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Zircon and Titanite U–Pb SHRIMP dating of unexposed basement units of the Buenos Aires region, southeastern Río de La Plata Craton, Argentina

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ABSTRACT

We present U–Pb Sensitive High Mass Resolution Ion MicroProbe (SHRIMP) data of unexposed igneous-metamorphic basement rocks from two areas of the southeastern Río de la Plata craton (RPC; Buenos Aires city) located within the Buenos Aires–Piedra Alta (BAPA) terrane – and the Tapalqué area (Buenos Aires province) – located within the Tandilia terrane, and discuss the tectonic evolution of that portion of the craton based on both the new data and previous work. The newly obtained geochronological data of drill cores indicate that: (a) arc magmatism occurred at 2164–2186 Ma corresponding to early 'Trans-Amazon' (early Rhyacian) arc magmatism; (b) the age of collision between the BAPA and Tandilia terranes is inferred to have commenced at ca. 2110 Ma; (c) peak metamorphism occurred at ca. 2069 Ma; and (d) the presence of rocks related to the RPC is confirmed under Cenozoic sediments in a large area between Martin Garcia Island and Tandil. We envisage an early Rhyacian divergent double subduction scheme between the BAPA and Tandilia terranes – i.e. N-dipping towards BAPA and S-dipping towards Tandilia – prior to the late Rhyacian collision between these two terranes.

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Río de la Plata Craton; Rhyacian; Buenos Aires Province; U–Pb SHRIMP dating

1. Introduction

The South America continent has three main cratons: Amazon, São Francisco, and Río de la Plata. The Río de la Plata craton (RPC) is the least known of these, mainly because it is extensively covered by the Paraná Basin and, to a smaller extent, by the Salado and Claromecó Basins, as well as by Cenozoic sedimentary cover. The craton is dominantly Rhyacian (Palaeoproterozoic, 2300–2050 Ma) in age but it includes older Archaean segments – such as the Nico Perez terrane of Uruguay (Hartmann *et al*. 2001) – and younger Statherian components such as the Taquarembó terrane of south Brazil (Camozzato *et al*. 2013).

The craton has more than 90% of its area covered, and the recent access of drill cores in Buenos Aires province has provided an opportunity to investigate its hidden basement, verifying its age and confirming the presence of the craton.

The present U–Pb Sensitive High Mass Resolution Ion MicroProbe (SHRIMP) and geochemical study focuses attention on unexposed igneous-metamorphic basement units from two areas of the southeastern RPC. The first is the city of Buenos Aires, located within the Buenos Aires-Piedra Alta terrane (see section 2, below), and the second is the Tapalqué area about 300 km to the south (Buenos Aires province), located within the Tandilia terrane (*sensu* Chernicoff *et al*. 2014); Figure 1.

For the present work, drill cores from the city of Buenos Aires were made available by the Geological and Mining Survey of Argentina (SEGEMAR), as these formed part of an old rotary-drilling programme undertaken by SEGEMAR's predecessor institution during the first half of the twentieth century. The drill cores analysed correspond to the wells referred to as 'Sociedad Rural 290' and 'Riachuelo 355', where the numbers 290 and 355 indicate the depth in metres at which the basement was reached. In addition, a recent exploratory reverse circulation well undertaken on behalf of SEGEMAR to evaluate the (low-enthalpy) geothermal potential of the Tapalqué area, central Buenos Aires province, unexpectedly reached the basement at ~400 m and producied basement cuttings which we have subsequently analysed.

The new U–Pb SHRIMP and geochemical data presented in this article are analysed in the context of the evolution of the southeastern RPC (e.g. Chernicoff *et al*. 2014, and references therein).

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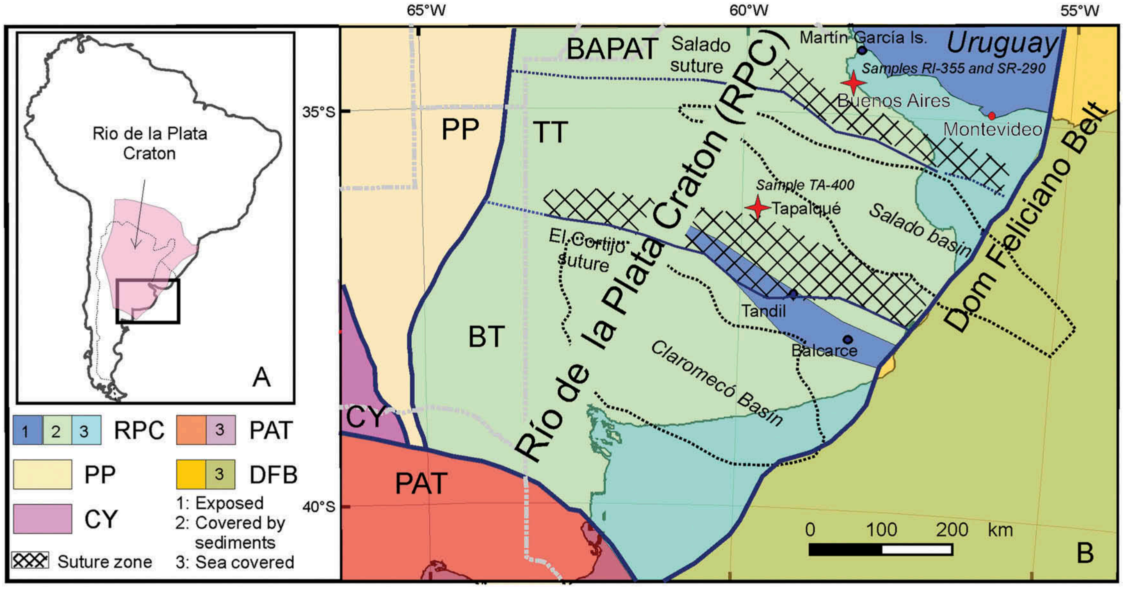

Figure 1. (a) Locality map of the RPC in South America (national boundaries of Argentina and Uruguay delineated for easy reference; extension of the craton includes Pampia terrane, in accordance with Chernicoff *et al*. 2010. (b) Locality map and tectonic context of the drill holes at Buenos Aires City and Tapalqué (modified after Chernicoff *et al*. 2014). RPC, Río de la Plata Craton; BAPAT, Buenos Aires–Piedra Alta terrane[(1)]; TT, Tandilia terrane[(2)]; BT, Balcarce terrane[(2)]; PAT, Patagonia terrane[(3)]; PP, Pampia terrane[(4)]; CY, Cuyania terrane[(4)]; DBF, Dom Feliciano Belt[(5)]. Cross-hatching: Salado and El Cortijo suture zones. Location of boreholes: Tapalqué borehole 36°21´33.75´´ S, 60°02´10.19´´ W; Sociedad Rural 290 borehole 34°24.37´28´´ S, 58°34.41´26´´W; Riachuelo 355 borehole 34°38.52´37 ´´S, 58°21.25´45´´W [(1)]Mostly Palaeoproterozoic (Archaean, Mesoproterozoic); [(2)]mostly Palaeoproterozoic; [(3)]mostly Palaeo-Mesoproterozoic; [(4)]mostly Mesoproterozoic; [(5)]late Neoproterozoic.

2. Geological setting

The RPC of southern South America encompasses autochthonous Rhyacian (2300 to 2050 Ma) (e.g. Cordani *et al*. 2000; Santos *et al*. 2003; Dalla Salda *et al*. 2005; Rapela *et al*. 2007; and references therein), locally Archaean (e.g. Hartmann *et al*. 2002; Pankhurst *et al*. 2003; Cingolani 2011; and references therein), and younger Statherian (1800 to 1600 Ma) components such as the Taquarembó terrane of south Brazil (Camozzato *et al*. 2013). These components were interpreted as descendant segments of Rodinia fragmentation rearranged within the Gondwana framework (e.g. Fuck *et al*. 2008). Its main exposures occur near the Atlantic margin of the continent, as in south Brazil (Tijucas and Taquarembó terranes – Hartmann *et al*. 2007; Pertille *et al*. submitted; Curitiba and Luiz Alves 'microcratons'-Siga Júnior *et al*. 2007; Basei *et al*. 2013), in Uruguay (Piedra Alta and Nico Perez terranes; Bossi and Cingolani 2009), and also in the Buenos Aires province of Argentina (Tandilia belt; Hartmann *et al*. 2002; Cingolani 2011). In addition, small outcrops of the craton also occur within the Río de la Plata estuary (i.e. Martín Garcia Island (Argentina)) and on small islands off the towns of Carmelo and Colonia del Sacramento (Uruguay).

Chernicoff *et al*. (2014) recently analysed the geological, geochronological, and geophysical information from the southern RPC, suggesting that the formation of that part of the craton involved two coeval Rhyacian sutures (associated with the 'Trans-Amazon' orogeny, or 'Transplatense' orogeny as referred to by Santos *et al*. (submitted), within the RPC) amalgamating three terranes (i.e. Balcarce, Tandilia, and Buenos Aires). This amalgamation would have been preceded by the Siderian (2500 to 2300 Ma) extension of Neoarchaean crust (proto-RPC), the development of narrow oceans, sedimentation over transitional continental to oceanic crust, and arc magmatism.

The Buenos Aires–Piedra Alta terrane (BAPA), a term preferred by the present authors to denote the Buenos Aires terrane (as per Chernicoff *et al*. 2014), plus the Piedra Alta terrane (as per Sanchez Bettucci *et al*. 2010; Oyhantçabal *et al*. 2011; and references therein), is largely covered though easy to infer as a single tectono-stratigraphic unit in the available gravimetric surveys (e.g. Servicio Geográfico Militar del Uruguay 1996). In southwestern Uruguay, the BAPA terrane is composed of a granitic gneiss (Florida) belt separated by two supracrustal metamorphic belts (San José and Arroyo

Grande). Santos *et al*. (submitted) have recently identified Mesoproterozoic rocks (e.g. early Ectasian and Stenian metagabbros) on Martín García Island, and intermediate-to-acidic Rhyacyan plutonic rocks – bound to have formed part of the westernmost Florida belt on the Sola and Dos Hermanas Islands off Carmelo town – as part of their reassessment of the geographic and temporal extensions of the RPC.

The Precambrian basement of Tandilia comprises a Rhyacian igneous-metamorphic assemblage, Buenos Aires Complex, covered by thin Neoproterozoic to lower Palaeozoic sedimentary units displaying sub-horizontal bedding (e.g. Cingolani 2011, and references therein). The Buenos Aires Complex is highly deformed, characterized by the occurrence of wide mylonitic belts, and mostly consists of gneisses, migmatites, amphibolites, and minor ultramafic rocks intruded by tonalitic/granitic and leuco-monzogranitic plutons. There are also subordinate amounts of schist, marble, metavolcanic units, and dikes of felsic and mafic compositions. An association of low-grade metamorphic rocks comprising metacherts, metagreywackes, and metabasites (El Cortijo Formation) is thought to represent a slice of oceanic crust (Teruggi *et al*. 1988; Ramos 1999), and would be part of the Rhyacian El Cortijo suture amalgamating the Balcarce and Tandilia terranes (Chernicoff *et al*. 2014). The latter authors have also indicated the occurrence of a conspicuous low magnetic anomaly at the southern boundary of the Tandilia terrane, caused precisely by demagnetization associated with shearing and mylonitization.

The emplacement of the mostly I-type granitoid plutons in the thick gneissic sequence of the Tandil area is thought to be broadly coeval with the regional high-temperature metamorphism, mylonitization, and anatexis (Cingolani 2011, and references therein).

In the Balcarce area, Massonne *et al*. (2012) estimated the onset of migmatization – viewed as a widespread process producing heat at mid crustal levels – at ca. 2073 Ma, as indicated by U–Th–Pb dating of monazite in a partially migmatized metapelite. The latter authors have also invoked the occurrence of underthrusting of oceanic crust without eclogitization – as opposed to subduction leading to continental collision – for the Rhyacian peak pressure metamorphism in the Balcarce area.

Hf and Nd isotopic data of the Tandil and Balcarce areas unequivocally point to the hidden occurrence of Neoarchaean crust in the southeastern portion of the RPC (e.g. Cingolani 2011).

3. Analysed rocks

Two drill cores were sampled from the Buenos Aires area (Sociedad Rural 290 and Riachuelo 355). Sample Tapalqué 400 – from the basement at the bottom of a well through Cenozoic sediments, ~130 km to the northwest of Tandil – corresponds to drilling cuttings. All three samples are orthogneiss. Representative quantitative modal data are plotted in Figure 2a (i.e. Tapalqué sample plots as granodiorite, and both Riachuelo and Sociedad Rural samples plot as monzogranite). The Sociedad Rural 290 drill core is a medium- to coarse-grained (0.5–2.5 mm), pinkish-grey monzogranitic gneiss. Its foliation is defined by alternating bands of muscovite and mostly chloritized biotite, often showing flexures, and bands of moderately sericitized microcline, albite, and cataclastic quartz.

The Riachuelo 355 drill core is a medium-grained monzogranitic gneiss. Its foliation is also characterized by alternating bands of partially chloritized biotite (muscovite, titanite) and bands of moderately sericitized microcline, sodic oligoclase, and cataclastic quartz.

The basement cuttings retrieved from the Tapalqué well are small fragments of granodioritic gneiss that were first analysed with binocular magnifying glasses and then assembled for thin sections. They are composed of calcic oligoclase – with deformed twinning, partially altered to sericite and epidote, microcline – less altered than plagioclase, cataclastic quartz, cloritized biotite, and titanite.

4. Geochemistry

Samples of the three units were analysed for major elements by inductively coupled plasma (ICP) and for trace and rare earth elements (REEs) by ICP mass spectrometry (ICP-MS) at Activation Laboratories of Ancaster, Ontario, Canada, as a complement to the geochronological study. The studied gneisses are monzogranitic to granodioritc (Supplementary Table 1; see http://dx.doi.org/10.1080/00206814.2015.1110503 for supplementary tables), with lower SiO_2 (68.78%) and high total iron (3.19%) contents in the Tapalqué sample as compared to the monzogranitic gneisses (SiO2 > 73% and total iron < 1.4%) of Buenos Aires; all are constrained to the subalkaline field. Considering the likely mobilization of major elements during metamorphism, the classification of Winchester and Floyd (1977) is a guide only, in addition to the TAS classification of Le Maitre *et al*. (1989), both being consistent with the petrographic classification. In the A/CNK–A/NK diagram (Maniar and Piccoli 1989), samples show slightly peraluminous to metaluminous features.

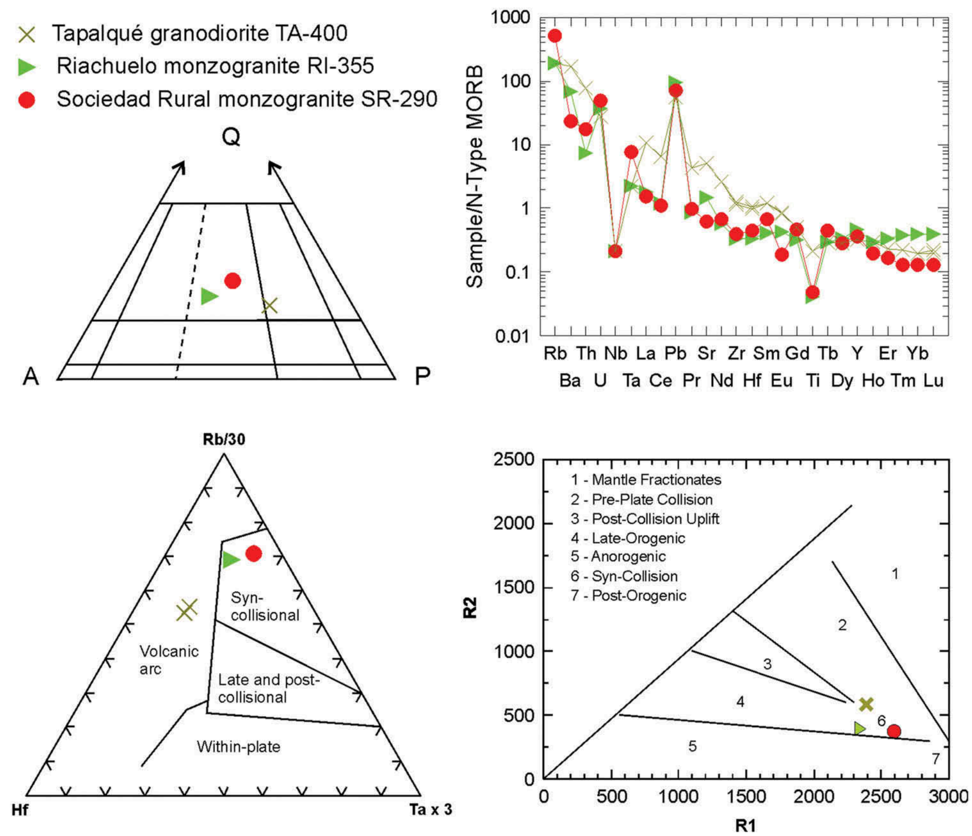

Figure 2. Composition diagrams of the analysed samples. (a) Modal Quartz (Q)–Alkali–Feldspar (F)–Plagioclase (P) diagram for oversaturated plutonic rocks (after Streckeisen 1976); (b) N-MORB normalized spider diagram (primitive mantle values after McDonough and Sun 1995); (c) trivariate plot of Hf, Rb/30 and Ta × 3 (Harris *et al*. 1986); (d) plot of the composition of the analysed granitoids into the R1–R2 diagram of Batchelor and Bowden (1985). R1, 4Si-11(K+Na)-2(Fe+Ti); R2, 6Ca+2Mg+Al. Green triangle, Riachuelo monzogranite (RI-355); red circle, Sociedad Rural monzogranite (SR-290); green crosses, Tapalqué granodiorite (TA-400).

Table 1. Synthesis of new geochronological data in the context of the Trans-Amazon orogeny, southeastern RPC. SHRIMP ages obtained by previous authors indicated for comparison.

Subduction stage	Collision stage	Peak metamorphism
At ca. 2164–2186 Ma: - Crystallization of magmatic zircon at 2164 ± 5 Ma (granodioritic gneiss Tapalqué well, Tandilia terrane; magmatic arc chemical signature) - 2186 ± 10 Ma: Age of inherited zircon grains (granitic gneiss Riachuelo well, Buenos Aires terrane).	Commencement at ca. 2110 Ma, i.e.: - metamorphic titanite grown at 2120 ± 11 Ma, (granodioritic gneiss Tapalqué well, Tandilia terrane) - magmatic zircon crystallized at 2106 ± 5 Ma, (granitic gneiss Riachuelo well, Buenos Aires terrane; syn-collisional chemical signature).	At 2069 ± 13 Ma, represented by late growth of metamorphic titanite, in the granitic gneiss Sociedad Rural well, Buenos Aires terrane. Syn-collisional chemical signature of granitic gneiss, Sociedad Rural well.
COMPARABLE U–Pb SHRIMP AGES OBTAINED BY PREVIOUS WORKERS		
2166 ± 7 Ma (monzogranite, Tandil)[1,2] 2162 ± 5 Ma (granitoid, Azul)[2] 2170 ± 14 Ma (charno-enderbite, Tandil)[1] 2176 ± 6 Ma (garnet granite, Tandil)[1] 2183 ± 4 Ma (tonalite gneiss, Tandil)[1,2] 2162 ± 6 Ma (diorite, borehole Córdoba)[4]	2109 ± 15 Ma (syenogranite, Azul)[1] 2113 ± 12 Ma (mylonitized granotoid, Azul)[2] ca. 2100 Ma (trondhjemite, Tandil)[1]	Ca. 2073 Ma (partially migmatized metapelite. U-Pb-Th monazite, Balcarce)[3] 2073 ± 7 Ma (garnet tonalite, Balcarce)[1,2] 2066 ± 9 Ma (monzogranite, Tandil)[1] 2088 ± 6 Ma (granite, borehole Córdoba)[4]

Note: [1]Hartmann *et al*. 2002; [2]Cingolani *et al*. 2002; [3]Massonne *et al*. 2012; [4]Rapela *et al*. 2007

Chondrite-normalized REE patterns (not shown) display no light rare earth element (LREE) enrichment (except for the Tapalqué granodioritic gneiss) and relatively flat patterns for the heavy rare earth elements (HREEs), which suggests a shallow garnet-free source.

In an N-MORB-normalized spider diagram (Figure 2b), all samples exhibit enriched large-ion lithophile elements (LILEs) (Rb, Ba, K) relative to high-field-strength elements (HFSEs) (Nb, Ti, Th) typical of continental arc-related signatures. In the trivariate plot of Hf, Rb/30, and Ta × 3 (Figure 2c, after Harris *et al*. 1986), the Tapalqué sample falls within the volcanic arc field and the Sociedad Rural and Riachuelo samples within the syn-collisional field. This is also consistent with the R1–R2 diagram (Figure 2d, after Batchelor and Bowden 1985) where the Tapalqué sample plots near the pre-plate collision field and the other two samples within the syn-collisional field. As a whole, the presented diagrams are consistent with the envisaged arc magmatic protolith of the studied samples (see Discussion, below).

5. Geochronology

5.1. Methodology

The samples analysed are Sociedad Rural 290 (monzogranitic gneiss), Riachuelo 355 (monzogranitic gneiss), and Tapalqué 400 (granodioritic gneiss). The rocks were crushed, milled, sieved at 60 mesh, and washed to remove the clay and silt fractions. The remaining material, corresponding to fine and very fine sand, was dried and processed by two heavy liquids: lithium-sodium tungstate (LST), density 2.85 and tetra-bromo-ethane (TBE), density 3. The heavy mineral concentrates were separated into four fractions using a Frantz® magnetic separator. Zircon grains were picked from the less magnetic fraction and titanite from the more magnetic fraction at 1 ampere and 5° lateral inclination, and then mounted in an epoxy disc of 2.5 cm diameter together with the analytical standards. The mount was polished and coated with carbon for imaging using a TESCAN-VEGA scanning electron microscope at the Centre for Microscopy, Characterization and MicroAnalyses of the University of Western Australia. This carbon coating was removed and replaced by a gold coating for SHRIMP U–Pb analyses.

SHRIMP II U–Pb analyses were performed at Curtin University in two sessions using an analytical spot size of about 20–25 micrometres in diameter. Individual analyses are composed of nine measurements repeated in five scans. The following masses were analysed for zircon: (Zr_2O, ^{204}Pb, background, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{238}U, ^{248}ThO, ^{254}UO), and ($^{200}CaTi_2O_4$, ^{204}Pb, background, ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{248}ThO, ^{254}UO, $^{270}UO_2$) for titanite. The standards D23 and NBS611 were used to identify the position of the peak of the mass ^{204}Pb, whereas the calibration of the U content and the Pb/U ratio were done using the zircon standard BR266 (559 Ma, 903 ppm U; Stern 2001). For titanite the standard used for calibration was Khan (522 Ma; 680 ppm U; Heaman 2009). Data were reduced using SQUID® 1.03 software (Ludwig 2001) and the ages calculated using Isoplot® 3.0 (Ludwig 2003). The ages presented are $^{207}Pb/^{206}Pb$ ages, calculated as the upper intercept of the concordia plot or concordia ages (Ludwig 2003), all calculated at the 2σ level. The individual analyses are quoted at the 1σ level (Supplementary Table 1).

5.2. Results and evaluation

5.2.1. Sample Riachuelo 355

A total of 13 zircon crystals were analysed (Supplementary Table 2). Most of the grains suffered lead loss generating discordant data that nevertheless align in two regression lines: (1) five analyses align in the same line intercepting the concordia curve at 2186 ± 10 Ma (MSWD = 1.4) ($^{207}Pb/^{206}Pb$ age, Figure 3); and (2) eight analyses align in the same line intercepting the concordia curve at 2106 ± 5.0 Ma (MSWD = 1.7) ($^{207}Pb/^{206}Pb$ age, forced to origin, Figure 3). It is worth noting that the uncertainties of these two populations do not overlap, since the older population ranges from 2196 to 2176 Ma and the younger population from 2111 to 2101 Ma. Notably, the older population has higher Th/U ratios (0.4) when compared to the magmatic population (0.14). The older population has less U (87 ppm) whereas the younger group has more U (276 ppm). Examples of back-scattered electrons (BSE) images used for spot location are given in Figure 4.

5.2.2. Sample Sociedad Rural 290

Only three metamorphic titanite crystals could be recovered and dated (Supplementary Table 2), yielding a mean average age of 2069 ± 13 Ma (MSWD = 1.6, probability = 0.21; Figure 5).

The determined age (2069 ± 13 Ma; MSWD = 1.6, calculated at 2 sigma) is the upper concordia intercept forcing the lower intercept to zero. This age also coincides

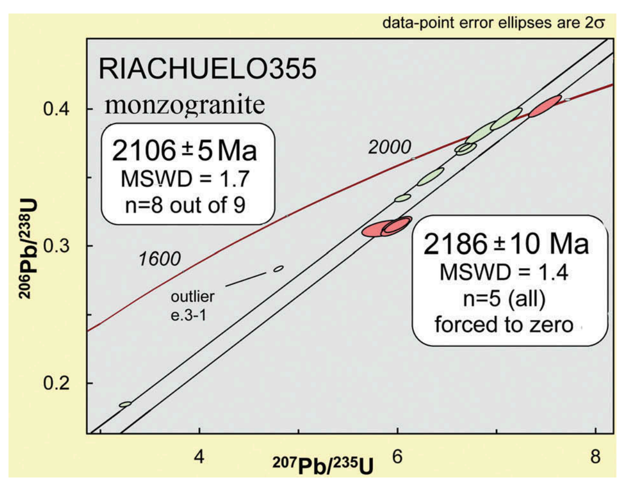

Figure 3. Concordia diagram showing discordant data of zircon (n = 13) of monzogranitic gneiss (sample Riachuelo 355).

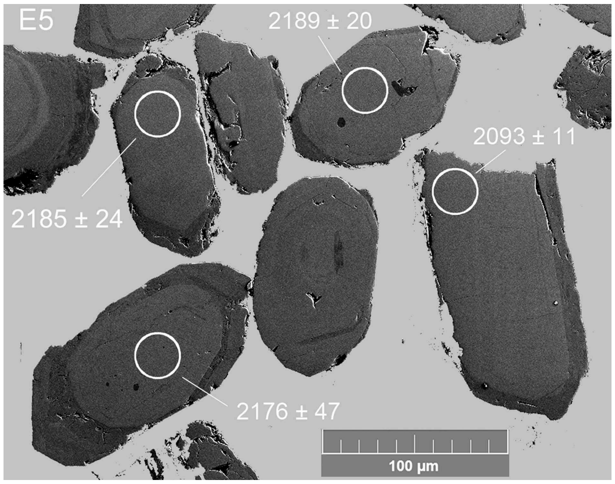

Figure 4. Back-scattered image of zircon (spots e.5–1, e.5–1-2, e.5–1-3, e.5–2) sample Riachuelo 355.

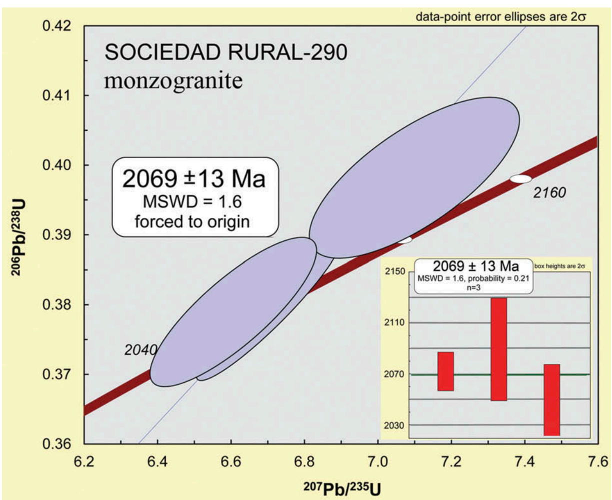

Figure 5. Plot of weighted mean average ^{207}Pb/^{206}Pb age of three metamorphic titanite crystals and upper concordia intercept age; see text for explanation (sample Sociedad Rural 290).

with the mean average age of the ^{207}Pb/^{206}Pb ages (2069 ± 13 Ma), and we show both diagrams in Figure 5. However, we do not use the concordia age for this sample because one grain (b.1–2) is 3.3% discordant, precluding calculating the concordia age at 2 sigma.

5.2.3. Sample Tapalqué 400

A total of 11 crystals were analysed (seven zircons and four titanites; Supplementary Table 2). All zircons are magmatic. Most of the grains suffered lead-loss generating discordant data. The presented age of 2164 ± 5 Ma (MSWD = 1.5, probability = 0.19) has its lower intercept forced to zero, as indicated in the plot (Figure 6). This is the magmatic age of the granodiorite.

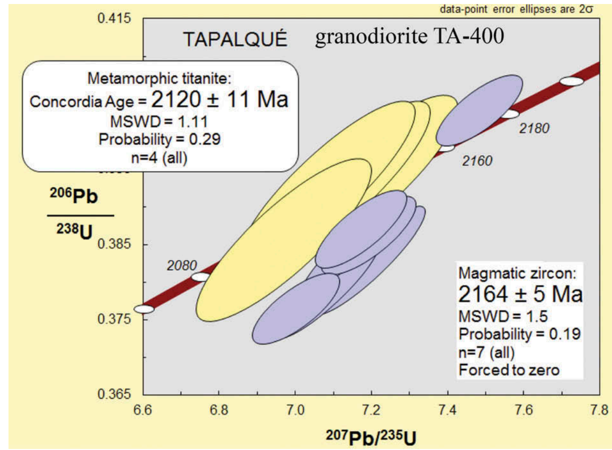

Figure 6. Concordia diagram showing discordant line for zircon (7) and titanite (4) of granodioritic gneiss (sample Tapalqué, TA-400).

Four analyses of metamorphic titanite group at the concordia age of 2120 ± 11 Ma (MSWD = 1.11; probability = 0.29), including the errors of the radiogenic decays, marking the timing of a metamorphic event (Figure 5).

6. Discussion

The pre-Brasilian (Neoproterozoic-Cambrian) tectonic evolution of the southeastern RPC is considered to have involved two coeval Rhyacian sutures – associated with the Rhyacian 'Trans-Amazon' orogeny (newly proposed to be termed as Transplatense orogeny, within the RPC; Santos *et al*., submitted) – that amalgamates three terranes: Balcarce, Tandilia, and Buenos Aires. This amalgamation would have been preceded by the Siderian extension of Neoarchaean crust (proto-RPC), the development of narrow oceans, sedimentation over transitional continental to oceanic crust, and arc magmatism (Chernicoff *et al*. 2014).

The model proposed by the latter authors is mostly followed in the present article, though differing by a divergent double-subduction scheme between the Tandilia and Buenos Aires terranes, envisaged here for the early 'Transplatense' arc magmatism (Figure 7). The latter scheme – also described at many localities worldwide and at different time frames (e.g. Palaeozoic Lachlan fold belt; Soesoo *et al*. 1997; recent Molucca Sea Plate; Widiwijayanti *et al*. 2004) – takes into account the evidence of roughly coeval arc magmatism at both the Tandilia and Buenos Aires terranes, which is permissive of coeval subduction beneath both terranes. This scheme matches the new geochronological (and

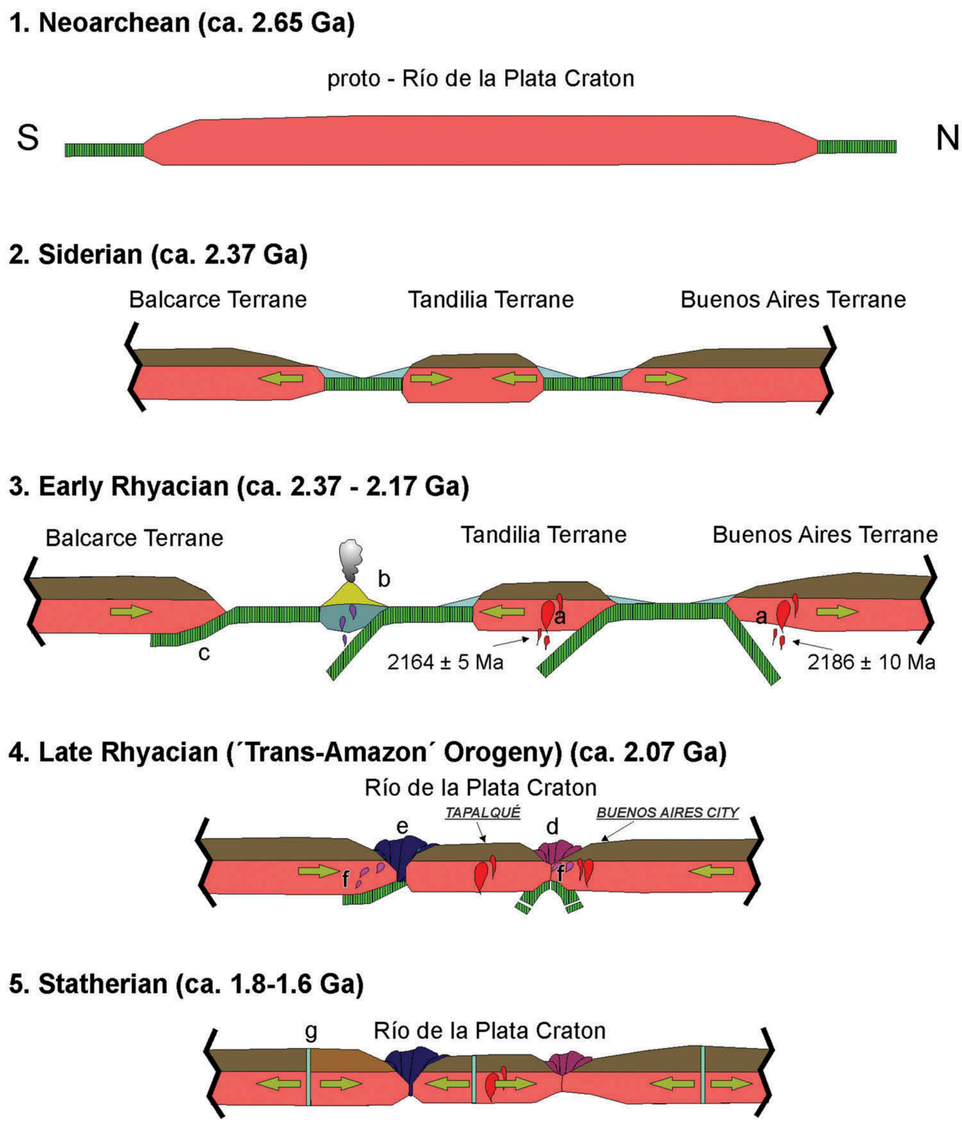

Figure 7. Pre-Neoproterozoic tectonic evolution of the southeastern RPC (modified after Chernicoff *et al.* 2014). a, calc-alkaline magmatism; b, El Cortijo island arc; c, underthrusting of oceanic crust (after Massonne *et al.* 2012); d, Salado suture zone; e, El Cortijo suture zone; f, syn-collisional magmatism; g, tholeiitic dikes. Tapalqué and Buenos Aires City indicated (see stage 4) for easy reference. Sketch not to scale.

geochemical) data presented in this article (see Table 1): (1) 2164 ± 5 Ma (zircon age, granodioritic gneiss Tapalqué, Tandilia terrane); and (2) 2186 ± 10 Ma (age of inherited zircon grains, monzogranitic gneiss Riachuelo, Buenos Aires city, Buenos Aires terrane). In turn, the latter ages are also consistent with most of the Rhyacian ages of igneous rocks of the Tandil area, as reported by Hartmann *et al.* (2002) and Cingolani *et al.* (2002) – 2162 ± 5, 2166 ± 7, 2170 ± 14, 2176 ± 6, 2183 ± 4 Ma – and by Rapela *et al.* (2007) – 2162 ± 6 Ma, in a diorite from a borehole in Córdoba province (see Table 1). Otherwise, the roughly coeval tectonic framework between the Tandilia and Balcarce terranes is not further discussed here as it follows the scheme previously proposed by Chernicoff *et al.* (2014); see also Figure 7.

According to the new geochronological data, the subsequent, late Rhyacyan collisional stage (see Table 1) would have started by ca. 2110 Ma, as indicated both by the metamorphic titanite (granodioritic gneiss Tapalqué, Tandilia terrane) dated at 2120 ± 11 Ma and the magmatic zircon (granodioritic gneiss Riachuelo, Buenos Aires terrane) dated at 2106 ± 5 Ma. These ages coincide with a group of values reported by previous workers – a syenogranite of Azul dated at 2109 ± 15 Ma (Hartmann *et al.* 2002), a mylonitized granitoid of Azul dated at 2113 ± 12 Ma (Cingolani *et al.* 2002), and a trondhjemite of Tandil dated at ca. 2100 Ma (see Table 1) – in addition to a quartz-diorite and a syenodiorite of Martín García Island dated, respectively, at 2103 ± 7 and 2115 ± 13 Ma (Santos *et al*., submitted).

The metamorphic peak would have been reached at ca. 2069 Ma (i.e. approximately 40 million years after commencement of collisionat ca. 2110 Ma), as indicated by the age of the metamorphic titanite of the monzogranitic gneiss (Sociedad Rural, Buenos Aires terrane; Table 1). The syn-collisional geochemical signature yielded by the latter gneiss is consistent with this tectonic framework. Notably, the age of metamorphism herein referred to coincides with a U–Pb–Th monazite age of a partially migmatized metapelite of Balcarce (ca. 2073 Ma; Massonne *et al*. 2012), a garnet tonalite of Balcarce (2073 ± 3 Ma; Hartmann *et al*. 2002; and Cingolani *et al*. 2002), a monzogranite of Tandil (2066 ± 9 Ma; Hartmann *et al*. 2002), as well as – within the error range – an undeformed granite from a borehole in Córdoba province (2088 ± 6 Ma; Rapela *et al*. 2007)(see Table 1).

Otherwise, it should be mentioned that no older (>2200 Ma) magmatic zircon, like that detected by Hartmann *et al*. (2002) and Cingolani *et al*. (2002) in Tandil – i.e. tonalite TA-1: 2234 ± 15 Ma/2228 ± 6 Ma – has been identified in our study area, nor have any inherited zircons >2200 Ma, as in Tandil (Hartmann *et al*. (2002); Cingolani *et al*. (2002), been found. The only inherited zircon we have found is dated at 2186 ± 10 Ma (Riachuelo monzogranite, crystallization age 2106 ± 5 Ma), in a rather similar age range relationship between inheritance and crystallization to that identified in the granitoid 'TA-11' of Azul, i.e. 2185 ± 6 and 2162 ± 5 Ma, respectively (Cingolani *et al*. 2002).

The type of temporal relationship herein envisaged between collision and metamorphic peak – i.e. collision preceding metamorphic peak by tens of millions of years – would indicate that the 'Transplatense' (or 'Trans-Amazon', within the RPC) could represent a hot orogen (e.g. Clark *et al*. 2014).

The timing and context of the tectonic stages herein envisaged for the southeastern Río de la Plata Craton are similar to those of the 'Trans-Amazon' Cycle in southern Brazil (e.g. Silva *et al*. 2000), notably the strongly juvenile Águas Mornas granitic gneiss dated at 2175 ± 13 Ma – assigned to an early subduction stage, and the late event of collision and crustal melt dated at ca. 2.0 Ga. Pending Hf isotope study of the dated zircon should contribute to confirm the juvenile nature of the early Rhyacian arc magmatism in the study region, as already established at Tandil and Balcarce (Cingolani *et al*. 2010).

Disclosure statement

No potential conflict of interest was reported by the authors.

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