut-down in the retroarc domain. Magmatism followed with flattening of the subduction angle (Barro Branco II and Moinho granodiorite). This period relates to the continental collision between the Paranapanema and São Francisco paleoplates. The last-longing subduction enabled crustal additions to the source leaving evolved isotopic imprints. We interpret the crustal signatures as result of relaminated forearc or trench material at the base of the crust and, in part, contamination during emplacement from the overlaying metasedimentary sequence.

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APPENDIX

I. Sample coordinates

Table 1: Sample UTM coordinates.

Outcrop	UTM Coordinates		Rock description	Unit	Analytical methods	Structural features	
	Long.	Lat.				Foliation (S _x)	Lineation (L _x)
BB-01	367632	7438428	Porphyritic-porphyroclastic biotite granite-gneiss	Barro Branco orthogneiss	Thin section		
BB-02	366214	7438579	Porphyritic-porphyroclastic, grey biotite granite-gneiss	Barro Branco orthogneiss	Thin section	307/85	
BB-03	365687	7438690	Pink-to-grey biotite granite-gneiss	Barro Branco orthogneiss	Thin section	342/20, 355/40, 335/45	
BB-04	364952	7438847	Grey biotite granite-granodiorite gneiss	Barro Branco orthogneiss	Thin section; LA-ICP-MS (U-Pb, Lu-Hf); XRF; ICP-MS	123/30	
BB-05	365480	7439271	Granoblastic biotite-quartz schist	Metasedimentary unit		355/50, 128/25	Str: 065/18, ml: 050/35
BB-06	366557	7440090	Dark grey muscovite-biotite-quartz schist	Metasedimentary unit	Thin section; LA-ICP-MS (U-Pb, Lu-Hf)	130/15, 110/12, 140/85	ml: 050/13
BB-07	366940	7440625	Grey, foliated biotite granite	Barro Branco II	Thin section		
BB-08	367485	7441110	Leucocratic, foliated biotite granite	Metasedimentary unit		125/55	Str: 035/20
BB-09	368498	7436272	Grey biotite granite-granodiorite	Barro Branco II	Thin section; LA-ICP-MS (U-Pb, Lu-Hf); XRF	104/40	
BB-10	378832	7434698	Porphyroblastic quartz-rich metassiltite	Metasedimentary unit II		095/80, 104/75	Int: 193/12, cr: 042/70, 028/60
BB-11	378933	7434971	Porphyroblastic mica schist	Metasedimentary unit II		295/80	
BB-12	379741	7436430	Muscovite-quartzite	Metasedimentary unit II		093/25, 095/15	
BB-13	380228	7437096	Mica schist with quartzitic/calc-silicate veins	Metasedimentary unit II		134/40, 290/10, 340/12	
BB-14	380932	7438067	Muscovite-quartzite with amphibolite	Metasedimentary unit II		325/15, 165/15, 140/35, 202/30	
BB-15	381088	7438343	Amphibolite	Metasedimentary unit II			
BB-16	379591	7440216	Tourmaline-monzogranite	Ediacaran biotite granite		320/70	
BB-17	379439	7440990	Foliated biotite granite	Ediacaran biotite granite	Thin section; XRF; ICP-MS		
BB-18	379329	7441152	Fine-grained mylonitic biotite gneiss	Ediacaran biotite granite		108/65	
BB-19	379475	7436798	Porphyroblastic muscovite quartzite	Metasedimentary unit		300/80, 123/60	007/55, 010/45
BB-20	381056	7438225	Muscovite-quartz metawacke	Metasedimentary unit	LA-ICP-MS (U-Pb)	136/60, 112/45, 110/50, 132/70	L1: 120/50, L2: 050/10, L3: 090/65
BB-21	379072	7441892	Muscovite-quartz metawacke	Metasedimentary unit	LA-ICP-MS (U-Pb)	090/45, 084/53, cl: 345/80, cl: 318/75, ap: 326/75	Int: 080/50, L2: 040/40, b: 073/50
BB-22	378820	7441562	Quartz-mica schist	Metasedimentary unit		072/47, 052/65	Int: 030/65, 045/45
BB-23	378550	7441831	Greenish mica schist with granitic veins	Metasedimentary unit			
BB-24	377444	7442549	Biotite granite gneiss	Barro Branco II	Thin section; XRF; ICP-MS	078/40	
BB-25	377056	7442594	Muscovite quartzite with granitic layers	Metasedimentary unit		285/45, 310/40	Int: 290/40
BB-26	375393	7444497	Foliated biotite granite	Ediacaran biotite granite		158/20	

BB-27	372246	7445320	Foliated biotite granite	Ediacaran biotite granite			
BB-28	371949	7445307	Fine-grained biotite granite gneiss	Ediacaran biotite granite	Thin section; XRF; ICP-MS		
BB-29	370502	7445371	Ultramylonitic gneiss	Jundiuvira shear zone		140/90, 134/87	Int: 045/05, 048/15
BB-30	371249	7444581	Biotite granite gneiss	Barro Branco orthogneiss			
BB-31	371202	7444362	Biotite gneiss	Barro Branco orthogneiss	Thin section; XRF; ICP-MS (Sm-Nd)	146/40	
BB-32	367105	7434458	Quartzitic mica schist	Metasedimentary unit		335/80, 188/30, 090/02, 048/30, 240/85	b: 320/05
BB-33	367786	7434290	Biotite gneiss	Barro Branco II			
BB-34	367963	7434446	Biotite granite gneiss	Barro Branco II			
BB-35	368958	7434959	Protomylonitic biotite gneiss	Barro Branco orthogneiss			
BB-36	369369	7434503	Mylonitic biotite gneiss	Ediacaran biotite granite			
BB-37	369716	7434387	(Hornblende)-biotite gneiss	Ediacaran biotite granite	Thin section; XRF; ICP-MS		
BB-38	370239	7434779	Fine-grained porphyroblastic gneiss/schist	Igaratá gneiss		156/62, 138/33, 116/55	Str: 210/03
BB-39	370283	7436528	Amphibolite	Metasedimentary unit		cl:110/85, 330/40	Int: 025/23
BB-40	364506	7438718	Quartzitic mica schist	Metasedimentary unit		098/35, 116/40, 350/55, cl:147/85	Str: 027/20, 026/15, Int: 055/20
BB-41	364985	7438867	Biotite gneiss	Barro Branco orthogneiss	Thin section; XRF; ICP-MS		
BB-42	368334	7441930	Grey biotite gneiss	Barro Branco orthogneiss	Thin section; XRF; ICP-MS		
BB-43	368728	7442464	Fine-grained biotite gneiss	Barro Branco orthogneiss	Thin section; XRF; ICP-MS		
BB-44	363772	7434814	Foliated biotite monzogranite	Moinho granodiorite	Thin section; XRF; ICP-MS (Sm-Nd)	090/60, 102/60	
BB-45	364102	7434537	Foliated biotite monzogranite	Moinho granodiorite		140/60, 124/50	
BB-46	364304	7434543	Muscovite quartzite with calc-silicate quartzite	Metasedimentary unit		130/23, 085/25, 108/35, 115/17	Str: 054/10, Int: 050/15
BB-47	366664	7435751	Foliated biotite granite	Moinho granodiorite	Thin section; XRF; ICP-MS		
BB-48	366178	7435695	Foliated biotite granite	Moinho granodiorite	Thin section; XRF; ICP-MS		
BB-49	365969	7435749	Foliated biotite monzogranite	Moinho granodiorite	Thin section; XRF; ICP-MS	147/70, 108/75	M: 192/02
BB-50	365832	7435858	Foliated biotite monzogranite	Moinho granodiorite	Thin section; XRF; ICP-MS		
IGT-03	376630	7435898	Grey foliated biotite granite	Barro Branco II	Thin section; XRF; ICP-MS	085/40, 085/50	085/40
IGT-04	372290	7436981	Fine-grained biotite gneisses interlayered with granite lenses and hbl-bt gneiss	Metasedimentary unit	Thin section; LA-ICP-MS (U-Pb); XRF; ICP-MS (Sm-Nd)		

cl: cleavage, ap: axial plane, str: stretching lineation, int: intersection lineation, ml: mullion, b: fold axis, cr: crenulation, m: mineral lineation

II. Modal analyses of representative samples

Table 2: 2000-point modal analyses of representative samples.

	Barro Branco					Inequigranular			Moinho		
Sample	BB-04A	BB-04C	BB-31C	BB-41D	BB-42B	BB-09II	BB-43I	IGT-03	BB-31A ¹	BB-44A	BB-47
Quartz	24.90	30.85	32.63	39.70	39.49	26.70	26.98	38.74	51.80	29.99	21.96
Plagioclase	28.45	25.95	32.00	29.70	27.56	29.04	33.22	31.03	19.31	40.92	35.48
Microcline	22.20	19.55	11.52	3.70	24.44	33.38	20.41	17.70	11.80	8.86	19.24
Orthoclase	3.75	0.20	-	0.30	-	-	0.25	0.10	-	-	-
Biotite	15.50	19.50	20.06	22.00	6.98	7.98	14.84	8.16	12.30	15.59	19.87
Titanite	1.00	0.65	0.30	1.20	0.15	-	-	0.20	-	0.84	0.39
Epidote	0.90	0.60	0.54	0.20	0.05	0.35	-	0.25	0.05	1.58	0.92
Magnetite	1.55	1.40	0.05	1.90	0.35	1.05	0.74	0.70	0.30	0.54	0.73
Apatite	0.85	0.55	1.33	1.00	0.15	0.25	1.08	0.20	0.55	0.89	0.63
Allanite	0.20	0.10	0.25	0.10	0.05	-	-	-	-	0.25	0.10
Hornblende	0.10	-	-	-	-	-	-	-	-	0.45	0.39
Carbonate	-	0.05	-	-	-	-	-	1.74	-	-	-
Chlorite	0.05	0.05	-	0.10	-	-	-	0.40	-	-	0.05
Muscovite	-	-	1.13	-	0.79	0.80	2.03	0.80	3.75	-	-
Sericite	0.30	0.50	0.15	-	-	0.35	0.34	-	0.15	-	-
Zircon	0.25	0.05	0.05	0.10	-	0.05	0.10	-	-	0.10	0.24
Monazite	-	-	-	-	-	0.05	-	-	-	-	-
Q	31.40	40.30	42.85	54.09	43.16	29.96	33.36	44.24	62.48	37.59	28.63
P	35.88	33.90	42.03	40.46	30.12	32.59	41.09	35.43	23.29	51.30	46.27
A	32.72	25.80	15.13	5.45	26.72	37.46	25.55	20.33	14.23	11.10	25.09

¹Quartz-rich facies

III. Whole-rock and trace-elemental characterization

Barro Branco orthogneiss

The Barro Branco orthogneiss presents the most scattered dataset tracing a negative correlation of SiO₂ versus TiO₂ (0.7-1.3%), Fe₂O₃(t) (3.4-5.3%), MgO (1.3-1.6%), Al₂O₃ (15.0-20.9%), CaO (2.6-3.8%), Na₂O (3.4-5.4%) and P₂O₅ (0.3-1%), and a positive trend for K₂O (3.8-5.3%) and higher K₂O/Na₂O (0.9-1.5) toward more evolved compositions. The unit varies from more primitive to moderately evolved samples (57-68% SiO₂). The #mg values range 37-42.

The chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns are predominantly moderate where (La/Lu)_N vary within 23-51, apparently independent of SiO₂, and negative Eu anomalies are nearly absent (0.87-1.02). LREE fractionation is usually stronger [(La/Eu)_N=4-7], compared to HREE [(Gd/Lu)_N= 2-8]. Sr/Y mainly range (41-85), and shows coupled behaviour with high Sr (809-1079 ppm) and Ba (1513-2054 ppm), that result in high Ba/Sr (1.7-2.1) and variably low Y (12-20 ppm).

Moinho granodiorite

The Moinho orthogneiss has a narrow range of more primitive compositions (59-65% SiO₂) and clusters among the highest Fe₂O₃(t) (3.9-5.3%), MgO (1.4-1.8%) and CaO (3.2-3.5%) contents overlapping the primitive Barro Branco samples. As opposed to the Barro Branco, K₂O and SiO₂ are negatively correlated. However, they do not compose a continuous spectrum, the lower contents cluster around 3.5-4.3% K₂O in the “evolved” members (63-65% SiO₂). The #mg values are restricted to 39-42.

Chondrite-normalized (McDonough and Sun, 1995) REE yield moderate to low fractionated patterns [(La/Lu)_N=10-42], lacking negative Eu anomalies (Eu/Eu* = 0.89-1.02). (La/Eu)_N vary 1.9-7.4 reflecting the depletion in LREE compared to the other granitoids. There is a remarkable enrichment in Ba (1424-2210 ppm) and Sr (858-1032 ppm) and depletion in Zr (190-295 ppm) and Rb (111-162 ppm). Y (15-18 ppm) is close to the Barro Branco abundances and Sr/Y ratios vary 49-66. The Moinho samples from Ragatky (1998) display a negative Tm anomaly that does not appear in our dataset.

Inequigranular orthogneiss

The non-porphyritic inequigranular biotite gneiss is roughly more peraluminous (ASI=1.01-1.17) and more evolved (66-70 wt% SiO₂), presenting high K₂O/Na₂O (1.2-1.7).

The granitoid displays the lowest TiO_2 (0.5-1.1%), $\text{Fe}_2\text{O}_3(\text{t})$ (2.1-4.3%), MgO (0.4-1.2%), CaO (1.5-2.2%) and P_2O_5 (0.2-0.3%) concentrations as opposed to the higher K_2O (5-5.2%). The mg# range encompasses lower values (25-38).

Chondrite-normalized (McDonough and Sun, 1995) REE contents are highly fractionated with $(\text{La/Lu})\text{N}$ from 59 to 160. Eu anomalies are slightly negative ($\text{Eu/Eu}^*=0.67-0.92$) indicating that fractionation may have occurred in the presence of plagioclase. LREE fractionation is remarkably high $[(\text{La/Eu})\text{N}=13-14]$ and HREE fractionation is slightly stronger $[(\text{Gd/Lu})\text{N}=4-9]$ than the Barro Branco.

Ba (1268-1917 ppm) and Sr (456-929 ppm) contents are high. Sr/Y ratios present moderate to extreme values (33-121) due to a wider variation of Y (4-14 ppm). Moreover, the inequigranular orthogneiss strongly relates to the most evolved and peraluminous Barro Branco samples. There are some exceptional values such as high Zr (665 ppm) and low Nb (4 ppm) associated to the biotite granites and detached from the entire dataset (described below).

Biotite granites

The biotite granites are more evolved (67-70 wt.% SiO_2) and overall present a similar geochemistry to the inequigranular orthogneiss and some peraluminous Barro Branco samples. They have high K_2O (4.2-5.6%) and low CaO (1.2-2.3%), MgO (0.6-1.1%), $\text{Fe}_2\text{O}_3(\text{t})$ (2.3-4%), Na_2O (3.2-3.7%) and TiO_2 (0.5-0.9%). They classify as alkali-calcic with peraluminous character. The granites also comprise low Nb (4-18 ppm), V (21-38 ppm) and Y (4-17 ppm) whereas higher Ba (1133-1729 ppm) and Sr (472-994 ppm) with a wide range of Sr/Y (29-224).

Chondrite-normalized (McDonough and Sun, 1995) REE fractionation patterns are moderate to strong $[(\text{La/Lu})\text{N}=15-189]$ with LREE enrichment $[(\text{La/Eu})\text{N}=4-16]$ and nearly-flat HREE $[(\text{Gd/Lu})\text{N}=3-7]$. Negative Eu anomalies are weak to absent ($\text{Eu/Eu}^*=0.73-1$).

Metavolcaniclastic rock

The metavolcanic biotite gneiss has a much more evolved composition (75% SiO_2) and describes the lowest TiO_2 (0.3%), Al_2O_3 (13%), Fe_2O_3 (1.9%), MgO (0.4%), K_2O (2.9%) and P_2O_5 (0.1%) contents. This pattern is observed for major elements that describe an almost-perfect linear spectrum in the dataset. It is the only calcic and calc-alkaline sample and plots in the peraluminous field. The mg# is among the lowest values, 30. The rock has relatively high Y (19 ppm) yielding low Sr/Y (19), low Ba (714 ppm) and reaches higher Nb (15 ppm). It has a rhyolitic composition, according to the TAS diagram (Middlemost, 1994).

The metavolcaniclastic rock exhibits a slightly different REE pattern. Chondrite-normalized values (McDonough and Sun, 1995) present a moderate REE fractionation [(La/Lu) $N=40$]. However, there is a significant enrichment in LREE [(La/Eu) $N=14$] and more pronounced negative Eu anomaly (Eu/Eu $^*=0.64$), similar to the inequigranular orthogneiss and biotite granites. HREE fractionation is nearly-flat [(Gd/Lu) $N=3$] mostly resembling the Barro Branco and Moinho patterns.

(Hornblende)-biotite gneiss

Sample IGT-04H has the most primitive composition with 56.5% SiO₂, lowest Na₂O (2.72%) and highest occurrences of TiO₂ (1.8%), Fe₂O₃ (8.9%), MgO (3.3%) and CaO (5.5%) of the dataset. It has the strongest metaluminous character (A/CNK=0.85) and classifies as high-K calc-alkaline due to K₂O=3.2%. The P₂O₅ abundance is among the highest (0.9%) alongside a primitive Barro Branco sample. Despite the distinctively high concentrations of Fe₂O₃ and MgO, the mg# lies within the general range (42). HFSE, V and Y contents are also higher (V=123 ppm; Y=26 ppm; Nb=36 pp; Zr=487 ppm). The rock has an andesitic-trachyandesitic composition, according to the TAS diagram (Middlemost, 1994).

Chondrite-normalized (McDonough and Sun, 1995) REE fractionation pattern is a nearly linear trend, similar to the discrete Moinho slopes, with (La/Yb) $N=49$. Although it is as LREE-enriched as the inequigranular orthogneiss and biotite granites, the fractionation pattern is more discrete [(La/Eu) $N=8$] and the negative Eu anomaly (Eu/Eu $^*=0.88$) is nearly absent. Although HREE fractionation is nearly-flat, we note the rock is more enriched in MREE, probably due to the abundant occurrence of hornblende.

Biotite paragneiss

Sample IGT-04D has a 68 wt.% SiO₂ and the major oxide distribution mostly accompanies the trend of the granitoids and the metavolcaniclastic rock with only exceptions to lower Na₂O (2.4%) and P₂O₅ (0.08%) and slightly lower CaO (0.8%). Since ASI (~1.17) describes a peraluminous affinity, the rock often clusters around the most evolved and peraluminous granitoids whereas the mg# is as high as for the primitive ones (40). It is also characterized by remarkably high Rb (279 ppm) and low Sr/Y (~11) due to low Sr (246 ppm).

Chondrite-normalized (McDonough and Sun, 1995; Figure 8) REE contents yield a weakly fractionated pattern with relatively strong LREE fractionation [(La/Eu) $N=7.5$], discrete negative Eu anomaly (Eu/Eu $^*=0.71$) and concave-upward HREE fractionation [(Gd/Lu) $N=1.8$], more enriched in Yb and Lu.

IV. Whole-rock and trace-element analyses

Table 3: Whole-rock major and trace-element data (XRF and ICP-MS) of all sampled rocks.

	Barro Branco							Barro Branco II			
	Porphyroblastic bt orthogneiss							Inequigranular bt orthogneiss			
	BB-04B	BB-04C	BB-04E	BB-31C	BB-41A	BB-41B	BB-41D	BB-09	BB-24	IGT-03	BB-43
SiO ₂	64.16	62.18	57.43	67.57	63.31	64.1	61.49	69.76	65.8	68.09	69.18
TiO ₂	0.992	1.093	0.775	0.71	1.061	1.059	1.303	0.512	1.056	0.65	0.578
Al ₂ O ₃	16.06	16.85	20.93	14.98	16.36	16.01	16.59	14.83	15.72	15.56	15.31
Fe ₂ O ₃	4.45	4.95	4.15	3.4	4.48	4.53	5.32	2.13	4.3	2.76	2.79
MnO	0.06	0.076	0.062	0.06	0.065	0.065	0.069	0.027	0.039	0.033	0.043
MgO	1.44	1.5	1.25	1.28	1.51	1.53	1.64	0.35	1.17	0.85	0.76
CaO	3.07	2.97	3.12	2.6	3.19	3.17	3.8	1.45	2.15	2.23	1.47
Na ₂ O	3.76	4.28	5.37	3.35	3.48	3.49	4.04	4.13	3.53	3.34	3.11
K ₂ O	4.68	4.29	5.32	4.36	5.23	4.68	3.79	5.01	5.15	5.51	5.17
P ₂ O ₅	0.425	0.384	0.99	0.31	0.438	0.445	0.588	0.152	0.341	0.271	0.231
LOI	0.48	0.56	0.46	0.62	0.49	0.5	0.49	0.26	0.76	0.55	0.81
Total	99.577	99.133	99.857	99.24	99.614	99.579	99.12	98.611	100.016	99.844	99.452
Co	9	10	8	7	9	8	9	b.d.l.	6	b.d.l.	6
Cr	13	27	116	17	13	14	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Cu	8	17	b.d.l.	6	11	11	14	6	6	b.d.l.	5
Ga	22	26	29	23	23	24	24	24	26	21	24
Ni	6	9	34	b.d.l.	6	5	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Sc	b.d.l.	b.d.l.	b.d.l.	b.d.l.	15	15	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
V	76	87	80	54	69	76	86	29	47	44	41
Zn	84	106	94	68	87	88	100	62	96	68	60
F	2167	3425	2509	1926	2661	2585	2430	1689	3216	1389	1196
S	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Rb			224.42	164.00	190.00	178.00	172.00		234.00	139.00	199.00
Sr			1031.87	809.00	943.00	876.00	1079.00		474.00	929.00	456.00
Y			12.10	18.00	16.30	17.50	15.70		10.00	8.09	13.80
Zr			240.70	287.00	338.00	336.00	359.00		665.00	277.00	331.00
Nb			15.74	16.50	19.10	19.60	21.60		17.60	4.11	11.50
Cs			6.84	8.66	7.11	6.96	6.82		1.07	2.38	4.48
Ba			2053.87	1513.00	2023.00	1703.00	1835.00		1747.00	1917.00	1268.00
La			65.99	50.10	74.10	59.00	45.80		123.00	106.00	79.80
Ce			136.01	97.50	150.00	127.00	100.00		334.00	200.00	155.00
Pr			15.78	11.70	15.40	13.30	11.20		27.90	19.50	14.90
Nd			54.33	41.50	65.90	58.40	51.60		84.60	75.00	58.70
Sm			9.43	6.90	10.30	9.99	9.46		12.50	9.04	8.23
Eu			2.31	1.76	2.45	2.38	2.65		2.08	1.94	1.40
Gd			5.46	4.59	6.93	6.92	6.63		5.63	4.51	4.89
Tb			0.70	0.65	0.76	0.79	0.74		0.63	0.41	0.50
Dy			3.13	3.31	3.50	3.59	3.22		2.47	1.73	2.37
Ho			0.51	0.62	0.59	0.61	0.49		0.34	0.26	0.40
Er			1.13	1.68	1.39	1.49	1.08		0.86	0.68	1.09
Tm			0.16	0.24	0.18	0.19	0.13		0.09	0.08	0.15
Yb			1.06	1.60	1.05	1.16	0.72		0.54	0.46	0.95
Lu			0.17	0.22	0.15	0.17	0.10		0.08	0.07	0.14
Hf			7.13	6.45	7.30	7.09	7.53		13.10	5.95	7.22
Pb			41.85	29.00	29.90	28.20	24.70		20.30	30.50	42.20
Th			20.26	16.40	16.10	15.50	12.30		34.30	16.40	23.80
U			4.00	6.30	2.78	2.92	2.36		1.39	0.55	6.00

*b.d.l. = below detection limit

Table 3 (cont.)

	Moinho						Fine bt gneiss	Bt para- gneiss	Hbl-bt gneiss	Bt granites			Qtz-rich granitoid
	(Hbl)-bt orthogneiss												
	BB-44A	BB-44B	BB-44C	BB-47	BB-48	BB-50	IGT-04C	IGT-04D	IGT-04H	BB-17	BB-28	BB-37	BB-31A
SiO ₂	64.51	64.8	58.57	63.39	59.41	63.25	75.07	68.44	56.5	66.94	69.96	69.69	85.9
TiO ₂	0.644	0.692	0.633	0.76	0.751	0.7	0.285	0.53	1.802	0.874	0.51	0.495	0.278
Al ₂ O ₃	15.71	16.41	19.06	16.37	18.24	16.16	13.02	14.11	15.29	15.62	15.18	14.71	7.06
Fe ₂ O ₃	4.52	4.53	3.93	5.21	5.33	4.73	1.85	5.1	8.88	4.04	2.47	2.33	1.86
MnO	0.073	0.07	0.068	0.075	0.047	0.073	0.056	0.074	0.136	0.039	0.022	0.048	0.016
MgO	1.51	1.49	1.43	1.73	1.81	1.53	0.4	1.71	3.28	1.05	0.6	1.02	0.6
CaO	3.17	3.35	3.52	3.42	3.36	3.3	1.77	0.8	5.53	2.28	1.17	2.01	1.1
Na ₂ O	3.92	3.97	4.26	3.89	4.09	3.75	3.61	2.43	2.72	3.55	3.19	3.73	1.84
K ₂ O	3.99	3.99	6.3	3.49	4.98	4.25	2.86	6.2	3.21	5.26	5.61	4.17	0.94
P ₂ O ₅	0.326	0.338	0.738	0.396	0.545	0.346	0.117	0.081	0.911	0.287	0.152	0.22	0.07
LOI	0.46	0.6	0.54	0.55	0.55	0.43	0.95	0.61	0.68	0.52	0.58	0.74	0.46
Total	98.833	100.24	99.049	99.281	99.113	98.519	99.988	100.085	98.939	100.46	99.444	99.163	100.124
Co	7	8	6	9	11	8	b.d.l.	11	26	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Cr	b.d.l.	15	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	83	41	b.d.l.	b.d.l.	b.d.l.	47
Cu	9	12	6	12	12	7	b.d.l.	7	42	5	b.d.l.	8	b.d.l.
Ga	22	22	22	23	23	22	17	19	22	19	22	21	11
Ni	b.d.l.	7	b.d.l.		6	b.d.l.	b.d.l.	39	21	b.d.l.	b.d.l.	b.d.l.	8
Sc	b.d.l.	b.d.l.	13	15	b.d.l.	b.d.l.	b.d.l.	b.d.l.	18	b.d.l.	b.d.l.	b.d.l.	b.d.l.
V	57	54	47	72	67	63	15	57	123	21	23	38	22
Zn	71	75	69	83	92	76	34	87	197	70	57	55	31
F	988	922	912	1090	1045	942	946	2383	3315	2121	1405	838	906
S	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	b.d.l.	1230	b.d.l.	b.d.l.	b.d.l.	b.d.l.
Rb	113.00	124.00	162.00	111.00	156.00	116.00	122.12	278.63	161.00	222.00	195.00	132.00	61.10
Sr	934.00	858.00	1032.00	1006.00	861.00	946.00	360.79	245.83	736.00	472.00	994.00	665.00	253.00
Y	15.00	15.70	15.60	17.20	17.50	16.90	18.88	21.11	25.80	16.50	4.44	9.68	8.84
Zr	249.00	250.00	221.00	295.00	190.00	260.00	210.15	224.02	487.00	641.00	304.00	195.00	262.00
Nb	14.80	15.80	14.40	16.70	22.10	15.50	18.30	14.70	35.70	17.70	3.98	11.00	5.27
Cs	2.47	4.18	4.26	3.68	5.56	2.61	4.29	16.01	12.30	1.25	1.15	5.22	2.04
Ba	1668.00	1424.00	2210.00	1652.00	1664.00	1861.00	780.76	766.20	1308.00	1606.00	1729.00	1133.00	162.00
La	51.10	46.50	14.20	65.20	23.80	45.90	77.87	37.03	110.00	89.10	73.00	19.00	32.00
Ce	98.90	89.80	32.90	121.00	47.40	99.70	145.38	74.38	219.00	216.00	163.00	46.40	61.20
Pr	10.30	10.80	5.19	12.90	7.06	10.60	16.35	8.88	24.20	18.00	13.50	5.58	7.54
Nd	43.60	39.00	23.50	53.80	30.20	42.80	52.21	31.37	92.20	69.70	48.60	20.90	26.50
Sm	7.02	6.37	5.71	8.47	6.61	7.22	8.64	5.88	14.30	10.10	5.26	3.98	4.59
Eu	1.80	1.73	1.79	2.10	2.17	1.93	1.36	1.18	3.33	1.88	1.08	1.08	0.88
Gd	5.10	4.57	5.05	6.05	6.36	5.17	4.87	4.37	9.21	6.03	2.34	2.70	3.20
Tb	0.60	0.55	0.67	0.68	0.84	0.67	0.69	0.64	1.09	0.67	0.20	0.37	0.41
Dy	2.90	2.70	3.11	3.26	3.63	3.29	3.60	3.46	5.03	2.97	0.85	1.82	1.84
Ho	0.53	0.47	0.54	0.57	0.58	0.59	0.63	0.68	0.87	0.49	0.14	0.33	0.31
Er	1.33	1.20	1.25	1.44	1.23	1.52	1.66	1.88	2.07	1.19	0.41	0.86	0.70
Tm	0.18	0.15	0.16	0.18	0.14	0.20	0.23	0.28	0.25	0.14	0.05	0.13	0.08
Yb	1.09	0.93	0.90	1.10	0.74	1.26	1.45	1.90	1.53	0.79	0.27	0.85	0.52
Lu	0.16	0.14	0.14	0.16	0.11	0.18	0.20	0.30	0.22	0.11	0.04	0.13	0.09
Hf	5.50	5.41	4.70	6.09	3.95	5.54	6.12	6.29	10.60	12.60	6.77	4.58	6.28
Pb	22.50	22.80	28.80	19.20	29.70	21.40	22.87	32.98	8.09	23.10	29.80	30.50	12.00
Th	9.83	9.53	2.49	10.30	3.06	10.60	19.31	12.26	10.70	28.80	20.70	9.11	10.90
U	1.46	1.78	1.78	1.38	0.65	0.99	3.91	2.90	1.67	1.26	1.12	2.86	1.04

V. CL (zircon) and BSE (monazite) images

SAMPLE BB-04C

SAMPLE BB-09

SAMPLE IGT-04C

SAMPLE BB-06C

SAMPLE IGT-04D ZIRCON

SAMPLE IGT-04D MONAZITE

VI. LA-ICPMS U-Pb data

Table 4: Results of LA-ICPMS U-Pb analyses in zircon and monazite.

Spot	Pb (com.) %	Pb rad ppm	Th ppm	U ppm	Th/U	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁶ Pb/ ²³⁸ U Age (Ma)	1σ	²⁰⁷ Pb/ ²⁰⁶ Pb Age (Ma)	1σ	conc (%)
<i>Barro Branco orthogneiss (Zircon - BB-04C)</i>																	
Concordia Age: 684.5 ±9.6 Ma																	
1.1	0.62	38	273	229	1.19	0.7855	0.0587	0.0975	0.0017	0.73	0.0584	0.0047	0.600	0.010	0.545	0.165	109
2.1	27.91	15	26	89	0.29	0.9199	0.0828	0.1131	0.0023	0.79	0.0590	0.0058	0.691	0.013	0.567	0.207	121
3.1	1.88	16	92	108	0.85	0.8532	0.0864	0.0974	0.0023	0.54	0.0636	0.0071	0.599	0.013	0.727	0.238	82
4.1	4.31	47	238	263	0.90	0.9767	0.0487	0.1155	0.0015	0.92	0.0613	0.0031	0.705	0.009	0.651	0.108	108
5.1	1.32	38	330	181	1.83	0.7140	0.0737	0.0823	0.0020	0.91	0.0629	0.0058	0.510	0.012	0.705	0.202	72
6.1	1.75	32	69	216	0.32	0.9473	0.0707	0.1124	0.0020	0.20	0.0611	0.0051	0.687	0.012	0.644	0.187	106
7.1	1.96	24	125	151	0.83	0.8382	0.0807	0.1010	0.0021	0.52	0.0602	0.0065	0.620	0.013	0.610	0.214	101
8.1	0.56	20	170	105	1.62	1.0050	0.0845	0.1209	0.0024	0.24	0.0603	0.0059	0.736	0.014	0.614	0.217	119
9.1	0.47	32	142	193	0.74	0.9075	0.0596	0.1092	0.0018	0.74	0.0603	0.0043	0.668	0.010	0.614	0.159	108
10.1	0.18	44	532	195	2.73	0.9455	0.0621	0.1114	0.0019	0.50	0.0616	0.0042	0.681	0.011	0.659	0.157	103
11.1	0.20	96	1014	513	1.98	0.9337	0.0497	0.1113	0.0025	0.91	0.0609	0.0041	0.680	0.015	0.634	0.137	107
12.1	10.66	19	189	94	2.01	1.0150	0.0738	0.1151	0.0038	0.22	0.0640	0.0060	0.702	0.022	0.741	0.204	94
13.1	3.10	28	163	173	0.94	0.9256	0.0446	0.1139	0.0024	0.60	0.0589	0.0034	0.695	0.014	0.565	0.118	123
14.1	0.38	115	50	234	0.22	5.9135	0.1451	0.3387	0.0048	0.92	0.1266	0.0036	1.881	0.023	2.051	0.050	91
15.1	0.38	48	433	228	1.90	0.9130	0.0491	0.1138	0.0025	0.21	0.0582	0.0040	0.695	0.014	0.537	0.125	129
16.1	0.56	33	242	160	1.51	0.8825	0.0476	0.1053	0.0025	0.26	0.0608	0.0041	0.645	0.015	0.633	0.138	101
17.1	0.48	11	27	84	0.32	0.8611	0.0528	0.1038	0.0028	0.30	0.0602	0.0045	0.637	0.016	0.609	0.177	104
18.1	0.50	20	116	121	0.97	1.0018	0.0779	0.1141	0.0041	0.07	0.0637	0.0058	0.697	0.023	0.730	0.184	95
19.1	0.13	78	86	125	0.69	8.4262	0.2324	0.4505	0.0075	0.96	0.1356	0.0043	2.398	0.033	2.172	0.055	110
20.1	0.54	18	124	111	1.11	0.9654	0.0523	0.1059	0.0027	0.33	0.0661	0.0044	0.649	0.016	0.811	0.152	80
21.1	0.44	32	239	164	1.46	0.9634	0.0871	0.1108	0.0043	0.08	0.0631	0.0080	0.678	0.025	0.710	0.229	95
22.1	1.08	24	97	139	0.70	0.9838	0.0652	0.1110	0.0033	0.86	0.0643	0.0057	0.678	0.019	0.752	0.180	90
23.1	0.66	25	100	157	0.64	0.9722	0.0410	0.1082	0.0022	0.38	0.0651	0.0032	0.662	0.013	0.779	0.111	85
<i>Inequigranular granitoid (Zircon - BB-09)</i>																	
Concordia Age: 624 ±11 Ma																	
1.1	0.09	68	55	74	0.75	16.3104	0.3072	0.5597	0.0057	0.29	0.2114	0.0037	2.865	0.023	2.916	0.028	98
2.1	0.16	62	84	442	0.19	0.9199	0.0271	0.1128	0.0016	0.87	0.0591	0.0018	0.689	0.009	0.572	0.069	120
3.1	0.93	7	23	46	0.51	0.7987	0.0628	0.1005	0.0036	0.49	0.0576	0.0055	0.617	0.021	0.516	0.210	119
4.1	0.80	9	44	55	0.80	0.8742	0.0559	0.0982	0.0031	0.01	0.0646	0.0051	0.604	0.018	0.761	0.178	79
5.1	0.13	99	67	171	0.39	7.2821	0.1315	0.3913	0.0037	0.01	0.1350	0.0023	2.129	0.017	2.164	0.030	98
6.1	2.04	11	53	72	0.73	0.8258	0.0362	0.0983	0.0020	0.59	0.0610	0.0032	0.604	0.012	0.638	0.114	94
7.1	1.36	5	26	29	0.90	0.7757	0.0989	0.1056	0.0057	0.64	0.0533	0.0093	0.647	0.034	0.340	0.284	190
8.1	1.66	5	45	25	1.81	0.7865	0.0810	0.0972	0.0046	0.54	0.0587	0.0076	0.598	0.027	0.555	0.273	107
9.1	0.24	132	110	221	0.50	7.6976	0.1410	0.4147	0.0042	0.97	0.1346	0.0024	2.236	0.019	2.159	0.031	103
10.1	5.88	11	138	61	2.28	0.8241	0.0577	0.1036	0.0033	0.52	0.0577	0.0049	0.636	0.019	0.517	0.183	122
11.1	7.89	7	45	43	1.06	0.9368	0.0712	0.1069	0.0040	0.01	0.0636	0.0063	0.655	0.023	0.727	0.208	90
12.1	0.15	51	30	91	0.33	7.8559	0.1484	0.4318	0.0045	0.95	0.1320	0.0026	2.314	0.020	2.124	0.034	108
13.1	63.38	12	131	59	2.24	0.8533	0.0588	0.1053	0.0034	0.34	0.0588	0.0051	0.645	0.020	0.559	0.168	115
14.1	2.80	15	125	73	1.70	0.8214	0.1717	0.1044	0.0053	0.41	0.0571	0.0131	0.640	0.031	0.495	0.359	129
15.1	0.13	97	10	147	0.07	13.4045	0.2732	0.5144	0.0047	0.98	0.1890	0.0039	2.676	0.020	2.733	0.037	97
16.1	2.94	10	56	58	0.97	0.8945	0.1315	0.1056	0.0041	0.08	0.0614	0.0107	0.647	0.024	0.655	0.330	98
17.1	0.63	15	100	79	1.27	0.9159	0.0998	0.1054	0.0032	0.01	0.0630	0.0078	0.646	0.019	0.709	0.261	91
18.1	2.01	13	78	76	1.03	0.8470	0.0816	0.0972	0.0026	0.01	0.0632	0.0070	0.598	0.015	0.715	0.247	83
19.1	2.35	8	46	47	0.96	0.8488	0.1715	0.1077	0.0052	0.78	0.0571	0.0136	0.660	0.030	0.497	0.385	132
20.1	5.28	11	73	63	1.17	0.7924	0.0930	0.1015	0.0030	0.39	0.0566	0.0077	0.623	0.017	0.477	0.285	130
21.1	1.05	7	57	37	1.55	0.7933	0.1174	0.0948	0.0037	0.18	0.0607	0.0102	0.584	0.022	0.629	0.371	92
22.1	0.29	99	19	155	0.12	6.9877	0.1591	0.3866	0.0035	0.94	0.1311	0.0029	2.107	0.016	2.112	0.039	99
23.1	1.56	16	146	76	1.93	0.8109	0.2021	0.1044	0.0061	0.44	0.0563	0.0188	0.640	0.036	0.466	0.357	137
24.1	0.64	50	41	83	0.49	8.4491	0.2514	0.4428	0.0059	0.95	0.1384	0.0045	2.363	0.026	2.207	0.056	107
25.1	0.43	7	22	48	0.47	0.9658	0.1483	0.1137	0.0045	0.76	0.0616	0.0118	0.694	0.026	0.660	0.385	105
26.1	5.29	6	58	35	1.67	0.8921	0.2606	0.1067	0.0078	0.01	0.0607	0.0187	0.653	0.045	0.627	0.526	104
<i>Metavolcanic granitoid (Zircon - IGT-04C)</i>																	
Concordia Age: 609.5 ±15 Ma																	
1.1	<0.001	98	0	139	0.00	14.7446	0.1531	0.5504	0.0056	0.90	0.1947	0.0012	2.827	0.023	2.787	0.011	101
2.1	0.13	81	13	154	0.09	7.7368	0.0784	0.4164	0.0043	0.90	0.1338	0.0009	2.244	0.02	2.145	0.011	105
2.2	0.48	16	19	34	0.57	7.3973	0.085	0.3939	0.0056	0.90	0.1357	0.0016	2.141	0.026	2.169	0.021	99
3.1	<0.001	5	30	38	0.79	0.8099	0.0168	0.0899	0.0034	0.90	0.0653	0.0029	0.555	0.02	0.78	0.092	71

4.1	<0.001	113	-7	174	-0.04	13.9344	0.1859	0.5344	0.0055	0.77	0.1844	0.0022	2.76	0.023	2.696	0.02	102
4.2	0.29	50	1	387	0.00	1.0234	0.0141	0.1242	0.0018	0.90	0.0592	0.0007	0.755	0.01	0.568	0.025	133
5.1	0.06	66	32	137	0.23	7.3743	0.0775	0.3881	0.004	0.90	0.1377	0.001	2.114	0.019	2.194	0.012	96
6.1	<0.001	10	14	64	0.22	1.1008	0.0245	0.1306	0.0031	0.90	0.064	0.0022	0.791	0.018	0.735	0.071	108
7.1	7.52	4	24	31	0.77	0.7294	0.0664	0.0979	0.0053	0.60	0.0613	0.0062	0.602	0.031	0.645	0.205	93
8.1	1.96	7	-16	53	-0.30	0.7149	0.0181	0.0932	0.004	0.90	0.0556	0.0045	0.574	0.023	0.43	0.169	134
9.1	0.24	11	37	67	0.55	0.7832	0.0247	0.1043	0.0039	0.90	0.0573	0.0036	0.64	0.023	0.495	0.131	129
9.2	31.34	5	-138	32	-4.26	0.7702	0.0728	0.1058	0.0037	0.37	0.0499	0.0058	0.6483	0.0213	0.1921	0.241	337
10.1	2.65	6	0	42	-0.01	1.004	0.0415	0.1196	0.0048	0.90	0.0655	0.0032	0.728	0.028	0.787	0.102	93
11.1	5.19	4	-14	35	-0.41	0.761	0.0366	0.0865	0.0063	0.90	0.0699	0.0066	0.5346	0.0371	0.9242	0.187	58
12.1	0.23	7	-58	43	-1.35	0.729	0.0386	0.1118	0.0052	0.87	0.0502	0.0031	0.6832	0.0298	0.2061	0.134	331
13.1	6.60	5	-44	26	-1.69	1.0376	0.0374	0.1146	0.0033	0.80	0.0651	0.0024	0.6995	0.0191	0.7733	0.076	90
14.1	0.18	39	66	327	0.20	0.8259	0.0092	0.1003	0.0012	0.90	0.0599	0.0008	0.6159	0.0071	0.5952	0.027	103
14.2	0.37	59	421	442	0.95	1.0716	0.0222	0.1281	0.0017	0.65	0.0605	0.0007	0.7771	0.0099	0.6166	0.026	126
15.1	1.05	5	-86	32	-2.68	0.6732	0.037	0.1013	0.0042	0.76	0.055	0.0038	0.6222	0.0246	0.4068	0.146	153
16.1	15.60	15	-181	115	-1.57	0.5987	0.0438	0.0793	0.0046	0.80	0.0694	0.0872	0.4922	0.0276	0.9093	1.507	54
17.1	21.78	61	-53	409	-0.13	1.1035	0.0219	0.1286	0.0017	0.66	0.0632	0.0007	0.7799	0.0095	0.7106	0.022	110
18.1	67.13	10	-117	66	-1.79	1.1184	0.0704	0.1231	0.0038	0.49	0.0645	0.0058	0.7481	0.0219	0.7532	0.181	99
19.1	4.16	4	-82	28	-2.89	0.8158	0.0481	0.1134	0.0066	0.90	0.0578	0.0052	0.6927	0.0381	0.5169	0.186	134
20.1	<0.001	44	-30	82	-0.37	8.123	0.0707	0.4254	0.0041	0.90	0.1377	0.0013	2.285	0.0187	2.1949	0.016	104
21.1	1.10	7	-4	46	-0.08	0.6823	0.0467	0.1001	0.0047	0.69	0.0535	0.0043	0.615	0.0277	0.3465	0.168	177
22.1	52.03	3	-59	21	-2.78	0.9344	0.0571	0.0961	0.0039	0.66	0.0751	0.0032	0.5916	0.0229	1.072	0.086	55
23.1	5.43	23	4	134	0.03	1.3247	0.0731	0.1475	0.0062	0.77	0.0624	0.0016	0.8867	0.035	0.6812	0.053	130
24.1	3.08	6	9	31	0.29	0.9503	0.0705	0.1221	0.0064	0.70	0.0544	0.0026	0.7427	0.0366	0.381	0.103	195
24.2	11.51	20	-1	126	-0.01	1.2619	0.073	0.1404	0.006	0.74	0.0621	0.0014	0.847	0.0341	0.6722	0.047	126
25.1	<0.001	5	-3	32	-0.09	0.9207	0.0652	0.1205	0.0068	0.80	0.0561	0.0021	0.7334	0.0391	0.4501	0.079	163
26.1	<0.001	32	1	54	0.01	8.8511	0.4674	0.4831	0.0204	0.80	0.1334	0.0007	2.5408	0.0883	2.1403	0.009	119
27.1	<0.001	5	14	23	0.61	1.028	0.1104	0.117	0.0081	0.65	0.0876	0.0154	0.7134	0.0467	1.3794	0.304	52
27.2	0.26	77	11	471	0.02	1.243	0.0646	0.153	0.0063	0.79	0.0596	0.0003	0.9179	0.0352	0.5836	0.011	157
28.1	0.44	3	-1	19	-0.07	0.8872	0.0701	0.1146	0.0066	0.73	0.0601	0.0038	0.6996	0.0381	0.6019	0.132	116
29.1	<0.001	45	-3	104	-0.03	5.9875	0.3162	0.3705	0.0155	0.79	0.1176	0.0006	2.0316	0.0727	1.9199	0.01	106
29.2	1.00	17	-1	112	-0.01	1.45	0.0832	0.1546	0.0068	0.77	0.0717	0.0009	0.9265	0.0381	0.9773	0.026	95
30.1	<0.001	3	3	17	0.18	0.833	0.0871	0.128	0.01	0.75	0.0597	0.0094	0.7762	0.0568	0.5868	0.312	132
31.1	2.69	18	-1	146	-0.01	0.8885	0.0487	0.1066	0.0044	0.76	0.061	0.0006	0.6529	0.0259	0.6339	0.022	103
32.1	0.16	4	-48	26	-1.85	0.7797	0.0333	0.0962	0.0027	0.67	0.054	0.0027	0.592	0.0161	0.3666	0.109	161
33.1	6.17	3	114	23	4.99	0.7353	0.0399	0.0963	0.003	0.58	0.0585	0.0031	0.5929	0.0178	0.5412	0.114	110
34.1	1.94	91	281	158	1.78	8.8005	0.2082	0.466	0.0085	0.77	0.137	0.0013	2.4658	0.0371	2.1858	0.016	113
35.1	0.24	98	256	177	1.45	9.1741	0.2026	0.5055	0.0082	0.74	0.1299	0.0011	2.6375	0.0351	2.0938	0.015	126
36.1	<0.001	27	264	78	3.39	4.82	0.1	0.2914	0.0048	0.80	0.1202	0.0015	1.6487	0.024	1.9593	0.021	84
37.1	0.63	30	152	166	0.91	1.2115	0.0269	0.1473	0.0024	0.72	0.0591	0.0006	0.8861	0.0132	0.5638	0.023	157
38.1	0.22	122	-162	171	-0.95	12.7963	0.2773	0.5489	0.0086	0.73	0.1647	0.0014	2.8205	0.0358	2.5019	0.014	113
39.1	1.09	11	195	75	2.60	1.049	0.0444	0.1202	0.0032	0.62	0.0674	0.0033	0.7316	0.0183	0.8462	0.102	86
40.1	<0.001	6	112	40	2.80	0.8355	0.0566	0.097	0.0031	0.47	0.0653	0.0039	0.5968	0.0182	0.7797	0.123	77
41.1	1.37	4	209	28	7.42	0.7108	0.0483	0.0873	0.0043	0.72	0.0584	0.0042	0.5398	0.0254	0.5396	0.152	100

*Biotite paragneiss (Zircon
- BB-06A)*

1.1	0.03	101	52	195	0.27	7.5518	0.2339	0.4002	0.0058	0.78	0.1369	0.0038	2.170	0.027	2.188	0.049	99
2.1	1.36	35	27	47	0.57	13.4883	0.5625	0.5286	0.0107	0.69	0.1851	0.0068	2.736	0.045	2.699	0.061	101
3.1	0.00	158	250	264	0.95	7.4593	0.2250	0.3943	0.0056	0.78	0.1372	0.0036	2.143	0.026	2.192	0.046	97
4.1	0.16	81	48	158	0.31	7.0270	0.2193	0.3792	0.0054	0.32	0.1344	0.0037	2.072	0.025	2.156	0.048	96
5.1	0.24	117	81	165	0.49	13.2286	0.3686	0.5193	0.0070	0.23	0.1847	0.0044	2.696	0.030	2.696	0.039	100
6.1	0.77	60	47	116	0.40	6.9907	0.2185	0.3803	0.0055	0.74	0.1333	0.0037	2.078	0.025	2.142	0.048	96
7.1	0.72	243	122	453	0.27	8.0201	0.2164	0.3964	0.0052	0.01	0.1467	0.0034	2.152	0.024	2.308	0.040	93
8.1	0.08	68	35	86	0.40	16.4307	0.5033	0.5508	0.0085	0.97	0.2164	0.0059	2.828	0.035	2.954	0.045	95
9.1	0.09	118	125	135	0.92	15.8491	0.4558	0.5391	0.0077	0.86	0.2132	0.0053	2.780	0.032	2.930	0.041	94
9.2	2.01	134	67	328	0.20	5.9144	0.1759	0.3402	0.0047	0.90	0.1261	0.0034	1.887	0.023	2.044	0.047	92
10.1	0.09	105	50	148	0.34	12.1651	0.3706	0.4774	0.0071	0.93	0.1848	0.0050	2.516	0.031	2.696	0.045	93
11.1	0.17	38	42	73	0.58	7.0565	0.2839	0.3793	0.0067	0.09	0.1349	0.0050	2.073	0.031	2.163	0.066	95
11.2	0.14	65	39	133	0.29	7.0550	0.2486	0.3764	0.0060	0.57	0.1360	0.0044	2.059	0.028	2.176	0.056	94
12.1	2.43	14	9	27	0.33	7.3108	0.4138	0.3860	0.0111	0.44	0.1374	0.0096	2.104	0.051	2.194	0.121	95
13.1	0.05	110	129	149	0.87	9.4404	0.2553	0.4478	0.0058	0.85	0.1529	0.0046	2.386	0.026	2.378	0.051	100
14.1	1.86	17	12	29	0.42	7.0730	0.4055	0.3916	0.0110	0.09	0.1310	0.0092	2.130	0.051	2.111	0.123	100

15.1	0.23	104	109	136	0.80	10.1923	0.2575	0.4572	0.0055	0.30	0.1617	0.0045	2.427	0.025	2.473	0.047	98
16.1	1.12	203	235	353	0.67	6.0292	0.1330	0.3448	0.0034	0.99	0.1268	0.0032	1.910	0.017	2.054	0.045	92
17.1	0.16	43	29	37	0.78	24.4937	0.7397	0.6655	0.0123	0.55	0.2669	0.0094	3.288	0.048	3.288	0.054	100
18.1	0.08	90	65	86	0.75	20.5137	0.4992	0.6074	0.0077	0.69	0.2449	0.0066	3.060	0.031	3.152	0.043	97
19.1	0.52	30	29	50	0.58	7.4708	0.2953	0.3877	0.0076	0.49	0.1398	0.0065	2.112	0.035	2.224	0.081	94
19.2	1.05	105	22	229	0.10	5.5453	0.1641	0.3032	0.0042	0.99	0.1327	0.0040	1.707	0.020	2.133	0.054	80
20.1	0.24	62	26	71	0.36	16.8057	0.4652	0.5736	0.0087	0.85	0.2125	0.0067	2.923	0.036	2.925	0.051	99
21.1	0.19	73	61	80	0.77	15.1141	0.4471	0.5340	0.0088	0.83	0.2053	0.0070	2.758	0.037	2.869	0.056	96
22.1	0.14	78	97	119	0.81	7.8252	0.2122	0.4054	0.0053	0.72	0.1400	0.0043	2.194	0.024	2.227	0.054	98
23.1	0.15	140	120	254	0.47	6.8610	0.1657	0.3799	0.0043	0.47	0.1310	0.0035	2.076	0.020	2.111	0.047	98
24.1	1.07	31	17	53	0.33	7.8421	0.2911	0.4114	0.0063	0.38	0.1383	0.0056	2.221	0.029	2.206	0.070	100
25.1	0.60	87	78	94	0.83	14.1864	0.3507	0.5287	0.0058	0.09	0.1946	0.0052	2.736	0.024	2.782	0.044	98
26.1	0.22	67	92	91	1.01	8.0196	0.2373	0.4168	0.0050	0.29	0.1396	0.0045	2.246	0.023	2.222	0.055	101
27.1	0.06	188	110	227	0.48	13.1742	0.2827	0.5220	0.0045	0.49	0.1831	0.0042	2.708	0.019	2.681	0.038	100
28.1	0.21	88	60	103	0.59	13.3530	0.3385	0.5219	0.0057	0.53	0.1856	0.0051	2.707	0.024	2.703	0.044	100
29.1	0.11	138	133	217	0.61	7.7883	0.2005	0.4091	0.0042	0.50	0.1381	0.0039	2.211	0.019	2.203	0.049	100
30.1	0.13	99	77	106	0.72	16.0203	0.3632	0.5554	0.0053	0.67	0.2092	0.0051	2.848	0.022	2.899	0.040	98
31.1	0.27	153	140	246	0.57	7.7030	0.1864	0.4113	0.0040	0.78	0.1358	0.0035	2.221	0.018	2.175	0.046	102
31.2	1.72	173	14	338	0.04	6.8741	0.1527	0.3810	0.0032	0.93	0.1309	0.0031	2.081	0.015	2.110	0.042	98
32.1	0.24	59	50	97	0.52	7.5846	0.2103	0.4025	0.0045	0.61	0.1367	0.0041	2.181	0.021	2.185	0.053	99
33.1	0.41	94	111	143	0.78	7.4882	0.2063	0.3997	0.0045	0.55	0.1359	0.0041	2.168	0.021	2.175	0.054	99
34.1	0.29	39	50	60	0.83	7.4781	0.2942	0.4110	0.0066	0.89	0.1320	0.0057	2.220	0.030	2.124	0.075	104
34.2	0.25	135	84	241	0.35	6.7776	0.1636	0.3770	0.0035	0.25	0.1304	0.0034	2.062	0.016	2.103	0.045	98
35.1	0.39	105	30	134	0.23	16.7399	0.5332	0.5920	0.0084	0.77	0.2051	0.0067	2.998	0.034	2.867	0.051	104
36.1	0.17	139	98	247	0.40	7.9528	0.2299	0.4326	0.0048	0.82	0.1333	0.0038	2.317	0.021	2.142	0.050	108
37.1	0.71	51	55	98	0.56	6.3211	0.2491	0.3577	0.0057	0.43	0.1282	0.0053	1.971	0.027	2.073	0.076	95
38.1	0.21	91	62	126	0.49	12.4661	0.3618	0.5000	0.0061	0.64	0.1808	0.0052	2.614	0.026	2.661	0.048	98
39.1	0.09	54	24	102	0.24	7.4538	0.2477	0.4015	0.0053	0.83	0.1346	0.0045	2.176	0.024	2.159	0.060	100
40.1	0.09	106	119	129	0.93	13.5945	0.3826	0.5385	0.0064	0.81	0.1831	0.0052	2.777	0.027	2.681	0.047	103
41.1	0.14	151	164	247	0.66	8.2047	0.2223	0.4402	0.0045	0.76	0.1352	0.0037	2.352	0.020	2.166	0.047	108
42.1	0.16	335	63	684	0.09	7.6907	0.1866	0.4175	0.0037	0.59	0.1336	0.0032	2.249	0.017	2.146	0.041	104
43.1	0.16	97	62	183	0.34	7.0960	0.2000	0.3906	0.0042	0.35	0.1318	0.0037	2.126	0.019	2.121	0.049	100
44.1	3.46	131	25	209	0.12	9.8868	0.2773	0.4045	0.0044	0.97	0.1773	0.0046	2.190	0.020	2.627	0.043	83
45.1	0.39	29	27	36	0.76	13.3675	0.6156	0.5223	0.0122	0.46	0.1856	0.0091	2.709	0.052	2.704	0.079	100
46.1	0.10	113	68	127	0.54	17.8623	0.4808	0.5810	0.0065	0.46	0.2230	0.0059	2.953	0.027	3.002	0.042	98
47.1	0.24	43	28	83	0.34	7.1305	0.2888	0.3858	0.0065	0.17	0.1340	0.0056	2.104	0.030	2.151	0.073	97
48.1	7.38	32	25	56	0.45	7.4154	0.2586	0.3923	0.0072	0.48	0.1371	0.0058	2.133	0.033	2.191	0.074	97
49.1	2.45	73	37	73	0.50	21.0935	0.4262	0.5957	0.0068	0.87	0.2568	0.0057	3.012	0.027	3.227	0.035	93
50.1	0.60	27	25	45	0.55	7.5788	0.2924	0.3978	0.0081	0.11	0.1382	0.0065	2.159	0.038	2.204	0.082	97
51.1	0.34	64	43	56	0.77	25.6811	0.5638	0.6596	0.0089	0.75	0.2824	0.0070	3.266	0.034	3.376	0.038	96
52.1	1.97	17	7	29	0.25	9.0099	0.5094	0.4283	0.0142	0.33	0.1526	0.0104	2.298	0.063	2.375	0.116	96
53.1	0.00	229	480	217	2.21	13.3375	0.2457	0.5298	0.0049	0.01	0.1826	0.0037	2.741	0.021	2.676	0.034	102
54.1	0.29	44	24	81	0.30	7.1979	0.2216	0.3865	0.0060	0.53	0.1351	0.0049	2.106	0.028	2.165	0.063	97
55.1	0.18	237	99	446	0.22	7.5137	0.1369	0.4026	0.0034	0.01	0.1354	0.0026	2.181	0.016	2.169	0.034	100
56.1	0.11	111	67	199	0.34	7.0025	0.1545	0.3929	0.0041	0.72	0.1293	0.0032	2.136	0.019	2.088	0.044	102
57.1	0.57	163	157	220	0.71	13.2397	0.2508	0.5308	0.0050	0.93	0.1809	0.0038	2.745	0.021	2.661	0.034	103
58.1	0.15	88	132	133	0.99	7.7530	0.1911	0.4062	0.0049	0.63	0.1384	0.0039	2.198	0.023	2.208	0.048	99
59.1	1.21	25	30	44	0.68	6.8965	0.2900	0.3903	0.0084	0.01	0.1281	0.0067	2.124	0.039	2.073	0.091	102
60.1	1.28	33	29	40	0.73	13.7100	0.4020	0.5286	0.0093	0.57	0.1881	0.0067	2.735	0.039	2.726	0.059	100

*Biotite paragneiss (Zircon
- IGT-04D)*

1.1	<0.001	51	-28	72	-0.39	12.7661	0.2531	0.5054	0.0055	0.55	0.1835	0.0018	2.637	0.024	2.687	0.016	98
2.1	<0.001	28	107	55	1.94	7.4300	0.1482	0.3932	0.0047	0.60	0.1372	0.0016	2.137	0.022	2.188	0.020	98
3.1	0.08	86	-9	112	-0.08	17.3860	0.3447	0.5691	0.0059	0.52	0.2216	0.0020	2.904	0.024	2.998	0.014	97
4.1	<0.001	130	-75	250	-0.30	7.2273	0.1447	0.3903	0.0040	0.51	0.1332	0.0012	2.124	0.019	2.137	0.016	99
5.1	<0.001	34	67	67	1.01	7.8360	0.1579	0.4009	0.0051	0.63	0.1415	0.0016	2.173	0.024	2.242	0.019	97
6.1	0.53	82	224	119	1.88	14.9032	0.3890	0.5392	0.0057	0.41	0.2028	0.0036	2.780	0.024	2.854	0.029	97
7.1	<0.001	82	-103	152	-0.68	7.8503	0.1552	0.4131	0.0043	0.53	0.1378	0.0013	2.229	0.020	2.195	0.016	102
8.1	<0.001	145	-61	206	-0.29	14.9662	0.3614	0.5355	0.0055	0.43	0.2077	0.0025	2.765	0.023	2.894	0.020	96
9.1	<0.001	106	11	158	0.07	13.8235	0.2762	0.5149	0.0053	0.52	0.1967	0.0019	2.677	0.023	2.804	0.016	95
10.1	0.07	108	-295	127	-2.33	22.1804	0.4542	0.6271	0.0065	0.51	0.2601	0.0027	3.138	0.026	3.245	0.015	97
11.1	0.04	217	-260	410	-0.64	7.5280	0.1547	0.3925	0.0040	0.50	0.1404	0.0014	2.134	0.019	2.228	0.017	96

12.1	0.16	37	98	72	1.37	7.3750	0.1470	0.3880	0.0045	0.58	0.1384	0.0014	2.113	0.021	2.204	0.018	96
13.1	0.45	75	3	103	0.02	19.5523	0.5066	0.6287	0.0176	0.90	0.2303	0.0023	3.144	0.069	3.059	0.016	103
14.1	<0.001	68	0	84	0.00	17.2492	0.4453	0.5938	0.0166	0.90	0.2109	0.0018	3.005	0.067	2.918	0.014	103
15.1	1.51	169	-8	546	-0.01	4.7544	0.1597	0.3282	0.0095	0.86	0.1107	0.0015	1.830	0.046	1.814	0.025	101
16.1	2.60	192	-10	412	-0.02	6.4497	0.1866	0.3813	0.0107	0.90	0.1270	0.0016	2.082	0.050	2.055	0.022	101
17.1	0.54	41	-18	52	-0.34	16.5965	0.4298	0.5777	0.0162	0.90	0.2133	0.0019	2.939	0.066	2.937	0.015	100
18.1	<0.001	186	12	432	0.03	7.0608	0.1883	0.3827	0.0107	0.90	0.1349	0.0012	2.089	0.050	2.159	0.015	97
19.1	0.09	203	-3	408	-0.01	7.6584	0.1987	0.4224	0.0118	0.90	0.1324	0.0011	2.271	0.053	2.127	0.014	107
20.1	0.04	173	-9	388	-0.02	7.0344	0.1813	0.3814	0.0106	0.90	0.1337	0.0011	2.083	0.049	2.143	0.014	97
21.1	0.07	121	-28	237	-0.12	7.4272	0.1933	0.3926	0.0109	0.90	0.1369	0.0012	2.135	0.050	2.184	0.015	98
22.1	0.04	154	-11	303	-0.03	7.6080	0.1970	0.4034	0.0112	0.90	0.1369	0.0011	2.185	0.051	2.184	0.014	100
23.1	0.04	84	-21	179	-0.12	7.0703	0.1822	0.3810	0.0106	0.90	0.1356	0.0011	2.081	0.049	2.168	0.014	96
24.1	0.13	127	2	160	0.01	14.0206	0.4429	0.5504	0.0160	0.90	0.1907	0.0020	2.827	0.066	2.752	0.018	103
25.1	0.26	190	-57	368	-0.16	7.3135	0.1496	0.3912	0.0062	0.78	0.1369	0.0012	2.129	0.029	2.184	0.015	97
26.1	<0.001	164	-154	321	-0.48	7.4860	0.0891	0.4039	0.0036	0.74	0.1350	0.0011	2.187	0.016	2.161	0.013	101
27.1	0.04	109	100	218	0.46	7.5916	0.0924	0.4082	0.0037	0.75	0.1352	0.0011	2.207	0.017	2.163	0.014	102
28.1	0.05	28	-350	49	-7.09	7.7724	0.0955	0.4153	0.0043	0.85	0.1376	0.0013	2.239	0.020	2.193	0.017	102
29.1	<0.001	55	-24	100	-0.24	7.7232	0.0950	0.4134	0.0040	0.79	0.1371	0.0013	2.230	0.018	2.187	0.016	102
30.1	0.54	99	-44	210	-0.21	6.9518	0.1111	0.3802	0.0046	0.75	0.1326	0.0011	2.077	0.021	2.130	0.014	98
31.1	<0.001	58	-152	82	-1.87	16.2761	0.1984	0.5530	0.0051	0.76	0.2123	0.0018	2.838	0.021	2.930	0.014	97
32.1	0.50	36	-331	54	-6.12	13.3258	0.1711	0.5168	0.0059	0.89	0.1877	0.0017	2.686	0.025	2.725	0.015	99
33.1	0.10	110	76	281	0.27	6.0493	0.0727	0.3581	0.0032	0.75	0.1236	0.0010	1.973	0.015	2.008	0.014	98
34.1	<0.001	100	-189	136	-1.40	13.1293	0.1582	0.5230	0.0049	0.77	0.1825	0.0015	2.712	0.021	2.677	0.014	101
35.1	<0.001	110	-187	210	-0.89	7.2974	0.0888	0.3972	0.0036	0.74	0.1327	0.0011	2.156	0.017	2.131	0.014	101
36.1	<0.001	163	-191	321	-0.59	7.5424	0.1609	0.4086	0.0052	0.60	0.1345	0.0013	2.208	0.024	2.154	0.017	103
37.1	<0.001	100	13	189	0.07	8.8772	0.0618	0.4257	0.0032	0.90	0.1517	0.0008	2.286	0.015	2.361	0.009	97
38.1	<0.001	157	-9	330	-0.03	7.3506	0.0499	0.4076	0.0029	0.90	0.1313	0.0007	2.204	0.013	2.113	0.009	104
39.1	0.04	167	23	357	0.06	6.7207	0.1262	0.3880	0.0030	0.41	0.1273	0.0020	2.114	0.014	2.059	0.027	103
40.1	<0.001	-5	13	-7	-2.01	14.5746	0.1927	0.5557	0.0048	0.66	0.1924	0.0017	2.849	0.020	2.767	0.015	103
41.1	0.19	57	12	77	0.15	13.9709	0.0850	0.5416	0.0043	0.90	0.1870	0.0012	2.790	0.018	2.719	0.010	103
42.1	<0.001	29	-8	62	-0.13	7.3479	0.0641	0.3883	0.0042	0.90	0.1359	0.0010	2.115	0.019	2.172	0.013	97
43.1	0.34	26	-8	52	-0.15	7.4851	0.0554	0.3988	0.0039	0.90	0.1376	0.0012	2.163	0.018	2.193	0.015	99
44.1	<0.001	81	-1	75	-0.01	14.7180	0.3938	0.5614	0.0110	0.73	0.1977	0.0027	2.872	0.045	2.812	0.023	102
45.1	0.38	241	13	492	0.03	7.4307	0.0565	0.4083	0.0032	0.90	0.1313	0.0011	2.207	0.015	2.112	0.015	105
46.1	<0.001	108	30	241	0.12	6.8006	0.0598	0.3768	0.0030	0.90	0.1310	0.0007	2.061	0.014	2.109	0.009	98
47.1	<0.001	240	10	490	0.02	7.4512	0.0455	0.3977	0.0027	0.90	0.1353	0.0006	2.158	0.013	2.164	0.008	100
48.1	0.04	133	-3	274	-0.01	7.9919	0.1007	0.4140	0.0047	0.90	0.1386	0.0008	2.233	0.021	2.206	0.011	101
49.1	<0.001	53	-19	105	-0.18	7.4909	0.0578	0.3941	0.0031	0.90	0.1358	0.0007	2.142	0.014	2.171	0.008	99
50.1	<0.001	77	-3	131	-0.02	10.1964	0.0878	0.4578	0.0038	0.90	0.1589	0.0007	2.430	0.017	2.441	0.008	100
51.1	<0.001	103	19	208	0.09	7.6023	0.0593	0.4089	0.0032	0.90	0.1331	0.0005	2.210	0.015	2.135	0.006	103
52.1	0.13	59	21	111	0.19	7.7697	0.0590	0.4119	0.0031	0.90	0.1373	0.0008	2.224	0.014	2.190	0.010	102
53.1	0.02	125	-11	286	-0.04	6.8667	0.0526	0.3805	0.0028	0.90	0.1308	0.0004	2.078	0.013	2.106	0.005	99
54.1	0.54	54	5	101	0.05	8.0586	0.0612	0.4229	0.0035	0.90	0.1399	0.0008	2.273	0.016	2.221	0.010	102
55.1	1.93	-11	11	-9	-1.24	21.9852	0.4894	0.6436	0.0054	0.38	0.2445	0.0049	3.203	0.021	3.151	0.030	102
56.1	0.08	81	-14	137	-0.10	10.3809	0.0729	0.4633	0.0035	0.90	0.1623	0.0007	2.454	0.015	2.477	0.007	99
57.1	1.05	33	-24	53	-0.45	9.7977	0.1672	0.4445	0.0068	0.89	0.1604	0.0012	2.371	0.030	2.457	0.013	97
58.1	0.06	90	-8	183	-0.05	7.2649	0.0542	0.3910	0.0029	0.90	0.1344	0.0005	2.127	0.013	2.152	0.007	99
59.1	0.02	221	-34	432	-0.08	7.7428	0.0689	0.4157	0.0029	0.79	0.1360	0.0006	2.241	0.013	2.173	0.008	103
60.1	0.07	114	11	241	0.05	7.2688	0.0547	0.3930	0.0028	0.90	0.1336	0.0004	2.137	0.013	2.142	0.005	100
<i>Biotite Paragneiss (Monazite - IGT-04D)</i>																	
Concordia Age: 599.9 ±1.9 Ma																	
1.1	0.01	2170	2178	4814	0.45	0.7971	0.0088	0.0963	0.0007	0.73	0.0600	0.0006	0.593	0.004	0.604	0.022	98
1.2	0.01	2170	2177	4814	0.45	0.8001	0.0088	0.0967	0.0007	0.73	0.0600	0.0006	0.595	0.004	0.605	0.022	98
2.1	0.01	2137	2095	4685	0.45	0.8091	0.0088	0.0979	0.0008	0.66	0.0600	0.0006	0.602	0.004	0.602	0.021	99
2.2	0.04	2023	2127	3580	0.59	0.8513	0.0098	0.1032	0.0008	0.01	0.0598	0.0006	0.633	0.005	0.597	0.022	106
3.1	0.04	1478	1563	3392	0.46	0.7904	0.0094	0.0964	0.0008	0.62	0.0595	0.0006	0.593	0.004	0.584	0.023	101
3.2	0.01	2438	2636	4184	0.63	0.7968	0.0092	0.0979	0.0008	0.74	0.0590	0.0006	0.602	0.004	0.568	0.023	105
4.1	0.04	1947	2125	3134	0.68	0.8054	0.0100	0.0986	0.0008	0.21	0.0592	0.0007	0.606	0.005	0.576	0.025	105
5.1	0.01	1482	1466	3335	0.44	0.8167	0.0097	0.0988	0.0008	0.72	0.0600	0.0007	0.607	0.004	0.602	0.024	100
6.1	0.01	1348	1438	2563	0.56	0.8102	0.0106	0.0986	0.0008	0.71	0.0596	0.0007	0.606	0.005	0.588	0.027	103
6.2	0.04	1458	1612	2580	0.63	0.8067	0.0102	0.0973	0.0008	0.66	0.0601	0.0007	0.599	0.005	0.608	0.026	98
7.1	0.03	1699	1834	3368	0.55	0.7991	0.0098	0.0976	0.0008	0.37	0.0594	0.0007	0.600	0.004	0.582	0.025	103

8.1	0.04	1952	2066	3953	0.52	0.7979	0.0091	0.0967	0.0007	0.85	0.0598	0.0006	0.595	0.004	0.597	0.023	99
9.1	0.03	1435	1396	3652	0.38	0.8384	0.0095	0.1006	0.0008	0.92	0.0605	0.0007	0.618	0.004	0.620	0.023	99
10.1	0.07	1612	1525	3830	0.40	0.8169	0.0120	0.0982	0.0010	0.76	0.0603	0.0008	0.604	0.006	0.616	0.030	97
11.1	0.04	1999	1883	5664	0.33	0.8045	0.0112	0.0970	0.0010	0.54	0.0602	0.0008	0.597	0.006	0.610	0.027	97
11.2	0.02	2095	1905	6345	0.30	0.8085	0.0110	0.0967	0.0010	0.65	0.0606	0.0007	0.595	0.006	0.627	0.026	94
12.1	0.01	2270	2569	3473	0.74	0.7977	0.0130	0.0984	0.0011	0.46	0.0588	0.0009	0.605	0.006	0.560	0.035	107
12.2	0.02	2348	2615	3711	0.70	0.7870	0.0127	0.0972	0.0011	0.54	0.0587	0.0009	0.598	0.006	0.556	0.033	107
13.1	0.06	2533	2569	4897	0.53	0.8138	0.0113	0.0986	0.0010	0.86	0.0599	0.0008	0.606	0.006	0.599	0.028	101
14.1	0.01	1943	1944	4081	0.48	0.8082	0.0125	0.0979	0.0010	0.2	0.0599	0.0009	0.602	0.006	0.599	0.032	100
14.2	0.01	2656	2585	6682	0.39	0.8082	0.0110	0.0975	0.0010	0.93	0.0601	0.0008	0.599	0.006	0.609	0.027	98
15.1	0.04	2662	2784	4582	0.61	0.8058	0.0116	0.0982	0.0010	0.53	0.0595	0.0008	0.604	0.006	0.586	0.030	103
16.1	0.05	1846	2003	3716	0.54	0.7966	0.0121	0.0968	0.0010	0.01	0.0597	0.0009	0.596	0.006	0.592	0.031	100
16.2	0.07	1659	1665	3579	0.47	0.8008	0.0127	0.0982	0.0010	0.16	0.0591	0.0009	0.604	0.006	0.573	0.033	105
17.1	0.01	1709	1633	4220	0.39	0.8151	0.0119	0.0978	0.0010	0.82	0.0604	0.0008	0.602	0.006	0.619	0.030	97
18.1	0.03	2137	2064	4969	0.42	0.8031	0.0117	0.0970	0.0010	0.01	0.0600	0.0008	0.597	0.006	0.605	0.030	98
19.1	0.04	2326	10372	4687	2.21	0.8032	0.0123	0.0976	0.0011	0.62	0.0597	0.0008	0.600	0.006	0.592	0.029	101
20.1	0.07	2085	7748	3645	2.13	0.8014	0.0131	0.0977	0.0011	0.27	0.0595	0.0009	0.601	0.006	0.585	0.031	102
20.2	0.05	2233	10264	3702	2.77	0.8166	0.0133	0.0995	0.0011	0.29	0.0595	0.0009	0.612	0.007	0.585	0.032	104
21.1	0.01	1928	8403	3968	2.12	0.8155	0.0129	0.0988	0.0011	0.92	0.0599	0.0008	0.607	0.006	0.598	0.031	101
21.2	0.04	2538	11780	3924	3.00	0.7876	0.0126	0.0966	0.0011	0.20	0.0592	0.0008	0.594	0.006	0.573	0.030	103
22.1	0.09	1778	7496	3384	2.22	0.8512	0.0138	0.1024	0.0011	0.88	0.0603	0.0009	0.629	0.007	0.613	0.031	102
22.2	0.02	1957	8412	4082	2.06	0.8075	0.0129	0.0979	0.0011	0.28	0.0598	0.0009	0.602	0.006	0.597	0.031	100
23.1	0.04	1808	7761	3645	2.13	0.8018	0.0131	0.0970	0.0011	0.51	0.0599	0.0009	0.597	0.006	0.601	0.031	99
24.1	0.01	2268	10146	3991	2.54	0.7968	0.0128	0.0969	0.0011	0.33	0.0596	0.0008	0.596	0.006	0.590	0.031	101
24.2	0.02	1789	8302	3355	2.48	0.7901	0.0134	0.0967	0.0011	0.47	0.0593	0.0009	0.595	0.006	0.577	0.033	103
25.1	0.05	1640	7453	2775	2.69	0.8060	0.0143	0.0981	0.0011	0.39	0.0596	0.0010	0.603	0.007	0.589	0.036	102
26.1	0.04	2495	11975	3465	3.46	0.8021	0.0133	0.0990	0.0011	0.22	0.0587	0.0009	0.609	0.007	0.558	0.033	109
27.1	0.03	1705	7434	3410	2.18	0.7859	0.0132	0.0950	0.0011	0.63	0.0600	0.0009	0.585	0.006	0.603	0.032	97

VII. LA-ICPMS Hf data

Table 5: Results of LA-ICPMS Hf analyses in zircon.

Spot	Age (Ma)	$^{176}\text{Hf}/^{177}\text{Hf}_{\text{meas}}$	$\pm 2s$	$^{176}\text{Lu}/^{177}\text{Hf}_{\text{meas}}$	$\pm 2s$	$\epsilon\text{Hf}_{(t)}$	$^{176}\text{Hf}/^{177}\text{Hf}_{(t)}$	$\epsilon\text{Hf}_{(t)}$	$\pm 2s$	TDM
<i>Barro Branco orthogneiss (Zircon BB-04C)</i>										
4.1	705	0.282239	5.5E-05	0.00128	9.0E-05	-19.32	0.282222	-4.19	1.94	1881
6.1	687	0.282244	4.5E-05	0.00095	4.0E-05	-19.15	0.282231	-4.25	1.59	1871
8.1	736	0.282153	2.9E-05	0.00065	2.1E-05	-22.35	0.282144	-6.24	1.03	2036
9.1	668	0.282322	3.6E-05	0.00108	4.1E-05	-16.38	0.282308	-1.95	1.28	1710
11.1	680	0.282143	5.3E-05	0.00110	5.6E-05	-22.71	0.282129	-8.04	1.88	2104
13.1	695	0.282275	4.0E-05	0.00097	6.2E-05	-18.03	0.282262	-2.97	1.41	1797
15.1	695	0.282406	2.1E-05	0.00190	2.1E-04	-13.39	0.282381	1.25	0.73	1529
16.1	645	0.282179	3.9E-05	0.00036	2.5E-05	-21.44	0.282174	-7.21	1.39	2025
18.1	697	0.282223	3.5E-05	0.00044	8.4E-06	-19.86	0.282218	-4.51	1.23	1895
22.1	678	0.282207	3.8E-05	0.00051	8.4E-05	-20.43	0.282201	-5.53	1.35	1945
<i>Inequigranular orthogneiss (Zircon BB-09)</i>										
2.1	689	0.281777	5.3E-05	0.00041	6.4E-06	-35.63	0.281772	-20.47	1.88	2888
3.1	617	0.282052	2.7E-05	0.00015	1.1E-05	-25.94	0.282050	-12.25	0.95	2319
10.1	636	0.282109	3.0E-05	0.00035	6.4E-06	-23.92	0.282104	-9.89	1.06	2186
14.1	640	0.282143	4.3E-05	0.00027	1.0E-05	-22.69	0.282140	-8.53	1.53	2104
16.1	647	0.282046	5.0E-05	0.00015	6.5E-06	-26.13	0.282044	-11.77	1.76	2313
17.1	646	0.282081	4.2E-05	0.00031	9.2E-06	-24.89	0.282077	-10.62	1.50	2239
19.1	660	0.282107	4.9E-05	0.00013	1.2E-05	-23.98	0.282105	-9.32	1.75	2169
20.1	623	0.282093	5.0E-05	0.00021	8.7E-06	-24.49	0.282090	-10.69	1.77	2225
23.1	640	0.282025	6.1E-05	0.00008	6.3E-06	-26.88	0.282024	-12.64	2.15	2362
25.1	694	0.282130	5.0E-05	0.00048	4.0E-06	-23.16	0.282124	-7.90	1.76	2107
<i>Biotite schist (Zircon BB-06)</i>										
1.1	2188	0.281588	3.8E-05	0.00058	1.0E-05	-42.32	0.281564	6.40	1.34	2382
7.1	2308	0.281367	3.8E-05	0.00092	2.4E-05	-50.14	0.281327	0.75	1.36	2838
13.1	2378	0.281360	3.7E-05	0.00074	4.2E-05	-50.38	0.281327	2.39	1.32	2788
14.1	2111	0.281585	5.0E-05	0.00039	2.5E-06	-42.43	0.281570	4.81	1.79	2423
17.1	3288	0.280669	4.3E-05	0.00066	6.7E-06	-74.84	0.280627	-1.09	1.53	3725
20.1	2925	0.281167	4.1E-05	0.00143	3.8E-05	-57.22	0.281087	6.68	1.45	2943
22.1	2227	0.281577	3.4E-05	0.00136	5.9E-06	-42.72	0.281519	5.71	1.22	2457
26.1	2222	0.281476	3.0E-05	0.00048	8.8E-06	-46.30	0.281455	3.33	1.07	2605
27.1	2681	0.281054	3.3E-05	0.00075	3.1E-05	-61.23	0.281015	-1.62	1.19	3282
28.1	2703	0.280915	4.2E-05	0.00072	4.1E-06	-66.14	0.280878	-5.99	1.50	3577
29.1	2203	0.281449	4.1E-05	0.00107	1.6E-05	-47.26	0.281403	1.04	1.47	2737
32.1	2185	0.281623	5.1E-05	0.00129	1.9E-05	-41.10	0.281569	6.51	1.82	2372
33.1	2175	0.281624	4.5E-05	0.00066	4.9E-05	-41.07	0.281596	7.23	1.59	2318
34.1	2124	0.281452	4.0E-05	0.00076	3.7E-05	-47.14	0.281421	-0.16	1.41	2750
36.1	2142	0.281617	4.1E-05	0.00089	2.0E-05	-41.29	0.281581	5.93	1.46	2376
39.1	2159	0.281581	4.4E-05	0.00072	4.1E-06	-42.59	0.281551	5.26	1.55	2432
43.1	2121	0.281373	6.7E-05	0.00107	3.9E-05	-49.95	0.281329	-3.50	2.39	2960
50.1	2204	0.281385	4.2E-05	0.00090	7.8E-06	-49.50	0.281347	-0.93	1.48	2863
56.1	2088	0.281355	4.6E-05	0.00028	5.0E-06	-50.56	0.281344	-3.73	1.63	2949
59.1	2073	0.281383	4.2E-05	0.00032	5.0E-06	-49.58	0.281371	-3.15	1.48	2900

VIII. Whole-rock Nd isotope data

Table 6: Whole-rock Nd isotope analyses of all sampled rocks plus data compilation.

Sample	Units	Sm (ppm)	Nd (ppm)	$^{147}\text{Sm}/^{144}\text{Nd}$	$^{143}\text{Nd}/^{144}\text{Nd}$	$f_{\text{Sm/Nd}}$	$\epsilon_{\text{Nd}(0)}$	T_{DM} (Ma)	$\epsilon_{\text{Nd}(T_{\text{DM}})}$	Age (Ma)	$\epsilon_{\text{Nd}(t)}$
IGT-04C	Bt gneiss	8.3	54.6	0.091671	0.511636	-0.53	-19.6	1757	4.0	609.5	-11.4
										739	-9.7
IGT-04D	Bt paragneiss	5.3	29.7	0.107129	0.511323	-0.46	-25.7	2473	2.6	2170	-0.9
BB-31C	Bt orthogneiss	6.7	40.6	0.100300	0.511840	-0.49	-15.6	1616	4.3	684.5	-7.1
BB-44A	Hbl-bt orthogneiss	7.2	43.6	0.100500	0.511586	-0.49	-20.5	1960	3.6	7620	-12.9
¹⁸	Ineq. orthogneiss	7.8	51.9	0.090940	0.511620	-0.53	-19.9	1788	3.9	624	-11.6
¹⁶	Ineq. orthogneiss	7.8	55.0	0.087250	0.511590	-0.56	-20.4	1752	4.0	624	-11.7
¹¹²	Moinho	7.0	40.8	0.104500	0.511690	-0.47	-18.5	1884	3.7	7620	-11.2
² SP-02	Moinho	-	-	0.108500	0.511602	-0.45	-20.2	2092	3.3	620	-13.2
² CT13J	Moinho	-	-	0.105200	0.511523	-0.47	-21.8	2132	3.2	620	-14.5
¹³⁸	Imbiruçu	5.5	34.1	0.097220	0.511970	-0.50	-13.0	1417	4.7	606*	-5.4
^{126-a}	Morro Azul	11.1	66.4	0.101820	0.511750	-0.48	-17.3	1768	4.0	601*	-10.1
^{126-c}	Morro Azul (enclave)	10.4	65.8	0.096480	0.511760	-0.51	-17.1	1666	4.2	601*	-9.4
¹²³	Boa Vista	5.9	40.2	0.089560	0.511750	-0.54	-17.3	1598	4.3	600	-9.2
¹¹⁸	Boa Vista	9.3	61.2	0.092050	0.511850	-0.53	-15.4	1499	4.6	600	-7.4
¹²⁴	Boa Vista	8.2	45.0	0.111280	0.512010	-0.43	-12.3	1548	4.4	600	-5.8
¹²⁹	Machado	13.9	111.7	0.075850	0.511480	-0.61	-22.6	1739	4.0	600	-13.4
¹¹⁴	Pedra Branca	9.8	55.8	0.106990	0.511630	-0.45	-19.7	2043	3.4	600	-12.9
¹³³	Morro do Pão	9.8	57.4	0.103590	0.511990	-0.47	-12.6	1465	4.6	589*	-5.7
¹³⁷	Morro do Pão	10.4	73.3	0.086390	0.511810	-0.56	-16.2	1477	4.6	589*	-7.9
¹³⁶	Morro do Pão	11.4	72.5	0.095950	0.511820	-0.51	-16.0	1588	4.4	589*	-8.4
³ SR-07	São Roque	8.4	48.4	0.105000	0.511506	-0.47	-22.1	2144	3.2	603.6	-15.0
³ SR-05	São Roque	3.3	15.5	0.127000	0.511620	-0.36	-19.9	2484	2.6	600	-14.4
³ ITQ-2	Itaqui	7.1	40.8	0.105000	0.511660	-0.47	-19.1	1926	3.6	600	-12.0
³ TAP-01	Taipas	5.2	29.9	0.105000	0.511775	-0.47	-16.8	1765	4.0	602.4	-9.7
³ MD-42B	Cantareira	3.6	22.5	0.098000	0.511791	-0.50	-16.5	1653	4.2	591.9	-9.1
³ MD-24	Fazenda Itahyê	7.9	44.7	0.107000	0.511716	-0.46	-18.0	1882	3.7	597.5	-11.1

*Lamoso and Janasi (2019)

¹Ragatky (1998)

²Tassinari et al. (2004)

³Janasi et al. (2016)

IX. EPMA monazite

Table 7: Results of WDS point analyses on monazite and calculated molar fractions.

Cation-corrected proportions on the basis of 4 oxygens

Name	Age $\pm 2\sigma$	F	Na	Mg	Al	Fe	Si	Sr	Ba	Mn	P	Ca	K	Zr
m9-1		0.080	0.002	0.000	0.001	0.000	0.023	0.000	0.000	0.000	0.954	0.011	0.000	0.000
m9-3		0.079	0.001	0.000	0.002	0.002	0.029	0.000	0.000	0.000	0.950	0.012	0.000	0.000
m3-4	593 ± 8	0.095	0.000	0.000	0.000	0.000	0.023	0.000	0.001	0.001	0.959	0.014	0.000	0.000
m3-5		0.061	0.000	0.000	0.001	0.000	0.037	0.000	0.000	0.000	0.941	0.017	0.000	0.000
m3-6	602 ± 8	0.070	0.003	0.000	0.003	0.000	0.022	0.000	0.000	0.000	0.956	0.015	0.000	0.000
m2-8	602 ± 8	0.060	0.000	0.001	0.001	0.000	0.029	0.000	0.000	0.000	0.947	0.021	0.000	0.000
m2-9		0.066	0.001	0.000	0.004	0.000	0.044	0.000	0.000	0.000	0.936	0.020	0.000	0.000
m2-10		0.063	0.002	0.001	0.002	0.000	0.036	0.000	0.000	0.000	0.944	0.020	0.000	0.000
m2-11		0.085	0.001	0.000	0.000	0.000	0.027	0.000	0.000	0.000	0.955	0.009	0.000	0.000
m2-12	633 ± 10	0.090	0.000	0.000	0.001	0.000	0.027	0.000	0.000	0.000	0.955	0.016	0.000	0.000
m22-1	602 ± 12	0.085	0.002	0.000	0.000	0.000	0.027	0.001	0.000	0.000	0.950	0.014	0.000	0.000
m22-2	629 ± 14	0.085	0.000	0.000	0.000	0.000	0.026	0.001	0.000	0.000	0.954	0.014	0.000	0.000
m22-3		0.083	0.000	0.000	0.000	0.000	0.028	0.000	0.000	0.000	0.949	0.014	0.000	0.000
m22-4		0.077	0.003	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.950	0.016	0.000	0.000
m21-5	594 ± 12	0.080	0.004	0.000	0.001	0.001	0.045	0.000	0.000	0.000	0.930	0.021	0.000	0.000
m21-6	607 ± 12	0.064	0.001	0.000	0.000	0.001	0.024	0.000	0.000	0.000	0.956	0.020	0.000	0.000
m20-7	612 ± 14	0.087	0.003	0.000	0.001	0.001	0.032	0.000	0.000	0.000	0.948	0.014	0.000	0.000
m20-8		0.088	0.000	0.001	0.001	0.000	0.032	0.000	0.000	0.000	0.948	0.014	0.000	0.000
m20-9		0.087	0.000	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.952	0.011	0.000	0.000
m20-11	601 ± 12	0.066	0.000	0.000	0.020	0.000	0.027	0.002	0.000	0.000	0.933	0.020	0.000	0.000

Table 7 (cont.)

Name	Nb	Ti	La	Ce	Pr	Nd	Sm	Gd	Dy	Yb	Y	Th	U
m9-1	0.000	0.000	0.265	0.486	0.045	0.134	0.021	0.009	0.004	0.000	0.023	0.033	0.003
m9-3	0.000	0.001	0.263	0.483	0.045	0.133	0.020	0.010	0.004	0.000	0.024	0.034	0.003
m3-4	0.000	0.000	0.259	0.481	0.046	0.134	0.021	0.010	0.004	0.000	0.028	0.030	0.002
m3-5	0.000	0.001	0.242	0.467	0.045	0.138	0.022	0.010	0.004	0.000	0.030	0.053	0.003
m3-6	0.000	0.001	0.242	0.477	0.046	0.142	0.023	0.011	0.005	0.001	0.033	0.035	0.003
m2-8	0.000	0.000	0.247	0.464	0.045	0.139	0.024	0.011	0.005	0.001	0.036	0.043	0.004
m2-9	0.000	0.000	0.253	0.472	0.045	0.135	0.020	0.010	0.004	0.000	0.023	0.046	0.004
m2-10	0.000	0.001	0.241	0.462	0.044	0.139	0.023	0.011	0.005	0.001	0.034	0.045	0.004
m2-11	0.000	0.000	0.249	0.478	0.046	0.141	0.024	0.011	0.004	0.000	0.026	0.038	0.002
m2-12	0.000	0.001	0.243	0.475	0.047	0.143	0.023	0.012	0.005	0.000	0.029	0.034	0.003
m22-1	0.000	0.000	0.247	0.483	0.046	0.140	0.022	0.010	0.004	0.000	0.027	0.040	0.003
m22-2	0.000	0.000	0.258	0.487	0.046	0.136	0.020	0.009	0.004	0.000	0.024	0.032	0.002
m22-3	0.000	0.000	0.242	0.478	0.046	0.143	0.023	0.011	0.005	0.001	0.028	0.043	0.003
m22-4	0.000	0.000	0.247	0.474	0.046	0.141	0.022	0.010	0.005	0.000	0.028	0.041	0.003
m21-5	0.001	0.000	0.246	0.458	0.044	0.140	0.022	0.010	0.003	0.000	0.018	0.071	0.003
m21-6	0.000	0.000	0.242	0.474	0.046	0.142	0.021	0.010	0.004	0.000	0.024	0.044	0.003
m20-7	0.000	0.000	0.243	0.475	0.046	0.141	0.023	0.010	0.004	0.001	0.026	0.045	0.003
m20-8	0.000	0.001	0.248	0.471	0.047	0.140	0.022	0.010	0.004	0.000	0.027	0.045	0.003
m20-9	0.000	0.000	0.247	0.479	0.047	0.144	0.024	0.010	0.005	0.000	0.032	0.037	0.001
m20-11	0.000	0.000	0.248	0.479	0.046	0.139	0.023	0.010	0.005	0.001	0.037	0.035	0.004

Table 7 (cont.)

Grain	Molar fractions ¹									Huttonite ²	Cheralite ²
	XLaPO ₄	XCePO ₄	XPrPO ₄	XNdPO ₄	XSmPO ₄	XGdPO ₄	XDyPO ₄	XYbPO ₄	XYPO ₄	4*(Th+U+Si)	4*(REE+Y+P)
m9-1	0.2560	0.4693	0.0438	0.1299	0.0201	0.0091	0.0041	0.0003	0.0224	0.2363	7.7705
m9-3	0.2553	0.4680	0.0433	0.1289	0.0197	0.0093	0.0039	0.0003	0.0233	0.2647	7.7274
m3-4	0.2513	0.4674	0.0448	0.1305	0.0206	0.0094	0.0035	0.0004	0.0271	0.2218	7.7714
m3-5	0.2348	0.4522	0.0433	0.1339	0.0211	0.0100	0.0042	0.0003	0.0294	0.3724	7.6039
m3-6	0.2346	0.4622	0.0441	0.1377	0.0220	0.0105	0.0049	0.0006	0.0319	0.2404	7.7378
m2-8	0.2381	0.4468	0.0431	0.1336	0.0226	0.0108	0.0048	0.0007	0.0346	0.3041	7.6713
m2-9	0.2446	0.4569	0.0439	0.1305	0.0198	0.0099	0.0037	0.0003	0.0223	0.3783	7.5912
m2-10	0.2343	0.4485	0.0431	0.1350	0.0225	0.0105	0.0044	0.0007	0.0333	0.3433	7.6170
m2-11	0.2420	0.4655	0.0446	0.1369	0.0234	0.0107	0.0042	0.0003	0.0256	0.2669	7.7369
m2-12	0.2362	0.4610	0.0454	0.1385	0.0225	0.0113	0.0049	0.0001	0.0286	0.2576	7.7256
m22-1	0.2382	0.4662	0.0442	0.1356	0.0210	0.0094	0.0039	0.0002	0.0265	0.2779	7.7180
m22-2	0.2492	0.4714	0.0441	0.1318	0.0196	0.0092	0.0036	0.0003	0.0237	0.2434	7.7566
m22-3	0.2340	0.4613	0.0444	0.1379	0.0218	0.0102	0.0049	0.0005	0.0266	0.2959	7.6996
m22-4	0.2392	0.4593	0.0442	0.1362	0.0212	0.0100	0.0046	0.0002	0.0273	0.2975	7.6894
m21-5	0.2373	0.4421	0.0424	0.1354	0.0211	0.0092	0.0032	0.0000	0.0176	0.4746	7.4802
m21-6	0.2344	0.4603	0.0443	0.1377	0.0208	0.0094	0.0040	0.0004	0.0230	0.2855	7.6744
m20-7	0.2359	0.4610	0.0450	0.1365	0.0223	0.0099	0.0037	0.0005	0.0251	0.3202	7.6627
m20-8	0.2407	0.4573	0.0455	0.1358	0.0213	0.0095	0.0041	0.0004	0.0258	0.3174	7.6654
m20-9	0.2382	0.4618	0.0455	0.1385	0.0229	0.0101	0.0044	0.0003	0.0313	0.2555	7.7575
m20-11	0.2369	0.4574	0.0441	0.1326	0.0217	0.0097	0.0046	0.0006	0.0356	0.2657	7.6818

^{1,2}Calculated after Pyle et al. (2001).

Acceleration voltage 20kV

Probe diameter 5µm