ZIRCON U-Pb SHRIMP DATING OF THE SERRA DOS ÓRGÃOS AND RIO DE JANEIRO GNEISSIC GRANITIC SUITES: IMPLICATIONS FOR THE (560 Ma) BRASILIANO/PAN-AFRICAN COLLAGE*

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Abstract Recent systematic geological mapping at a scale of 1:400,00 scale revealed that the State of Rio de Janeiro State is an important field-laboratory to test the connections of the Costeiro Domain of the Ribeira Belt (former Rio Doce Orogen) and the Araçuaí Orogen. The regional geological mapping was supported by zircon U-Pb SHRIMP geochronological data of three syn-orogenic, thrust-related key plutons, namely the pre- to syn-collisional Serra dos Órgãos Batholith and the syn-collisional Corcovado and Pão de Açúcar gneissic granites (Rio de Janeiro Suite). These plutons have a chemical and tectonic signatures akin to the Australian I-and S-type continental arc granitoids. The Serra dos Órgãos Batholith yielded a crystallization age of 569± 6 Ma, whereas the syn-collisional Pão de Açúcar and Corcovado gneissic granites ages of 559 ± 4 Ma and 560± 7 Ma, respectively. The new data, supported by the integration of the geochronological data on the Araçuaí Orogen magmatism in Espírito Santo and Minas Gerais states, cast new lights on the regional Neoproterozoic (Brasiliano) evolution. Similar late Precambrian ages, spanning from *ca.* 580-560 Ma, recently obtained on similar syn-collisional plutons from the northern segment of the Araçuaí Orogen, highlights the synchronous development of the collisional event in Costeiro Domain of Rio de Janeiro State and in the northern domain of the Araçuaí Orogen and, accordingly, the synchronicity of the Neoproterozoic orogenic collage in both domains. As far as the Pan-African connections are related, the age of the collisional peak in the western African orogens (West Congo, Kaoko, Damara, Gariep and Saldania) are also synchronous with the *ca.* 560 Ma Brasiliano collisional event. However, the data do not confirm previous correlation of this segment with the adjacent southwestern Paranapiacaba Orogen (Ribeira Belt), owing to the much older collisional climax (*ca.* 630 Ma) dated on the latter.

Keywords: Brasiliano/Pan-African, Pão de Açúcar gneissic granite, Corcovado gneissic granite, Serra dos Órgãos batholith, Araçuaí Orogen, U-Pb SHRIMP, zircon

Resumo *IDADE U-Pb SHRIMP DE ZIRCÃO DE SUÍTES GNAISSES GRENÍTICOS DA SERRA DOS ÓRGÃOS E DO RIO DE JANEIRO: IMPLICAÇÕES PARA A (560 Ma) COLAGEM BRASILIANO/PAN-AFRICANA* O recente mapeamento geológico sistemático na escala 1:400.000 revelou que o Estado do Rio de Janeiro é importante laboratório de campo para testar as conexões do Domínio Costeiro da Faixa Ribeira (Orógeno Rio Doce) e o Orógeno Araçuaí. O mapeamento, apoiado por datações geocronológicos U-Pb SHRIMP em zircão de três plútons-chave sinorogênicos, tangenciais, quais sejam, o batólito pré- a sincolisional Serra dos Órgãos e os granitos-gnáissicos sincolisionais Corcovado and Pão de Açúcar (Suíte Rio de Janeiro). Esses plútons-alvos têm assinatura química e tectônica compatíveis, respectivamente, com a dos granitóides dos tipos I e S australianos, característicos de arcos continentais maduros. O Batólito Serra dos Órgãos forneceu idade de cristalização de 569± 6 Ma, enquanto os granitos-gnáissicos sincolisionais Pão de Açúcar e Corcovado apresentaram idades de 559 ± 4 Ma e 560± 7 Ma, respectivamente. Os novos dados, apoiados na integração dos dados geocronológicos disponíveis sobre o magmatismo do Orógeno Araçuaí nos estados do Espírito Santo e Minas Gerais, lançam novas luzes sobre a evolução Neoproterozóica (Brasiliana) em escala regional. Idades tardi Pré-cambrianas entre *ca.* 580-560 Ma, obtidas recentemente optidas em plútons sincolisionais similares do segmento setentrional do Orógeno Araçuaí, evidenciaram o desenvolvimento síncrono entre o evento colisional no Estado do Rio de Janeiro e no domínio norte do Orógeno Araçuaí e, conseqüentemente, o sincrinismo da colagem orogênica Neoproterozoica em ambos os domínios. Nas possíveis conexões pan-africanas, a idade do pico colisional nos orógenos do sudoeste africano (Kaoko, Damara, Gariep e Saldania) também é síncrônica com esse evento colisional brasiliano de *ca.* 560 Ma. Entretanto, os dados aqui obtidos não confirmam correlações prévias com o Orógeno Paranapiacaba (Cinturão Ribeira), extensão sudoeste, devido ao clímax colisional nesse, datado de *ca.* 630 Ma, e portanto mais precóce.

Palavras-chave: Brasiliano/Pan-africano, Granito gnáissico Pão de Açúcar, Granito gnáissico Corcovado, Batólito Serra dos Órgãos, Orógeno Araçuaí, U-Pb SHRIMP, zircão

INTRODUCTION The southeastern and southern Brazilian Precambrian terrane comprises the Neoproterozoic (1000-490 Ma) Mantiqueira Province (Almeida *et al.* 1973), which extends for nearly 3,000 km from Montevideo (33^{o} S), in Uruguay, to the southern border of the Bahia State (15^{o} S). The province preserves the record of the complex Neoproterozoic (Brasiliano) collage (*ca.* 880 Ma to *ca.* 490 Ma), embracing accretionary and collisional orogenic events, as well as important post-tectonic sedimentary

*** - Tables 2, 3 and 4 referred in the text are available by request from the Senior Author by e–mail.**

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basins and associated magmatism, ascribed to the tectonic collapse of the orogen.

The poly-orogenic tectonic evolution of the province has been characterized in recent studies as a complex superposition, in space and time, of successive branched orogens, namely the Pelotas (Dom Felicano Belt), São Gabriel, Paranapiacaba (Ribeira Belt, in *part*) Rio Doce/Araçuaí and Búzios belts (Campos Neto & Figueiredo 1995, Brito-Neves *et al.* 1999, Campos Neto 2000, Schmitt 2000, Silva *et al*. 2002b).

In spite of the great number of geological maps and structural studies of the Rio de Janeiro State (e.g. Heilbron *et al*., 1995, 2000, Silva *et al*. 2001), reliable geochronological data are still scarce, particularly when compared to the northern extension of the orogen into Espírito Santo and Minas Gerais (Table 1). Previous isotopic data are available only for the Serra dos Órgãos batholith, dated by conventional U-Pb systematics, which yielded an age of 559±4 (Tab.1), interpreted as the crystallization age of the batholith (Tupinambá 1999). The age of the Rio de Janeiro Suite augengneissic granites have not been determined. The aim of this paper is to present zircon U-Pb SHRIMP data for the determination of the crystallization ages of the pre- to syn-collisional plutons of the Serra dos Órgãos and Rio de Janeiro batholith, major granites of the Ribeira Belt (Almeida *et al.*, 1973), in Rio de Janeiro (Figs. 1 and 2). Owing to the emplacement of the Costeiro Domain batholiths during the waning stages of the collisional evolution of the orogenic belt, they also provide a good estimate for the age of the collision (northwestward thrusting) of the arc onto the São Francisco Plate margin, and correlation with other Neoproterozoic terranes.

GEOLOGICAL SETTING Figure 1 shows the distribution of major tectonic units embracing the targeted plutons, according to Silva *et al.* (2001). The studied plutons belong to the Costeiro Domain of the Ribeira Belt (Machado *et al*. 1996), Rio Doce Orogen (Campos Neto & Figueiredo 1995, Campos Neto 2000), or Oriental Terrane (of the Ribeira Belt) (Heilbron *et al*. 2000). The eastern limit of the domain in represented by the *ca.* 2000 Ma Paleoproterozoic Região dos Lagos orthogneissic complex. Fonseca (1998) and Schmitt (2000) speculate that this unit consists of a displaced terrane (Cabo Frio Terrane), probably derived from an eastern, concealed cratonic segment, which was attached to the Costeiro Domain during the Cambrian, Búzios Orogeny (Schmitt 2000).

The batholiths are related to the roots of a largely exposed Neoproterozoic continental margin (Paraíba do Sul Complex), which consists of clastic and carbonatic sequence, with rare MORB-type amphibolites (Grossi-Sad & Dutra 1988) dated at *ca.* 840 Ma (Heilbron 2002). This age represents the best estimate for the opening of a continental margin. These rocks underwent metamorphism at the transition between amphibolite and granulite facies during the main collisional orogenic phase (thrust and fold belt), giving rise to the extensive syn-collisional, S-type leucogranitic and leucocharnockitic plutonic associations (Silva *et al*., 2001).

The orogen also contains the record of an (early) pre-collisional, expanded calc-alkaline association, dated at *ca.* 630 Ma and interpreted as a juvenile cordilleran arc (Tupinambá 1999). The accretion of the cordilleran Rio Negro Arc should have occurred in response to an eastward subduction of the São Francisco Plate under the Costeiro Domain, followed by the dissipation of a supposedly oceanic arm (Tupinambá *et al.* 2000). This oceanic arm should be a southeastern extension of the *ca.* 816 Ma Araçuaí Orogen ocean floor assemblage (Pedrosa Soares *et al.* 1998) exposed in the northwest tip of the belt.

Minor remnants of an early pre-collisional tonalitic phase, coeval with *ca.* 630 Ma Rio Negro Arc is recorded far north, in the Minas Gerais State; it furnished a Pb-Pb evaporation age of *ca.* 625 Ma (Paes 1999), and a conventional U-Pb age of *ca.* 630 (L.C. Silva, unpublished data) (Table 1). As this northern occurrence occupies a small known exposure area, at this moment we are unable to judge whether it has any geotectonic relation to the Rio Negro Arc or represents a distinct tectonic unit.

Nevertheless these uncertainties, the recognizing of a coeval tonalitic associations further north, highlights the importance of this earlier pre-collisional magmatism within the Araçuaí Orogen evolution. Hence, the supposed evolution of the Rio Negro Arc as a distinct orogen, relatively to the Rio Doce/Araçuaí Orogen, must be reviewed.

Finally, Heilbron (2002) characterized remnants of older gneissic tonalitic rocks, dated at *ca.* 790 Ma so far; the oldest recognized record of Brasiliano plutonism in the Rio Negro Arc. Contemporaneous gneissic tonalitic remnants has been recognized in other segments of the Mantiqueira Province, namely the *ca.* 780 Ma tonalitic gneisses associated to the ca. 630 Ma Pelotas Arc (Silva et *al*. 1999) and the *ca.* 810 Ma gneissic tonalitic within the Embu Terrane (Cordani *et al*.,2002). The significance of these dismembered and dispersed Cryogenian remnants, contemporaneous with the accretion of the oldest Brasiliano crustal segments in Brazil (São Gabriel Orogen and Goiás Magmatic Arc-system of orogens Brasiliano I), is not known.

U-Th-Pb SHRIMP SYSTEMATICS AND PROCEDURES Sample #1 represents the Serra dos Órgãos Batholith, a cordilleran I-type, expanded, pre-to syn-collisional batholith. Samples #2 and #3 were collected from the Pão de Açúcar and Corcovado granitic augengneissic in Rio de Janeiro metropolitan area (Rio de Janeiro Suite), the more extended syn-collisional, anatectic phase within the orogen (Figs. 1 and 2). Approximately 10 kg of each sample were collected and subsequently crushed, milled and sieved. The 80-150-mesh fraction was concentrated by heavy liquids, followed by zircon separation by magnetic methods and hand picking.

About 100 crystals were collected from the least magnetic zircon fraction and then cast in a standard 25-cm epoxy mount and polished. The mount was initially carbon-coated for backscattered electrons (BSE) and cathodoluminescence (CL) image using the JEOL 6200 scanning electron microscope (SEM) at the Centre for Microscopy and Microanalysis, University of Western Australia. Images (BSE) were acquired under accelerating voltage of 15 kV, current of 10 nA, and focus of 15 mm. The mount was later lightly repolished and gold-coated for SHRIMP analysis.

The isotopic U–Pb analyses were obtained at the SHRIMP II facility of the Curtin University of Technology in Perth, Western Australia, and followed the procedure described by Compston *et al.* (1984, 1992) and the operational routine described by Smith *et al*. (1998). Lead, Uranium and Thorium concentrations were referenced to the standard zircon (cz3). One determination on the standard was obtained for each three analyses of unknowns. Each spot size is typically 25-30 mm in diameter. The age uncertainties are at the 95% confidence level for the concordant populations, and the internal precision for single analyses in the Tables is 1s.

PRE-TO SYN-COLLISIONAL SERRA DOS ÓRGÃOS BATHOLITH (SAMPLE #1-HC 52) The Serra dos Órgãos

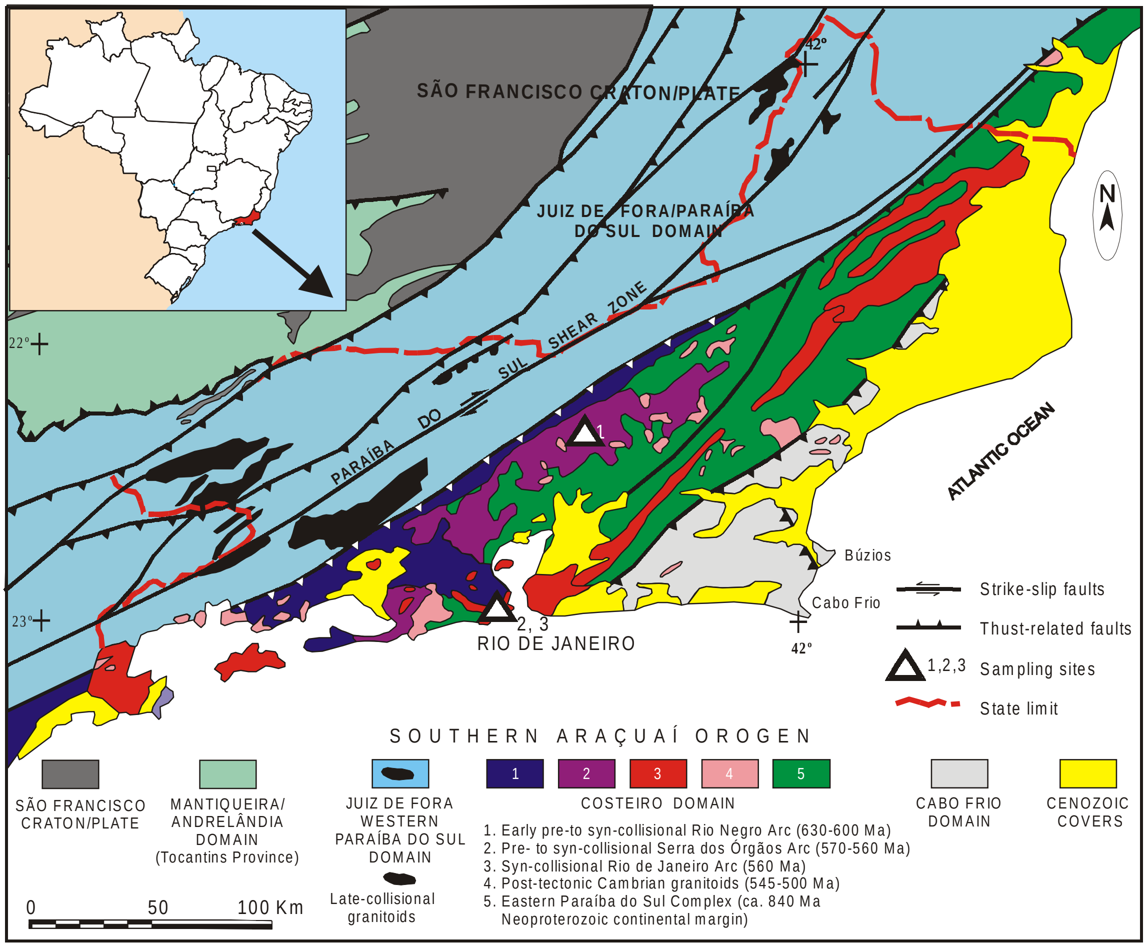

Figure 1 – Tectono-geologic sketch map of the Rio de Janeiro State, modified from Maachado (1997) and Silva et al. (2001).

Figure 2 - View of the Rio de Janeiro Suite/Arc (ã3), showing Pao de Açúcar and Corcovado hills (at the first plane). The red circles show the approximate sampling sites and the obtained ages in Ma (white). Christ's Monument faces the Rio Negro ($ã_1$) and Serra dos Órgãos ($?_2$) batholiths/arcs, at the second plane. (Photographer: Fabio Vidigal).

Table 1 - U-Pb (and Pb-Pb evaporation) isotopic data from the Araçuaí Orogen granitoids

Pluton	Age (Ma)	Method	Reference
POST-COLLISIONAL PLUTONS (TECTONIC COLLAPSE OF THE OROGEN)			
Rio de Janeiro State			
Mangaratiba granite	492±15	C (T)	Machado *et al.* (1996)
Nova Friburgo Granite	540 ±60	C	Ledent & Pasteels (1968)
Espírito Santo and Minas Gerais States			
Younger facies of Nanuque batholith	532±10	C	L.S da Silva (Unpublished)
Younger facies of Muniz Freire batholith	500+4	C	L.S da Silva (Unpublished)
Aimorés Suite	505±5	C	Siga Jr (1986)
Padre Paraíso charnockite	519±2	E	Noce *et al.* (2000)
Caladão granite	520±2	E	Noce *et al.* (2000)
Granitoid vein	503± 9	E	Noce *et al.* (2000)
Santa Angélica Pluton	513 ± 8	C	Söllner *et al.* (1991)
Malacacheta Granite	530± 8	E	Basilio *et al.* (1998)
SYN-COLLISIONAL PLUTONS (ARC)			
Rio de Janeiro State			
Rio de Janeiro Suite (Pão de Açúcar gneissic granite)	**559± 4**	**S**	**This study**
Rio de Janeiro Suíte (Corcovado gneissic granite)	**560± 7**	**S**	**This study**
Espírito Santo and Rio de Janeiro States			
Nanuque Suite	573± 5	S	Silva *et al.* (2002a)
Manhuaçu Charnockite	584± 5	S	Silva *et al.* (2002a)
Governador Valadares I gneissic granite	565± 31	S	Silva *et al.* (2002a)
Governador Valadares II gneissic granite	561± 7	S	Silva *et al.* (2002a)
Wolf granite	582±5	E	Noce *et al.* (2000)
São Vitor Granite	576± 5	E	Noce *et al.* (2000)
Guarataia granite	574± 2	E	Noce *et al.* (2000)
Urucum granite Palmital facies	582± 2 2200 (UI)	C	Nalini Jr. *et al.* (2000)
Urucum granite Megafeldspar facies	573±4 2200 (UI)	C	Nalini Jr. *et al.* (2000)
Cd diatexite	575±10 2101 (UI)	C	Söllner *et al.* (1991)
Alegre complex migmatites	~ 590	C	Söllner *et al.* (1991)
Charnockitic gneiss	558±2	C	Söllner *et al.* (1991)
Enderbitic gneiss	565±5	C	Söllner *et al.* (1991)
Gt granite gneiss	564±9	C	Söllner *et al.* (1989)
Gt granodiorite gneiss	574±28	C	Söllner *et al.* (1989)
Lagoa Preta Granitoid	585± 2	E	Dussin *et al.* (1998)
PRE-TO SYN-COLLISIONAL PLUTONS (ARC)			
Rio de Janeiro State			
Serra dos Órgãos Batholith (Pedro do Rio granodiorite)	**569± 6**	**S**	**This study**
Serra dos Órgãos Batholith (Pedrinco Quarry tonalite)	559 ±4	C	Tupinambá (1999)
Espírito Santo and Rio de Janeiro States			
Muniz Freire Batholith	580±28	C	Söllner *et al.* (1989)
Ataléia Granite	591± 4	E	Noce *et al.* (2000)
Braslândia granite	595±3	E	Noce *et al.* (2000)
Galiléia Suíte tonalite	594± 6	C	Nalini Jr. (1997)
PRE-COLLISIONAL PLUTONS (ARC)			
Rio de Janeiro State			
Rio Negro Tonalite	635± 10	C	Tupinambá (1999)
	620±20 2200 (UI)	C	Dehlal *et al.* (1969)
Serra do Paquequer Leucogranite-gneiss	620± 2	C	Tupinambá (1999)
	599±5	E	Tupinambá (1999)
	589±6	E	Tupinambá (1999)
Minas Gerais State			
Cuité Velho Tonalite	630±3	C	L.C. da Silva (Unpublished)(*)
	625± 11	E	Paes (1999)
DISMEMBERD CRYOGENIAN GNEISSIC TONALITE			
Costeiro Domain Tonalite	~790	C	Heilbron (2002)
PRE-OROGENIC RIFTING PHASE			
RIO DE JANEIRO STATE			
Paraíba do Sul Complex Amphibolite	~840 Ma	C	Heilbron (2002)
BAHIA STATE			
Salto da Divisa subalkaline foliated granite	875±9	S	Silva *et al.* (2002a)

Methods and analysed minerals: S = Zircon U-Pb SHRIMP, C = Zircon U-Pb conventional; E = Zircon Pb-Pb evaporation; Other analysed minerals: T= Titanite ; UI = Upper intercept
(*) Data obtained at the CPGeo IGc/USP.

Batholith is exposed at the Serra do Mar Microplate (Campos Neto & Figueiredo 1995), west of the city Rio de Janeiro (Fig. 1). It corresponds to a major pre- to syn-collisional batholith, intrusive both into the continental margin deposits and the early pre-collisional Rio Negro arc. Its medium-K calc-alkaline and isotopic Sm-Nd signatures (Tupinambá 1999). suggest that the pluton formed under an evolved cordilleran continental arc magmatism (*sensu* Pitcher 1983). The batholith underwent a mild deformation during a regional tangential event, but locally still has magmatc texture, sometimes overprinted by discrete solid-state, thrust-related fabrics. Previous conventional U-Pb zircon dating on one facies of the batholith yielded an apparent age of *ca.* 559± 4 Ma, interpreted the crystallization age of the pluton (Tupinambá 1999).

Petrography The sample was collected in a road-cut at the BR 040 highway, at the access to Pedro do Rio town (Fig. 1). It is a porphyritic granodiorite with a discrete solid-state fabrics overprinting. Major minerals comprise quartz (35%), oligoclase (28%) and K-feldspar (26%). The accessory minerals are biotite (7%) and hornblende (4%). Large (2-3 cm) deformed and recrystallized microcline phenocrysts (augen) occur within a medium- to coarse-grained groundmass of microcline, oligoclase, quartz and sub-parallel biotite flakes and hornblende prisms. Minor minerals include zircon, apatite, ilmenite, titanite and opaque minerals. Chlorite is secondary after biotite. This facies is intrusive into the adjacent foliated tonalites from the Rio Negro Complex.

U-Pb-Th SHRIMP results The BSE-backscattering image shows an homogeneous zircon population, with discrete unzoned prismatic crystals and magmatic oscillatory zoning (Fig. 3a). The crystal length:width ratios between 2:1 and 3:1 are typical of calc-alkaline magmas. The faint rounding of crystals is probably due to the syn-collisional late crystallization. Some grains show minor radial or concentric fractures due to expansion by metamictization. Mineral inclusions are not abundant.

Seventeen analyses were performed on sixteen crystals (Table 2, Fig. 3b). On the concordia diagram they form a single concordant population cluster of 16 spots (blank error boxes in Fig. 3b), with a weighted mean $^{206}Pb/^{238}U$ age of 569 ± 6 Ma (2s), with no excess scatter other than the attributed to analytical error (mean $c^2 = 0.88$). This is interpreted as the crystallization age of the granodioritic magma. The spot 13-1 was rejected owing to the high degree of discordance and its high common Pb (filled error box), but its removal does not alter the age (Fig. 3b). Because the rock crystallized before the main collisional peak, the result also provides an estimate for the minimum age of the pre-collisional magmatic phase within this orogen. The obtained age of 569 ± 6 Ma is slightly older than the 559±4 Ma obtained by Tupinambá (1999) by conventional U-Pb zircon dating on another facies of the batholith. We interpret the older age to be a better estimate to the crystallization age of the pluton, owing to the high degree of discordance of the zircon fractions analyzed by Tupinambá (1999), and also because the batholith crystallized previously to the Rio de Janeiro Arc, precisely dated at ca. 560 Ma (see below).

SYN-COLLISIONAL RIO DE JANEIRO BATHOLITH The thrust-related gneissic granite plutons exposed in the Rio de Janeiro metropolitan area, including the famous Brazilian postcards of the Pão de Açúcar and Corcovado hills (Figs. 1,2), are the main components of the Rio de Janeiro Suite (Silva *et al*. 2001). Their tectonic-magmatic evolution has been documented in several

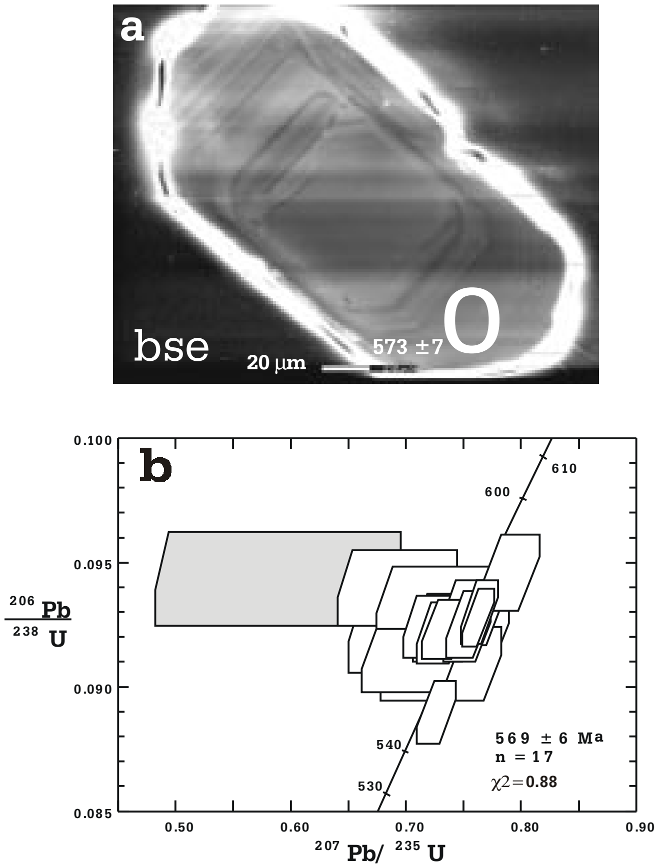

Figure 3 – (a) - Backscattering image, representative of the zircon population for sample #1 (Serra dos Órgãos Batholith). Explanation in the text. (b) - Concordia diagram plot from sample 1 (Serra dos Órgãos Batholith, Pedro do Rio Granodiorite). Age uncertainties at 95% confidence level for populations. Error boxes are 1s. Blank error boxes refer to the concordant crystallization ages.

detailed structural studies (Hembold *et al*. 1965, Silva & Silva 1987, Silva *et al*. 2001, Heilbron *et al*. 1993, 1995). Additionally, Machado & Demange (1992) focused the suite evolution on chemical grounds. Despite these studies, there is no geochronologic data for the suite, which has been attributed to the late Precambrian orogenic evolution on regional structural studies (Figueiredo & Campos Neto 1993, Campos Neto & Figueiredo 1995).

Owing to their characterization as thrust-related, syn-collisional, Neoproterozoic plutons (Heilbron *et al*. 1993, 1995), together with the Serra dos Órgãos Suite, they are key elements to constrain the age of the main collisional/metamorphic peak within the orogen.

Petrography Both plutons are foliated, thrust-related, displaying protomylonitic fabrics overprinted to the magmatic subsolidus texture (augen-gneisses), ascribed to the D_1/D_2 Neoproterozoic orogenic phase (Heilbron *et al.* 1993, 1995). The plutons frequently show partially resorbed biotite-garnet-rich restites and partially melted high-grade metapelitic-psammitic remnants of the country rock (mesosome).

Figures 1 and 2 show the sampling location of both plutons. Corcovado augen-gneissic granite (Sample3) is the dominant facies in the Rio de Janeiro Suite (Fig. 2). It is a peraluminous, garnet-biotite bearing, amphibole-free facies, with involvement of metasedimentary source, either as a major source (S-type) or as contaminant country rock. Pão de Açúcar augen-gneissic granite (Sample 3) shows locally metaluminous (hornblende)-biotite bearing facies and also green charnockitick patches, but regionally it has an S-type signature. Both units are recrystallized megaporphyritic (augen) granite gneissic, designated as "facoidal" gneisses in former literature. They contain large (3-8 cm) microcline phenocrysts (augen) set in a coarse-grained hypidiomorphic, weakly recrystallized groundmass of microcline, sodic plagioclase, quartz and biotite. Discrete ductile, post-magmatic, thrust-related protomylonitic structure is associated with peripheral feldspar sub-granulation and quartz recovery. The main planar fabric is a penetrative folded biotite foliation and feldspars phenocrysts alignment. The fabric reflects solid-state recrystallization (protomylonite) of a sub-solidus flow foliation, during the main thrust-related collisional crystallization event. Garnet and biotite are major accessories and zircon, apatite, titanite and opaque minerals are minor phases.

U-Th-Pb SHRIMP results BSE images of zircons from both facies reveal an homogeneous population of unzoned crystals, and with few exceptions (as shown in Figs. 4a, 5a), devoid of core/margin distinction. The prisms are euhedral, with a magmatic length:width ratios between 2:1 and 3:1. The Th/U ratios of most spots are between 0,2 and 0,6 (Table 2), within the typical range of felsic magmatic rocks. Magmatic fine oscillatory-zoned texture is common. Little rounding of crystals is seen (Fig. 5a), and some crystals are fractured. Few grains show inherited rounded cores (grain 12, Fig. 4a).

Pão de Açúcar Granite (Sample 2/ HC 768b) Thirty analyses were performed on 24 crystals (Table 2, Fig. 4b). Most of the analytical spots form a single cluster of 21 concordant analyses, obtained on 19 crystals (blank error boxes on Fig. 4b), with a weighted mean $^{206}Pb/^{238}U$ age of 559 ± 4 Ma (2s), showing little excess scatter than attributed to the analytical error (mean c^2 = 2.24). The result is interpreted as the crystallization age of the pluton. Because the granite crystallized simultaneously to the deformation peak, the date also provides an estimate for the age of the collision within the orogen.

Spots 9-2, 23-1 and 27-1 (filled error boxes in Fig. 4b) were discarded from the crystallization age calculation and are interpreted as either representing inherited xenocrysts, or as a highly discordant site (spot 27-1). Spot 12-1 was sputtered on an inherited detrital core (arrows in Fig. 4a) and yielded an apparent $^{207}Pb/^{206}Pb$ age of 1299± 19 Ma (Table 2) (not shown on Fig. 4b). This apparent age may be interpreted as the age of one of the sources of the clastic sequence from which the S-type granite was derived by anatexis. Analyses with the lowest $^{206}Pb/^{238}U$ ratios (Fig. 4b) probably experienced recent Pb-loss and have also been rejected from the age calculation (filled error boxes, below main concordant group). Spot 17-1 was also rejected owing to its high discordance.

Corcovado augen-gneissic granite (Sample 3/HC 767) Twenty analyses were performed on eighteen crystals (Table 2, Fig. 5b). Most of them form a single cluster of 19 concordant spots (blank error boxes in Fig. 6b), with a weighted mean $^{206}Pb/^{238}U$ age of 560 ± 7 Ma (2s), and no excess scatter occurs other than attributed to the analytical error (mean c^2 = 0.88). This result is interpreted as

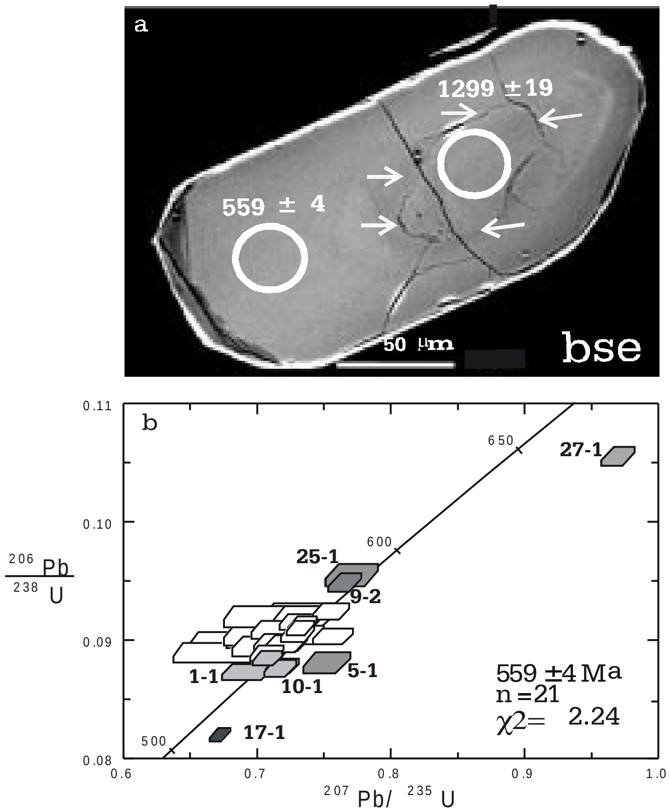

Figure 4 – (a) - Backscattering image, representative of the zircon population from sample 2 (Rio de Janeiro Suite, Pão de Açúcar gneissic granite). Explanation in the text. (b) - Concordia diagram plot for sample #2 (Rio de Janeiro Suite, Pão de Açúcar gneissic granite). Age uncertainties at 95% confidence level for populations; Error boxes are 1s. Blank error boxes refer to the concordant crystallization ages.

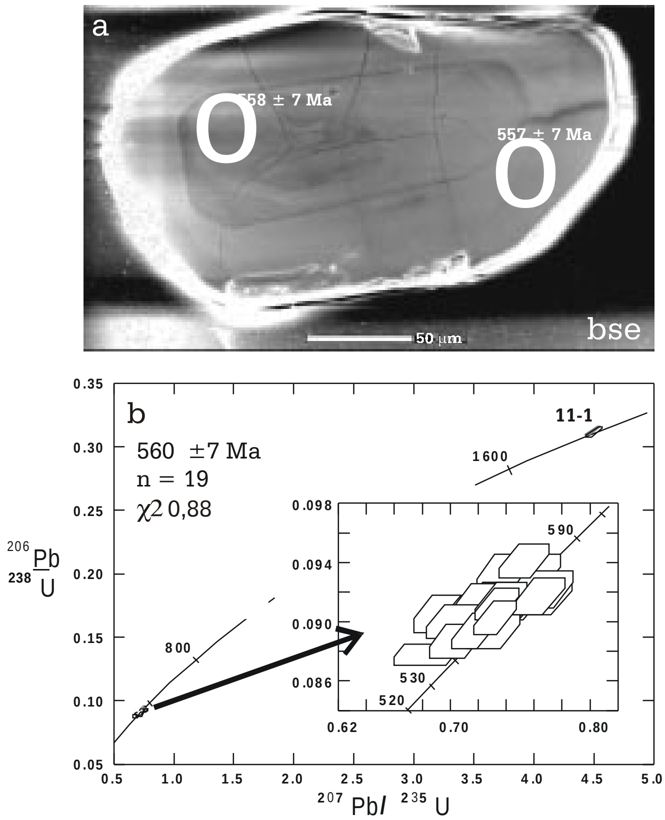

Figure 5 – (a) - Backscattering image, representative of the zircon population for sample #3 (Rio de Janeiro Suite, Corcovado gneissic granite). Explanation in the text. (b) - Concordia diagram plot for sample #2 (Rio de Janeiro Suite, Corcovado gneissic granite). Age uncertainties at 95% confidence level for populations; Error boxes are 1s. Blank error boxes refer to the concordant crystallization ages.

the crystallization age of the pluton. Because the granite crystallized simultaneously with the deformational peak, the date also provides an estimate for the age of the collision peak within the orogen. The only rejected spot (11-1, Fig. 5b) was sputtered on an inherited xenocryst which furnished an apparent $^{207}Pb/^{206}Pb$ age of 1733 ± 13 Ma.

CONCLUSIONS AND CONSEQUENCES FOR THE OROGENIC ARCHITETURE AND CORRELATIONS The results obtained from the pre- to syn-collisional Serra dos Órgãos and Rio de Janeiro suites are important clues to constrain the late Neoproterozoic orogen evolution, as predicted by the regional structural studies (Figueiredo & Campos Neto 1993, Campos Neto & Figueiredo 1995, among others) in the Costeiro Domain of the Ribeira Belt in Rio de Janeiro State. Additionally, the crystallization, collision and metamorphic peak ages of the analyzed plutons are synchronous with those obtained on similar plutons in the northern extension of the belt (Araçuaí Orogen) spanning from *ca.* 590-560 Ma (Nalini Jr. 1997, Silva *et al*. 2002a, among others - Table 1). As both segments shared common collisional and magmatic broadly synchronous histories, the Costeiro Domain (formerly Rio Doce Orogen) may be interpreted as the southern extension of the Araçuaí Orogen.

In fact, the westernmost pre- to syn-collisional calc-alkaline expanded association (Serra dos Órgãos) was accreted almost simultaneously to the Araçuaí Orogen Muniz Freire Batholith (*ca.* 580 Ma, Söllner *et al.* 1987), and to the Galiléia Tonalite (*ca.* 595 Ma, Nalini Jr. 1997) (Tab.1). Despite the discontinuity of the exposed areas, these three major batholiths share similar chemical and isotopic signatures, characteristic of a late Neoproterozoic, medium-K, and calc-alkaline series. Nevertheless, they do not define a continuous exposure area. They are akin with mature continental crust reworked arc association, with isotopic indication of the involvement of Paleoproterozoic continental crust (Nalini Jr. 1997, Tupinambá 1999). The arc extends discontinuously for about 800 km northwards from the city of Rio de Janeiro as the Serra dos Órgãos-Galiléia Arc (Silva *et al*. 2001, Silva *et al*. 2002b).

The easternmost syn-collisional, Himalayan-type S-type crustal derived arc association of the *ca.* 560 Ma Rio de Janeiro gneissic granitic suite, in turn, extends almost continuously for about 900 km from the city of Rio de Janeiro to the south of the Bahia state. The arc is coeval with the Araçuaí Orogen crustal batholiths, including several peraluminous, S-type garnet granitoids and charnockitoids (Table 1), namely the Nanuque Batholith (573 ± 5 Ma, Silva *et al.* 2002a), Charnockitic gneiss (558 ± 2 Ma, Söllner *et al*. 1991), Enderbitic gneiss (566 ± 5 Ma, Söllner *et al*. 1991), São Vitor Granite (576 ± 5 Ma, Noce *et al.* 2000), and the Urucum Granite (573 ± 4 Ma and 582 =2 Ma, Nalini Jr.1997). This extended S-type, Himalayan leucogneiss and charnockite association constitutes a major component of the Araçuaí collisional orogen, the *ca.* 580-560 Ma Rio de Janeiro-Nanuque Arc (Silva *et al*. 2001, Silva *et al*. 2002b). Table 1 also highlights the synchronicity among the post-collisional and post-tectonic granitoids of the Costeiro Domain and of the northern segment the Araçuaí Orogen, which yielded crystallization ages spanning from 530 to 490 Ma, and are ascribed to the tectonic collapse of the orogen.

The southern connections of the orogen are not so well constrained. In the state of São Paulo, the southeastern tip extends further south, as a narrow band exposed between the Atlantic coast and the eastern limit of the Embu Terrane, but there are not reliable geochronological data from granitoids of this segment. With reference to the southwestern connection, uncertainties on possible correlation are much bigger. Age difference of up to 70 m.y. between the syn-collisional Araçuaí magmatism (*ca.* 560 Ma-Brasiliano III) and syn-collisional magmatism within the adjacent southwestern (Ribeira Belt) Paranapiacaba Orogen (*ca.* 630 Ma-Brasiliano II), militates against a direct link between the two branches of the Ribeira Belt (Silva *et al.* 2002b).

Finally, as far as the Pan-African connections concerns, the new data from the syn-collisional batholiths (*ca.* 560 Ma) match well the *ca.* 565 Ma age of the collision in the West Congo Orogen (Tack & Fernandes-Alonso 1998). Accordingly, the present study is the first direct and well-constrained geochronologic data in Brazilian literature, and supports the hypothesis of the direct connection between the Araçuaí Orogen and the West Congo Orogen, as predicted previously (*e.g.* Tack & Fernades-Alonso 1998, Pedrosa-Soares *et al*. 2001). The Araçuaí-West Congo Orogen corresponds to the system of Brasilano/Pan-African III orogens (collisional climax at *ca.* 560 Ma, Silva *et al*. 2002b). The Pan-African III system also embraces other eastern and southern African orogens (Kaoko, Damara, Gariep and Saldania), some of which had their collisional peak only recently constrained and yielded the same age range. The syn-collisional Darling Batholith from the Saldania Orogen, yielded a *ca.* 550 Ma crystallization age (Silva *et al.* 2000), whereas the Coastal granite of the Kaoko Belt, a *ca.* 565 Ma age (Seth *et al*. 1998). Additionally, the pre-orogenic rifting phase from the Araçuaí Orogen of 875 ±9 Ma, obtained on subalkaline gneissic granite intruded the northern basement of the orogen (Silva *et al*. 2002, Table 1) are compatible with the ages obtained for the rift phase of the West Congo Orogen basement (*ca.* 900 Ma), by Tack *et al.* (2001).

Acknowledgments The Brazilian Government's Conselho Nacional do Desenvolvimento Científico e Tecnológico (CNPq) – Proc. 201.500.95-7" and Geological Survey of Brazil (CPRM) supported the senior author's investigations at The University of Western Australia. SHRIMP data were acquired on the SHRIMP II facility, which is operated by a consortium consisting of Curtin University of Technology, the Geological Survey of Western Australia and the University of Western Australia with the support of the Australian Research Council. Marion Marshall is thanked for technical assistance with SHRIMP mount preparation. Special thanks are due to the RBG reviewers for suggestions to the manuscript.

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Manuscrito A-1381
Recebido em 08 de outubro de 2002
Revisão dos autores em 20 de abril de 2003
Revisão aceita em 30 de abril de 2003