Anais da Academia Brasileira de Ciências (2007) 79(3): 441-455
(Annals of the Brazilian Academy of Sciences)
ISSN 0001-3765
www.scielo.br/aabc

Structural and geochronological constraints on the evolution of the Juréia Massif, Registro Domain, State of São Paulo, Brazil

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Manuscript received on April 4, 2006; accepted for publication on August 21, 2006;
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ABSTRACT

The Juréia Massif, southeastern São Paulo State (Brazil), is part of the Registro Domain, limited to the north by the Cubatão-Itariri Shear System and to the south by the Serrinha Shear Zone. Mostly composed of migmatitic granite-gneiss rocks, represents a Paleoproterozoic terrane (1.9–2.2 Ga) strongly deformed during the Neoproterozoic (750–580 Ma). The present tectonic scenario was established at the end of the Neoproterozoic, as a result of collages associated with the formation of Western Gondwana. The Ponta da Juréia, our study area within the Juréia Massif, is constituted by paragneisses (garnet-muscovite-biotite gneisses). The monazite U-Pb age of 750 Ma is related to a main regional metamorphic event that reached the high amphibolite facies, recorded in rocks from the Itatins Complex and Cachoeira Sequence as well, which also belongs to the Registro Domain. The paragneissic rocks of this study are affected by the E-W-trending Serrinha Shear Zone, registering a predominantly dextral movement. Biotite K-Ar ages of 482 $\pm$ 12 Ma may represent later movements and reflect the younger ages of reactivation of the major lineaments and juxtaposition of the tectonic blocks involved.

Key words: tectonic domain, shear zone, gneissic rocks, U-Pb geochronology.

INTRODUCTION

The southeastern portion of the State of São Paulo (Brazil), part of the southern sector of Ribeira Belt in the Mantiqueira Province (Almeida et al. 1981) consists of four major tectonic domains limited by important shear zones, with mainly E–W or NE/SW trends related to Neoproterozoic tectonic events.

The Registro Domain, a polydeformed and metamorphosed block composed of metasedimentary and granite-gneiss-migmatitic rocks, occurs between the Cubatão-Itariri and the Serrinha (SSZ) Shear Zones (Figure 1). The Juréia Massif, the aim of this work, is part of this domain, and is located between the towns of Peruíbe and Iguape. It forms the highest hills south of the Itatins Massif.

The Juréia Massif is composed of amphibolite facies mylonitic paragneisses and was subjected to more than one episode of metamorphism and deformation. It is usual that the preserved mineral assemblages and microfabrics mainly record the latest metamorphic/tectonic event since these erase the record of the respective earlier events (Krohe and Wawrzenitz 2000). The Juréia rocks preserve an unusual P-T path.

Neoproterozoic III igneous and metamorphic ages are widely documented on the granite-gneissic domains

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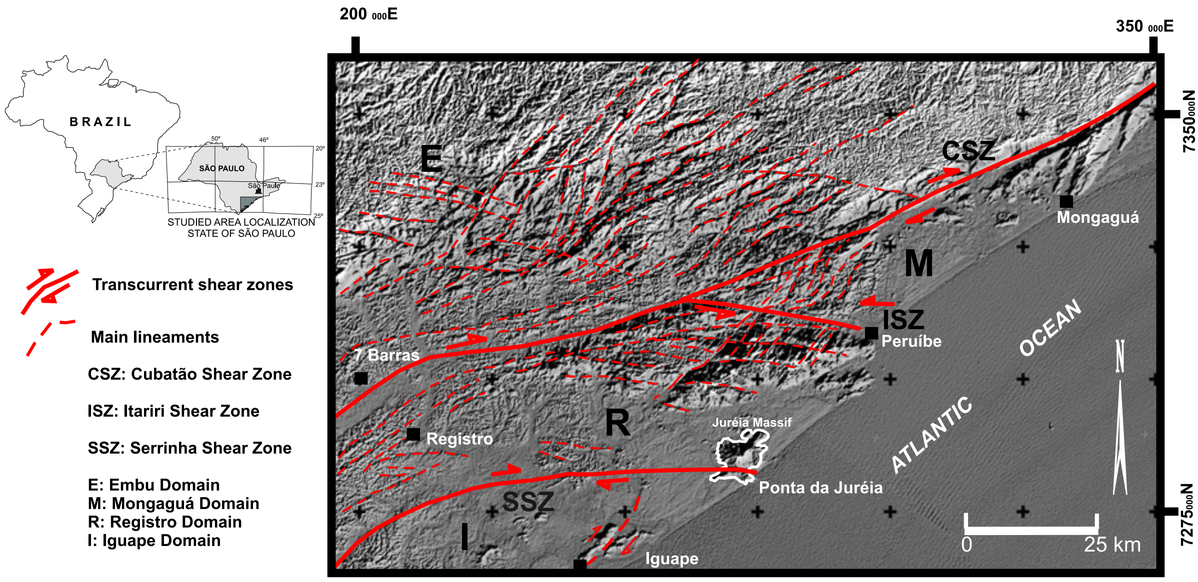

Fig. 1 – SRTM topographic image (*"Shuttle Radar Topography Mission"* – 2000) – southeastern part of São Paulo State – Brazil.

of the southern Ribeira Belt (Siga Jr. et al. 1995, Machado et al. 1996, Basei et al. 1997, Harara et al. 1997, Campos Neto 2000, Tupinambá et al. 2000, Hackspacher et al. 2000, Sato et al. 2001, Heilbron and Machado 2003, Passarelli et al. 2004). Recent geochronological studies of upper amphibolite facies paragneiss from the Juréia Massif provide evidence for an earlier metamorphic event of Cryogenian age in the Brasiliano-Pan-African Cycle.

Ages of this period were previously recorded only in the Embu Complex (Vlach 2001, Cordani et al. 2002, Janasi et al. 2003), in granites and juvenile volcanic rocks from the southern part of the Mantiqueira Province (Babinski et al. 1996), and also as a magmatic-metamorphic event in the Brasília Belt (Ferreira et al. 1994, Pimentel et al. 2000).

In this paper we present a preliminary structural and petrographic characterization of rocks from the Ponta da Juréia, the results of the first analyses of U-Pb in monazite from these rocks, together with a discussion of their tectonic meaning and the differences from the neighboring gneissic migmatites.

GEOLOGICAL SETTING

Four major tectonic domains limited by important shear zones, characterize the southeastern portion of the State of São Paulo, Brazil. In radar images, the lineaments that correspond to the bordering shear zones are conspicuous (Figure 1). E-W–NE/SW trending lineaments, related to the Neoproterozoic tectonic events, predominate in the whole area. However, former NW trending lineaments can also be individualized, mainly observed in the Registro Domain, or even later ones, related to the Guapiara Structural Alignment (Almeida 1983).

The Embu Domain, to the north of the Cubatão Shear Zone (CSZ), is composed mainly of medium to high grade metasedimentary rocks, locally migmatized, intruded by pre-collisional peraluminous granites, and stretched out by E–NE trending shear zones (Cubatão – Itariri Shear System – CISS). Gneiss-migmatite rocks and related granites presenting E–NE structural fabrics predominate in the Mongaguá Domain, which is limited by the Cubatão and Itariri (ISZ) Shear Zones. The Juréia Massif is part of the Registro Domain, which is composed of metasedimentary and granitic rocks with migmatitic structures, between the Cubatão-Itariri and the Serrinha (SSZ) Shear Zones. It represents a Paleoproterozoic domain intensely affected by Neoproterozoic tectonic events. The domain has a NW–SE trending structure, which swings to E or NE under the influence of the CISS. Rocks of the Iguape Domain, limited to the north by the SSZ, include granites and low-grade metasediments with a dominantly NE structural orientation (Figure 2).

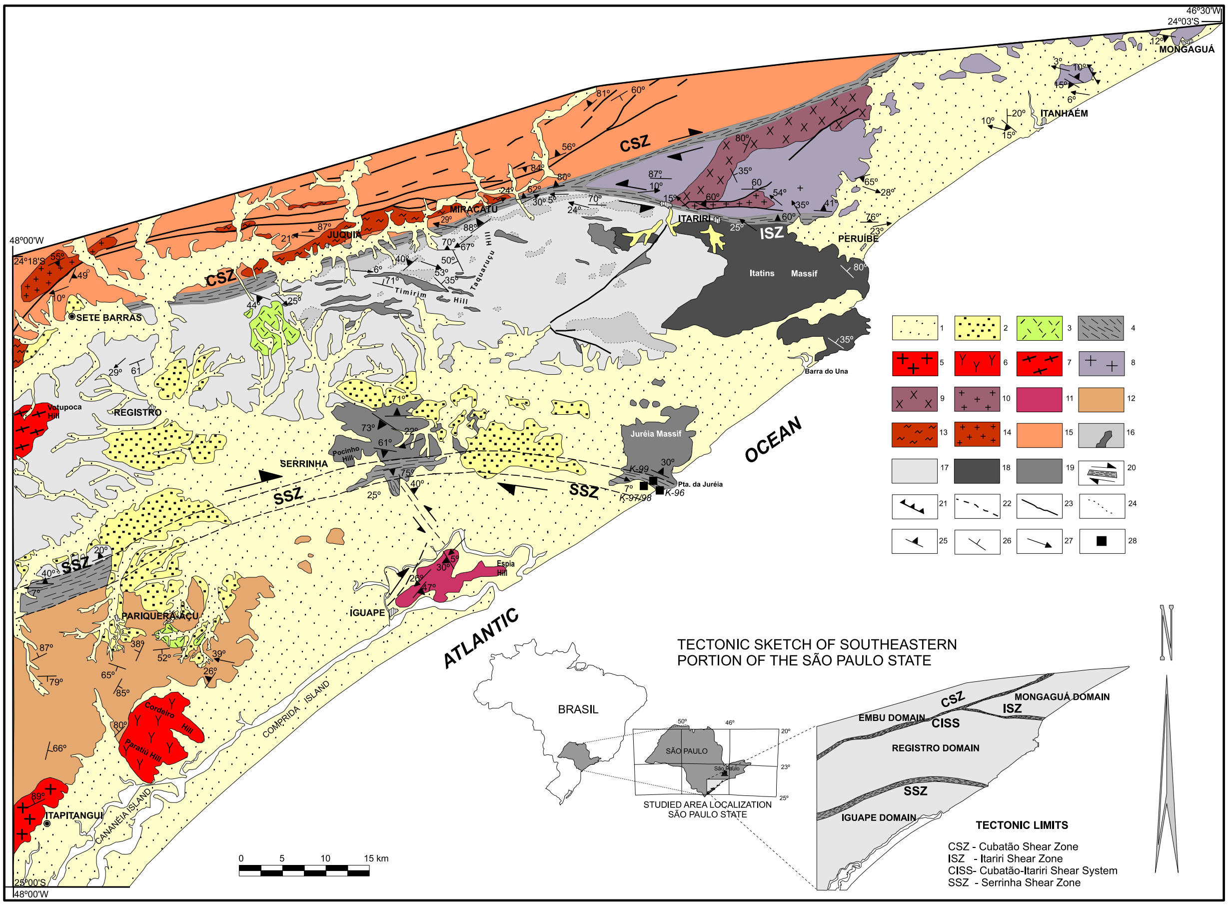

Fig. 2 – Geological Map of southeastern São Paulo State. 1. Quaternary sediments. 2. Tertiary sediments. 3. Juquiá Alkaline Complex (Cretaceous). 4. CISS and SSZ: mylonitic rocks (600–570 Ma). Serra do Mar Granitic Suite (c. 580 Ma): 5. Itapitangui 6. Serra do Cordeiro 7. Serra do Votupoca. Mongaguá Domain: 8. Granite-gneiss-migmatitic Domain (c. 615–580 Ma). 9. Areado Granite (c. 610–580Ma). 10. Ribeirão do Óleo Granite (c. 580 Ma). Iguape Domain: 11. Iguape Granite (c. 600 Ma). 12 Iguape Metassediments (< 2200 Ma). Embu Domain: 13. Juquiá Granite (c. 600 Ma). 14. Sete Barras Granite (c. 630 Ma). 15. Metassediments (< 1600–1800 Ma). Registro Domain: 16. Granite-gneiss-migmatitic Domain (2100–580 Ma). 17. Gneissic Domain (2200–580 Ma). 18. Itatins Complex (2200–580 Ma). 19. Cachoeira Sequence (> 750 Ma). 20. Transcurrent shear zones. 21. Fault with thrust component 22. Infered Faults. 23. Lineaments. 24. Gradational geological contact. 25. Mylonitic foliation. 26. Principal foliation. 27. Mineral lineation. 28. The studied Juréia Massif outcrops.

Migmatitic granite-gneiss rocks occupy the largest part of the Registro Domain and correspond to what Dantas et al. (1987) named Gneissic-Migmatitic Complex and Granitic Suite of the migmatitic facies. Likewise, the paragneisses cropping out in the Juréia Massif would correspond to the undifferentiated Gneissic-Migmatitic Complex of Silva (1981) and Silva et al. (1981).

The rocks from the outcrops of the studied area, Ponta da Juréia, were described for the first time by Morgental et al. (1973), as "gneissic leptinolites, with stretched quartz-feldspatic lenses" incorporated into the Undifferentiated Gneissic Migmatitic Complex (Morgental et al. 1975, Silva et al. 1978, 1981).

Hasui et al. (1981) related the Juréia Massif rocks to that gneissic-migmatitic of Costeiro Complex, a terrene that would include all rocks that outcrop to the south of the Cubatão shear zone in the area.

The gneissic-migmatitic rocks are associated with granitic and metasedimentary rocks of the Cachoeira Sequence (Silva et al. 1981, Dantas et al. 1987). The Juréia Massif rocks were correlated with the Cachoeira Sequence by Passarelli (2001), that comprise kinzigites and kinzigitic gneisses that crop out in the Itatins Massif area, petrographically characterized by sillimanite-biotite-garnet gneisses (Picanço et al. 1998).

The rocks of the Cachoeira Sequence are considered as supracrustal remains of volcano-sedimentary sequences, preserved from the intense Neoproterozoic migmatization and anatexis (Silva 1981, Dantas et al. 1987). In the area calci-silicatic rocks, dolomitic marbles, schists, quartzites and metabasic rocks were also mapped, besides gneisses and kinzigitic gneisses (Dantas et al. 1987, Gimenez Filho et al. 1987).

In a regional context, the Registro Domain (São Paulo State), is correlated with the Curitiba Domain (Paraná State), defined by Siga Jr. et al. (1993), as discussed by Basei et al. (1999) and Passarelli et al. (2004).

Petrographic-structural Characterization

The southeasternmost portion of the Juréia Massif, with an area of approximately 47 km^2, is composed of mylonitic paragneisses affected by the Serrinha Shear Zone (SSZ).

The contacts of the Juréia paragneisses with the gneissic-migmatitic rocks are normally hidden, due to the intense tropical weathering and the vast Tertiary and Quaternary sedimentary cover.

However, as suggested by some authors (Dantas et al. 1987, Gimenez Filho et al. 1987), a gradual contact can be locally suggested between these rocks. In the central part of the Registro Domain, Serrinha region, near Pocinho Hill (Figure 2) a gradual passage is observed between the paragneissic rocks and the cordierite-garnet-biotite granodiorites to tonalites with migmatitic features, which are not granodiorites/tonalites in the igneous sense, but probably deformed leucossomes. Two different paragneisses, seemingly: those blasto-mylonitic, developed under s.l. amphibolite-facies conditions, from the Juréia area, without signs of a former high-grade protholith, whilst those from Serrinha Region are possibly the reworked (mylonitized, sheared) equivalents of the high-grade, cordierite-garnet-biotite tonalitic gneisses. This can be seen even from the differences between biotite from the two sets of rocks.

The SSZ, defined by Passarelli et al. (2000), occurs between Registro and Iguape Domains, presenting mylonitic granitic rocks imbricated with mylonitic metasedimentary rocks.

The mylonitic foliation presents a general E–W strike and is associated with a predominantly dextral movement with a conspicuous pure shear component. The coaxial component is observed in the SSZ central portion by means of dextral and sinistral kinematic indicators and symmetric porphyroclasts.

The SSZ presents a conspicuous, 1 km – thick, N35W – trending, SE-dipping ramification, (Figure 2) where sinistral movement is observed associated with a NW thrust component.

The easternmost sector of SSZ affects the Juréia gneissic rocks, with the mylonitic foliation characterized by strong stretching of the quartz-feldspathic portions. The mylonitic foliation (Sm) is folded towards NW and NEE, dipping moderately to sub-horizontally to NE and NW, and the main strike is N54W/30NE (Figure 3), with a gently plunging mineral stretch lineation (Lm). In this east sector, the SSZ is characterized by a dextral lateral ramp.

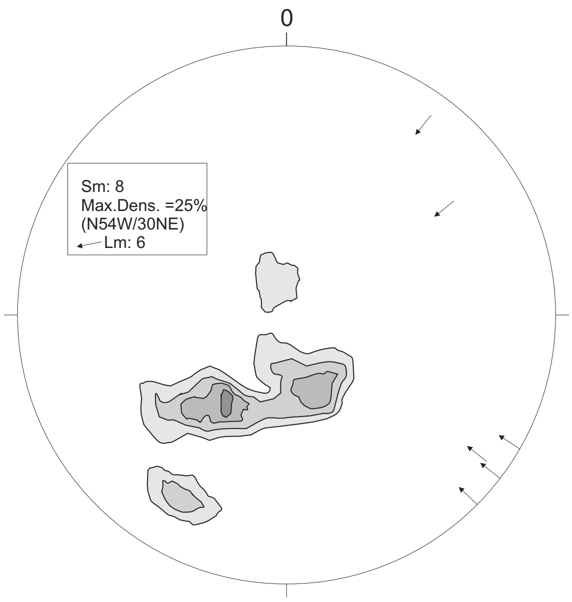

Fig. 3 – Stereonet plot for mylonitic foliation of Serrinha Shear Zone eastern sector. Mylonitic paragneisses – Juréia Massif.

The paragneisses are bluish-gray and their banding is characterized by cm-sized quartzo-feldspathic stripes intercalated with the predominant biotite-rich porphyroclastic bands. The mylonitic foliation is characterized by stretched porphyroclasts (feldspars and garnet) in a finely-foliated matrix, characterized by strong orientation of biotite crystals.

The mylonitic foliation presents moderate to low dips (Figure 4), and the relationship between mylonitic foliation, mineral stretching and kinematic indication suggests a predominantly eastward distensive transport.

Mafic minerals, such as biotite and muscovite, predominate in the paragneisses. The development of quartzo-feldspathic remobilizations is common. These rocks are garnet-rich and porphyroblasts/porphyroclasts may reach 3 × 3 cm (Figure 5).

The occurrence of very flat, stretched and boudinated remobilizations (Figure 6) is not rare in planes sub-parallel to the XZ section, suggesting the influence of deformation with prevailing pure shear component.

The presence of feldspar porphyroclasts or even quartz-feldspathic remobilizations with very symmetrical shapes is quite common in the XZ section of the deformation ellipsoid (Figure 7). However, S-C type structures and rotated plagioclase porphyroclasts of the δ-type (Hanmer and Passchier 1991) are observed in sections approximately parallel to XZ (Figure 8), indicating dextral movement.

The paragneisses are characterized by a quartz-biotite-muscovite-plagioclase assemblage, with traces of garnet and microcline, and monazite, zircon and tourmaline as accessories.

The foliation is defined by biotite and muscovite orientation and quartz and feldspar stretching. It is characterized by the strong segregation of the quartz-feldspathic bands from the biotite-rich bands. Plagioclase porphyroclasts indicate dextral movement (Figure 9, 10) and can develop pressure shadows, filled with recrystallized quartz (Figure 10).

The quartz crystals tend to segregate in polycrystalline ribbons. They are usually recrystallized or restored, forming sub-grains. The larger grains can preserve the undulose extinction.

The larger oligoclase crystals form fractured, sometimes recrystallized, sigmoidal-shaped porphyroclasts with quartz and muscovite inclusions (Figure 11). The smaller crystals of the matrix are subhedral and clean. They also appear segregated with quartz.

Biotite crystals occur in stripes. They present light yellow to dark, reddish-brown pleochroism, and are sub-euhedral.

Garnet crystals also form rounded porphyroclasts and are usually fractured. They present biotite, quartz and muscovite inclusions. They can also develop pressure shadows constituted by quartz, biotite and muscovite.

GEOCHRONOLOGY AND ISOTOPIC GEOLOGY

The U-Pb TIMS (Thermo Ionization Mass Spectrometry) analyses in monazite were carried out in CPGeo (Centro de Pesquisas Geocronológicas) of the Instituto de Geociências of the Universidade de São Paulo (IGc-USP).

Monazite crystals were concentrated by standard crushing and milling, sieving, density separation on the Wilfley table, electromagnetic separation using Frantz equipment, and density separation by heavy liquids (Bromoform and Methylene Iodide). Individual crystals were measured to enable the use of the relation between density and volume in weighing, were then photographed and washed in H_2O, HCl and HNO_3 prior to dissolution.

Individual monazite crystals were dissolved in 3 ml Savillex, capsules containing H_2SO_4. and HNO_3 and a mixed ^{205}Pb-^{235}U tracer solution (spike ^{205}Pb) on a hot plate for 72 hours.

Lead and uranium were isolated in anionic resin columns, according to the procedures described in Basei et al. (1995), adapted from Krogh (1973, 1982) and Parrish (1987).

The measurements were performed by the multi-collector mass spectrometer FINNIGAN MAT-262 (Sato and Kawashita 2002). At CPGeo, the average values obtained for the NBS-981 and NBS-983 standards were respectively $^{204}Pb/^{206}Pb = 0.05903 \pm 0.02\%$ and $0.000368 \pm 3\%$; $^{207}Pb/^{206}Pb = 0.91479 \pm 0.01\%$ and $0.071212 \pm 0.05\%$, and $^{208}Pb/^{206}Pb = 2.1675 \pm 0.01\%$ and $0.013617 \pm 0.06\%$, with annual variation of 1σ. The fractionation correction factor used for normalization was 0.095% a.m.u. (atomic mass unit). The results were calculated using the ISOPLOT program (Ludwig 2003) and presented with the corresponding 2σ deviations. The constants used are those recommended by Steiger and Jager (1977).

Fig. 4 – N45W/40 NE-trending mylonitic foliation in paragneiss. Outcrop K-96.

Fig. 5 – Mylonitic foliation in paragneiss, defined by quartzo-feldspatic bands and orientation and stretching of centimeter-sized feldspar and garnet porphyroclasts (arrow).

Total procedural blanks for this study ranged from 7 to 4 pg for Pb. Additional analytical details are presented in the Table I.

Analyzed crystals of monazite from a sample representative of the paragneisses from the Juréia Massif (sample K-96, Figure 2) were selected on the basis of their high transparency and lack of inclusions and cracks. Limpid, yellowish monazite crystals of the M (0.6) and M (0.7) magnetic fractions, weighing between 2.4 and 5.4μg, were separated and analyzed.

The analyzed M (0,6) and M (0,7) monazite magnetic fractions presented similar ages, 751 $\pm$ 4Ma and 741 $\pm$ 7Ma respectively. The age 751 $\pm$ 4Ma (Figure 12) is considered the best value due to very good ana-

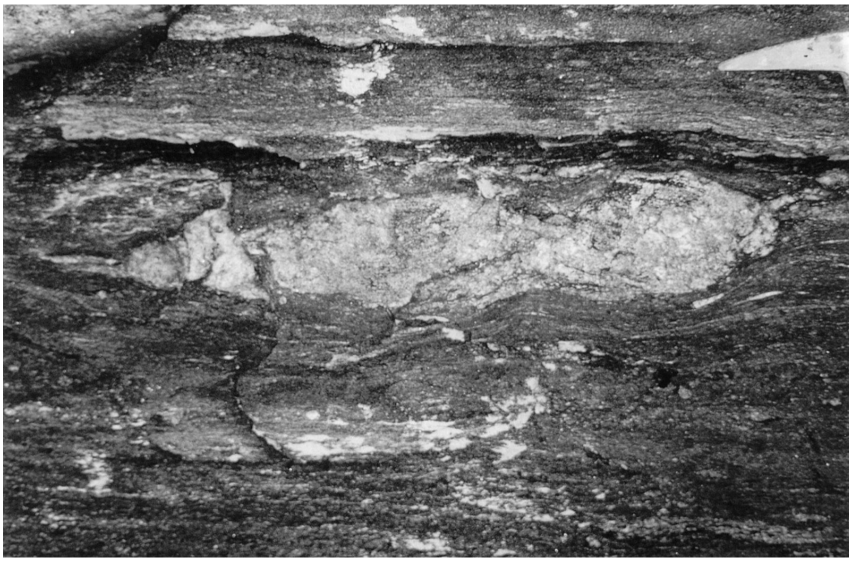

Fig. 6 – Flat, stretched quartzo-feldspatic remobilizations. XZ section.

Fig. 7 – Larger symmetric porphyroclasts in the XZ section, including S-C structures and sigmoidal porphyroclasts, suggesting dextral movement. Outcrop K-96.

lytical results, with low errors and high $^{206}Pb/^{204}Pb$ ratio (Table I).

This age is interpreted as the timing of the main regional metamorphic event, registered in metasedimentary rocks of the eastern portion of the Registro Domain (Passarelli 2001), associated with a paragenesis of the high amphibolite facies (J.M. Azevedo Sobrinho, unpublished data), reaching temperatures high enough for the generation of monazites. An important deformation phase around 722$\pm$30 Ma (Rb-Sr, WR isochron, Picanço et al. 1998) is also registered in the Itatins Complex and Cachoeira Sequence rocks.

As discussed by Giles and Nutman (2002), the possibility of prograde metamorphic growth at $> 450°C$ and thermal resetting at $\geq 700°C$ makes the U-Pb system in monazite a useful geochronometer for amphibolite facies metamorphism.

The T_{DM} model age of 2293 Ma obtained for these

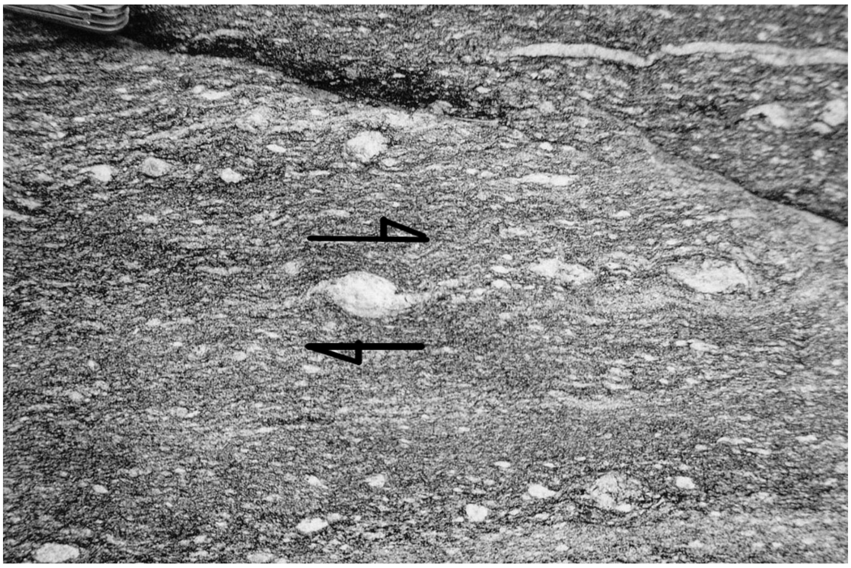

Fig. 8 – Rotated type-δ plagioclase porphyroclast in the XZ section, indicating dextral movement. Outcrop K-96.

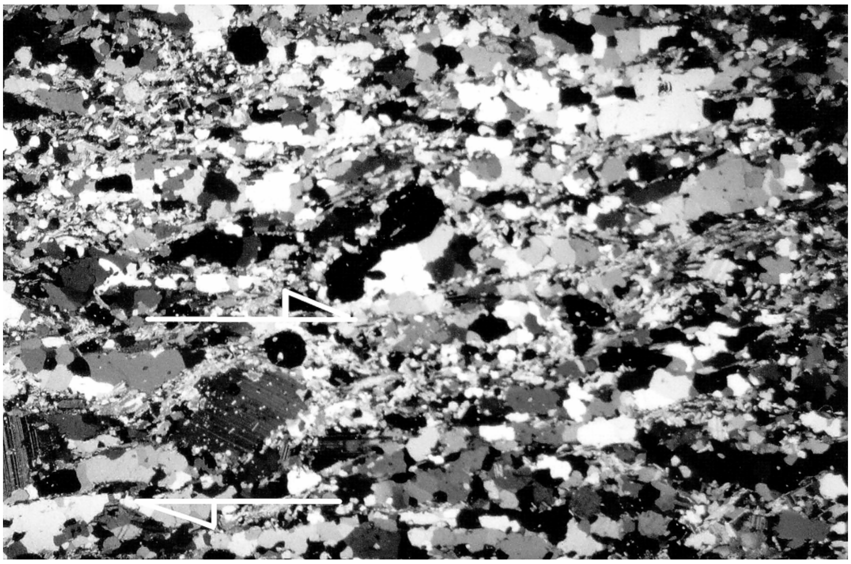

Fig. 9 – Photomicrograph (transmitted light, crossed nicols, magnification 10×). The foliation of the garnet-biotite-gneiss is characterized by the intercalation of mafic minerals in stretched quartzo-feldspatic bands. Asymmetric plagioclase porphyroclasts suggest dextral movement. K-97 Sample (XZ section).

paragneisses can represent a weighted average of the isotopic compositions of their source rocks, therefore a hybrid age.

Highly negative ϵNd(0) and $\epsilon Nd(t)_{(t=750\ Ma)}$ values of −22.04 and −13.88 respectively and very high Sr^{87}/Sr^{86} initial ratio of Ri = 0.72996 were obtained, considering the time of the metamorphic event determined by U-Pb dating (monazites). These values are expected for rocks that present important crustal contribution in their formation and long crustal residence. The analytical data are presented in Tables II and III.

The K-Ar method was applied to mylonites of the

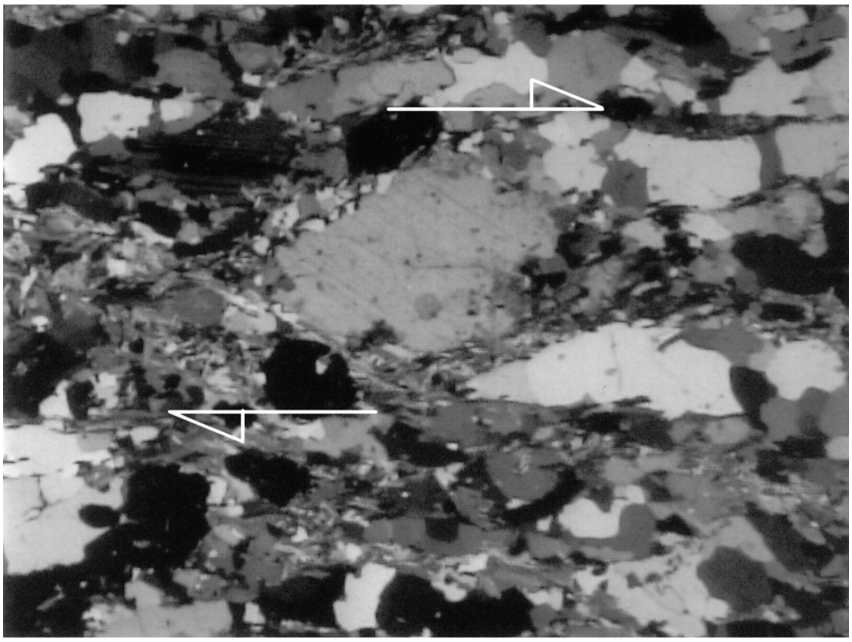

Fig. 10 – Photomicrograph (transmitted light, crossed nicols, magnification 10.5×). Sigmoidal-shaped plagioclase porphyroclast, indicating dextral movement. Note also symmetric garnet porphyroclasts. K-97 Sample (XZ section).

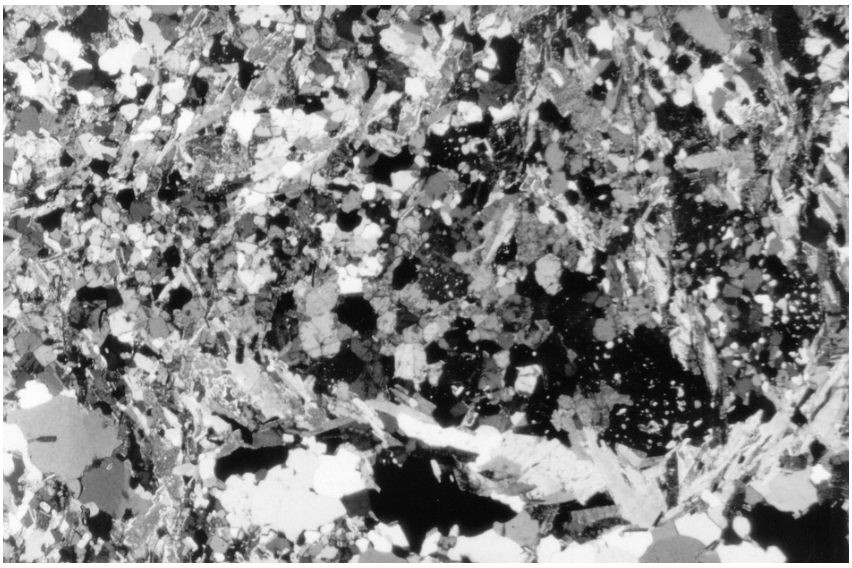

Fig. 11 – Photomicrograph (transmitted light, crossed nicols, magnification 25x). Mylonitic garnet-biotite-gneiss with recrystallization of plagioclase porphyroclasts. K-99 Sample (XZ section).

SSZ eastern, central and western sectors (Figure 13). The minerals used were fine-grained biotite of the Juréia paragneiss (eastern sector), fine-grained biotite of the monzogranitic protomylonite (central sector), and coarse-grained muscovite of the mylonitic metasedimentary rock (western sector). The analytical results yielded

TABLE I
Juréia Paragneiss U-Pb analytical data.

Juréia Paragneiss Registro Domain		Isotopic ratios							Pb	U	Weight	Ages (Ma)		
Sample	Fraction	Pb^{207}/U^{235}	Error (%)	$Pb^{206}/U^{238\#}$	Error (%)	Pb^{207}/Pb^{206}	Error (%)	Pb^{206}/Pb^{204}	(ppm)	(ppm)	(μg)	Pb^{206}/U^{238}	Pb^{207}/U^{235}	Pb^{207}/Pb^{206}
K-96 monazite	M (0.6) A	1,08722	1,07	0,123758	0,871	0,063716	0,61	176,7	1183	2555	4,2	752	747	732
	M (0.6) C	1,09655	0,855	0,123517	0,822	0,064388	0,23	1149,4	2024	4218	2,4	751	752	754
	M(0.7)	1,07455	1,33	0,121831	1,07	0,063969	0,76	469,9	1159	2396	5,4	741	741	741

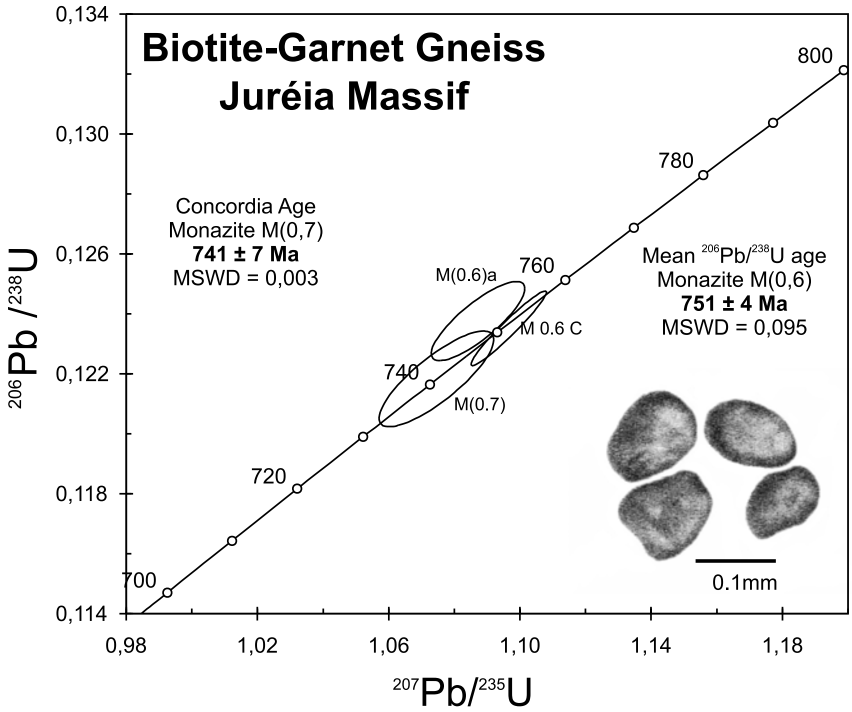

Fig. 12 – $^{207}Pb/^{235}U \times {}^{206}Pb/^{238}U$ Concordia Diagram for monazites – Ponta da Juréia- K-96 sample. Photomicrograph of typical monazite crystal of (M 0.6) fraction.

TABLE II
Juréia Paragneiss Sm-Nd analytical data.

Sample	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	Error	$\varepsilon_{(0)}$	$f_{Sm/Nd}$	T_{DM} (Ma)	$\varepsilon_{(TDM)}$	T_1 (Ma)	$\varepsilon_{(T1)}$
K-97	4.623	25.106	0.1113	0.511508	0.000016	–22.04	–0.43	2293.4	2.92	750	–13.88

TABLE III
Juréia Paragneiss Rb-Sr analytical data.

Sample	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	Error	$\varepsilon_{(0)}$	T_{DM} (Ma)	$\varepsilon_{(TDM)}$	T_1 (Ma)	$\varepsilon_{(T1)}$	$Ri–T_1$
K-97	86.0	180.0	1.388	0.744815	0.000037	572.25	2202.2	–16.77	750	374.19	0.72996

reliable ages of 482 ± 12 Ma, 493 ± 9 Ma, and 575 ± 16 Ma, from east to west (Table IV).

The age of 575 Ma for the mylonite of the SSZ western sector was obtained in coarser-grained muscovite (∼ 35 *mesh*), which must have properly retained the Ar gas in its crystalline lattice. It yielded a similar value to that obtained by the U-Pb method for monazites of the granitic protomylonite of the SSZ central sector, with ages between 570 and 580 Ma (Passarelli et al. 2003). This age, around 575 Ma, is interpreted as the main period of SSZ movement. Other results obtained for biotite crystals may reflect later movements of the shear zone, which can represent the closure of regional heating, associated with the kinematics of the involved tectonic blocks.

Additionally, despite of the analytical errors, the biotite age obtained for the central sector resulted a little older than that obtained for the eastern sector. This suggests that the eastern sector – Juréia paragneisses – would have remained heated for a longer time, that is, remained at temperatures higher than 250°C for a period a little longer than the other SSZ sectors.

DISCUSSION

The four tectonic domains in the studied area represent the product of assembly of West Gondwana during the Neoproterozoic.

The Juréia Massif paragneisses are inserted in the Registro Domain that shows tectonic contact with adjacent Embu and Mongaguá Domains to the north and with Iguape Domain to the south, through the Itariri-Cubatão Shear Zone System and the Serrinha Shear Zone respectively.

The geological contacts observed between the migmatitic granite-gneiss rocks and the paragneisses are gradational, and the Cachoeira Sequence rocks could represent the mesossome parts of the migmatites. The neossomatic portions would correspond to the cordierite-garnet-biotite granodiorites to cordierite-garnet-biotite tonalites, that crop out in the central part of the Registro Domain (Serrinha region). In the area between Itariri and Ana Dias, the migmatites neossome also has granodioritic to tonalitic composition, with garnet associated to plagioclase and biotite, and frequently the mesossomes are composed by biotite gneisses, biotite schists, or kinzigites (Picanço et al. 1998).

The Registro Domain correlates southwards with the Curitiba Domain (Basei et al. 1999), and the Juréia Massif paragneisses with the Cachoeira Sequence (Passarelli et al. 2004). However, it must be pointed out that the studied rocks from this work are correlated to those from Cachoeira Sequence, that outcrops in the S–SE area of São Paulo state, studied by Dantas et al. (1987), Gimenez Filho et al. (1987) and Picanço et al. (1998).

In addition, a more detailed study is necessary to furnish new insights into the correlation of these rocks with to those originally defined by Silva et al. (1981) also as Cachoeira Sequence, in Paraná State (NNE of Antonina city). In this area, this sequence is predominantly composed by metaultramafic and metapsamitic to metapelitic rocks in the amphibolite to granulite metamorphic facies. Hence, as the Cachoeira Sequence is not a continuously exposed unit, detailed field relations are necessary to confirm or reject the continuity of both units.

The migmatitic granite-gneiss rocks present a poorly preserved Paleoproterozoic record between 1.9 and 2.2 Ga (zircon U-Pb ages), and underwent strong reworking in the Neoproterozoic. The Neoproterozoic influence can also be observed in the structure of these rocks, with a gneissic banding developed usually subparallel to the mylonitic foliations the Cubatão and Itariri Shear Systems.

T_{DM} ages for the migmatitic granite-gneiss rocks of the Registro Domain, and Atuba Complex (Curitiba Domain) fall between 2.8 and 2.7Ga, locally 2.4 Ga (Gneisses of Timirim Hill – Registro Domain – Passarelli et al. 2004, and Mandirituba Gneisses, Atuba Complex – Siga Jr. et al. 1995), while a T_{DM} model age of 2.3 Ga for the Juréia gneisses is considered a hybrid age, due to the paraderived material. However, TDM ages around 1.5 Ga are found in a kinzigitic gneiss of Itariri (Picanço et al. 1998), assumed as Cachoeira Sequence outcropped between migmatitic granite-gneiss rocks and granulitic rocks of Itatins Suite, the latter with T_{DM} ages around 2.5 Ga (Picanço et al. 1998).

The age of deposition of the Juréia paragneiss protoliths is still uncertain. On the other hand, monazite U-Pb ages around 750 Ma imprinted in these rocks represent a conspicuous deformation phase that reached

TABLE IV
K-Ar analytical data for the Serrinha Shear Zone mylonitic rocks.

Sample Sector	Mineral	% K	Error	Ar40 Rad (* 10–6)	Ar40 Atm (%)	Age (Ma)	Error (Max.)
K-96 East	Biotite	7.35	0.80	157.52	3.91	482	12
K-102 Central	Biotite	7.63	0.50	168.25	3.98	493	9
K-27 West	Muscovite	6.35	1.56	167.06	3.22	575	16

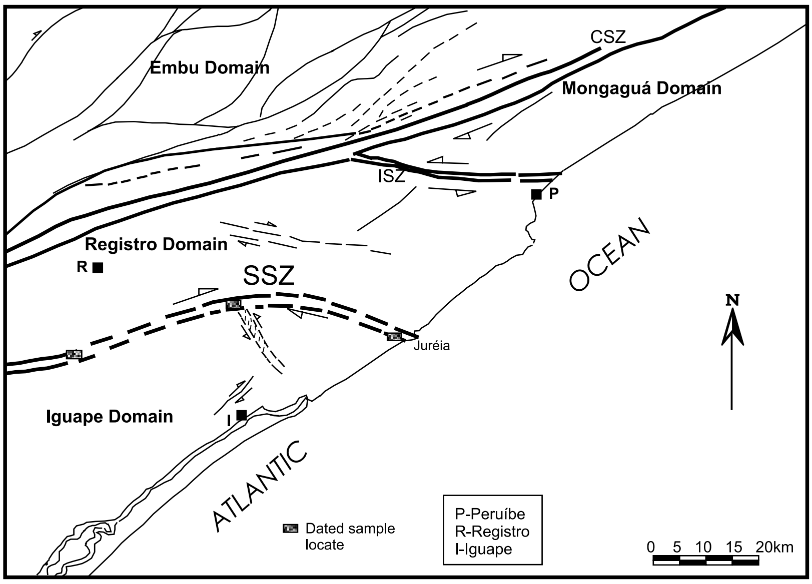

Fig. 13 – Schematic structural map with the location of dated samples.

the high amphibolite facies, similarly to what is observed in rocks of the Itatins Complex and the Cachoeira Sequence.

However, the age around 750 Ma, obtained by Rb-Sr on schists of the Embu Complex (Vieira and Tassinari 1988) is associated with the main metamorphic phase of the Embu Complex that achieved high grade (*in situ* migmatization) and medium grade (sillimanite zone) (Fernandes et al 1990). In addition, U-Pb monazite ages of 790 Ma obtained in gneissic rocks by Vlach (2001) is interpreted as the main metamorphic event in this domain and indicates a phase associated to a convergent tectonic process. In the São Lourenço da Serra area (São Paulo State), mylonitic orthogneisses, with migmatitic features, presented Rb-Sr (WR) isochron ages of 770 Ma and shrimp ages in zircons of 2000, 800 e 600 Ma, interpreted as inherited, magmatic and metamorphic zircons respectively (Cordani et al. 2000).

In addition, the granite-gneissic rocks of Serra dos Lopes, south of Taxaquara Shear Zone, near Piedade town (São Paulo State) presented an U-Pb zircon age of 788 ± 2 Ma (Leite 2003), interpreted as the better age for the magmatic crystallization of these orthogneisses, considered as host rocks of the sin-orogenic Agudos Grandes Batholith.

For the existent data, the record of the Cryogenian Period in the adjacent Embu and Registro Domains is evident as an important metamorphic and magmatic event. Evidences of this early thermal-metamorphic event, within the Brasiliano Cycle, have still not been found in Registro Domain more to the south (Curitiba Domain).

ACKNOWLEDGMENTS

This study was supported by grants (CRP and MASB respectively, 03/13246-6 and 04/07837-4) from Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). The authors thank Estação Ecológica da Juréia-Itatins (EEJI) for permission to field work in the restricted area of the Juréia Massif. Special thanks are due to the anonymous reviewers.

RESUMO

O Maciço da Juréia, localizado na porção sul-oriental do Estado de São Paulo, está inserido no Domínio Registro, limitado a norte pelo Sistema de Cisalhamento Cubatão-Itariri e a sul pela Zona de Cisalhamento Serrinha. Composto em sua maior parte por rochas granito-gnáissico migmatíticas, representa um terreno Paleoproterozóico (1.9–2.2 Ga) fortemente afetado durante o Neoproterozóico (750–580 Ma). Na área em questão, no final do Neoproterozóico estabeleceu-se o quadro tectônico atualmente observado, como resultado de colagens associadas à formação do Gondwana Ocidental. A Ponta da Juréia, porção estudada do Maciço da Juréia, é constituída por paragnaisses, onde predomina granada-muscovita-biotita gnaisses. A idade U-Pb obtida em monazitas, em torno de 750 Ma, é associada à principal fase de metamorfismo regional, que atingiu o fácies anfibolito alto, também registrado nas rochas do Complexo Itatins e da Sequência Cachoeira, igualmente pertencentes ao Domínio Registro. As rochas paragnáissicas estudadas apresentam-se afetadas pela Zona de Cisalhamento Serrinha, de direção principal em torno de E–W, com movimentação predominante dextral. Apresentam idade K-Ar em biotita de 482 ± 12 Ma que pode representar movimentações tardias desta zona de cisalhamento, e refletir a época mais jovem possível para a movimentação que ocorre ao longo dos grandes lineamentos e justaposição dos blocos tectônicos envolvidos.

Palavras-chave: domínio tectônico, zonas de cisalhamento, rochas gnáissicas, método U-Pb.

REFERENCES

ALMEIDA FFM. 1983. Relações tectônicas das rochas alcalinas Mesozóicas da região meridional da plataforma Sul-Americana. Rev Bras Geoc 13: 139–158.

ALMEIDA FFM, HASUI Y, BRITO NEVES BB AND FUCK RA. 1981. Brazilian structural provinces: an introduction. Earth Sci Rev 17: 1–29.

BABINSKI M, CHEMALE JR F, VAN SCHMUS WR, HARTMANN LA AND SILVA L. 1996. Juvenile accretion at 750–700 Ma in southern Brazil. Geology 25: 439–442.

BASEI MAS, SIGA JR O, SATO K AND SPROESSER WM. 1995. A metodologia Urânio-Chumbo na Universidade de São Paulo: Princípios metodológicos, aplicações e resultados obtidos. An Acad Bras Cienc 67: 221–237.

BASEI MAS, SIGA JR O, REIS NETO JM, HARARA OM, PASSARELLI CR AND MACHIAVELLI A. 1997. Geochronological map of the Precambrian terrains of Paraná and Santa Catarina States, southern Brazil: Tectonic Implications. In: SOUTH-AMERICAN SYMPOSIUM ON ISOTOPE GEOLOGY I, Campos de Jordão, Brazil. Extended Abstracts, p. 44–46.

BASEI MAS, SIGA JR O, REOS NETO JM, PASSARELLI CR, PRAZERES FILHO HJ, KAULFUSS G, SATO K AND LIMA PS DE. 1999. Paleoproterozoic granulitic belts of the Brazilian Southern Region (PR-SC). In: SOUTH-AMERICAN SYMPOSIUM ON ISOTOPE GEOLOGY II, Cordoba, Argentina. Extended Abstracts, p. 291–294.

CAMPOS NETO MC. 2000. Orogenic Systems from Southwestern Gondwana, an approach to Brasiliano-Pan-African cycle and orogenic collage in southeastern Brazil. In: CORDANI UG ET AL. (Eds), Tectonic Evolution of South America, Rio de Janeiro, RJ, Brazil, p. 335–365.

CORDANI UG, COUTINHO JMV AND NUTMAN A. 2000. Geochronological constraints for the age of the Embu Complex, São Paulo, Brazil. In: CONGRESSO BRASILEIRO DE GEOLOGIA 39, Rio de Janeiro, RJ, Brasil, SBG.

CORDANI UG, COUTINHO JMV AND NUTMAN A. 2002. Geochronological constraints for the age of the Embu Complex, São Paulo, Brazil. J S Am Earth Sci 14: 903–910.

DANTAS ASL, GIMENEZ FILHO A, TEIXEIRA AL, NAGATA N, FERNANDES LA, ALBUQUERQUE FILHO JL AND FRASCA MHBO. 1987. Evolução geológica e estrutural da faixa costeira nas regiões de Juquiá e Miracatu, Sul do Estado de São Paulo. In: SIMPÓSIO REGIONAL DE GEOLOGIA 6, Rio Claro, SP, Brasil, SBG 1: 173–189.

FERNANDES AJ, CAMPOS NETO MC AND FIGUEIREDO MCH. 1990. O Complexo Embú no leste do Estado de São Paulo: limites e evolução geológica. In: CONGRESSO BRASILEIRO DE GEOLOGIA 36, Natal, RN, Brasil, SBG 6: 2755–2763.

FERREIRA FILHO CF, KAMO SL, FUCK RA, KROGH TE AND NALDRET AJ. 1994. Zircon and rutile U-Pb geochronology of the Niquelândia layered mafic and ultramafic intrusion, Brazil: constraints for the time of magmatism and high grade metamorphism. Prec Res 68: 241–255.

GILES D AND NUTMAN AP. 2002. SHRIMP U-Pb monazite dating of 1600–1580 Ma amphibolite facies metamorphism in the southeastern Mt Isa Block, Australia. Aust J Earth Sci 49: 455–465.

GIMENEZ FILHO A, ALBUQUERQUE FILHO JL, DANTAS ASL, FERNANDES LA, NAGATA N AND TEIXEIRA AL. 1987. Geologia da Folha Miracatu, Sul-sudeste do Estado de São Paulo. In: SIMPÓSIO REGIONAL DE GEOLOGIA 6, Rio Claro, SP, Brasil, SBG 1: 225–241.

HACKSPACHER PC, DANTAS LD, SPOLADORE A, FETTER AH AND OLIVEIRA MAF. 2000. Evidence of Neoproterorozoic back-arc Basin development in the Central Ribeira belt, South-eastern Brazil: new geochronological geochemical constraints from the São Roque-Açungui Groups. Rev Bras Geoc 30: 110–114.

HANMER S AND PASSCHIER CW. 1991. Shear-sense indicators: a review. Geol Survey of Canada – Paper 90-17, 72 p.

HARARA MO, BASEI MAS AND SIGA JR O. 1997. Geochonological and Geochemical Data on the Transition Zone between Luis Alves and Atuba Complexes, South Brazil. In: SOUTH-AMERICAN SYMPOSIUM ON ISOTOPE GEOLOGY I, Campos de Jordão, Brazil, Extended Abstracts, p. 134–136.

HASUI Y, DANTAS ASL, CARNEIRO CDR AND BISTRICH CA. 1981. O embasamento Pré-Cambriano e Eo-Paleozóico em São Paulo. In: INSTITUTO DE PESQUISAS TECNOLÓGICAS DE SÃO PAULO. Mapa Geológico do Estado de São Paulo, Escala 1.500.000. São Paulo, SP, Brasil, 1: 12–45 (IPT – Monografia 6. Publicação 1184).

HEILBRON M AND MACHADO N. 2003. Timing of terrane accretion in the Neoproterozoic-Eopaleozoic Ribeira Orogen (SE Brazil). Prec Res 125: 87–112.

JANASI VA, ALVES A, VLACH SRF AND LEITE RJ. 2003. Granitos Peraluminosos da Porção Central da Faixa Ribeira, Estado de São Paulo: Sucessivos Eventos de Reciclagem da Crosta Continental no Neoproterozóico. Geol USP Sér Cient 1: 13–24.

KROGH TE. 1973. A low contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations. Geoch et Cosm Acta 37: 485–494.

KROGH TE. 1982. Improved accuracy of U-Pb zircon ages by the creation of more concordant systems using an air abrasion technique. Geoch et Cosm Acta 46: 637–649.

KROHE A AND WAWRZENITZ N. 2000. Domainal variations of U-Pb monazite ages and Rb-Sr whole-rock dates in polymetamorphic paragneisses (KTB Drill Core, Germany): influence of strain and deformation mechanisms on isotope systems. J Metam Geol 18: 271–291.

LEITE RJ. 2003. Petrogênese e geocronologia U-Pb do magmatismo granítico tardi – a pós-orogênico no Batólito Agudos Grandes (SP). Ph.D. Thesis. São Paulo, SP, Brasil IGc-USP, 218 p.

LUDWIG KR. 2003. User's manual for Isoplot 3.0: a geochronological toolkit for Microsoft Excel. Berkeley Geochronology Center, Special Publication n. 4, 71 p.

MACHADO N, VALLADARES C, HEILBRON M AND VALERIAN C. 1996. U-Pb geochronology of Central Ribeira Belt (Brazil) and implication for the evolution of the Brazilian Orogeny. Prec Res 79: 347–361.

MORGENTAL A, PINTO GG, DRUMOND JBV, PAIVA IP, RODRIGUES JC, MORAES AMV AND LEITE JS. 1973. Projeto SUDELPA-CPRM, Relatório da Primeira Fase/ Superintendência do Desenvolvimento do Litoral Paulista, Secretaria de Economia e Planejamento. São Paulo, SP, Brasil, 3v.

MORGENTAL A, BATOLLA JR F, PINTO GG, PAIVA IP AND DRUMOND JBV. 1975. Projeto SUDELPA-CPRM, Relatório Final. Geologia, vol. 1, São Paulo, SP, Brasil, 18v.

PARRISH RR. 1987. An improved micro-capsule for zircon dissolution in U-Pb geochronology. Isot Geosc 66: 99–102.

PARRISH RR. 1990. U-Pb dating of monazite and its application to geological problems. Can J Earth Sci 27: 1431–1450.

PASSARELLI CR. 2001. Caracterização estrutural e geocronológica dos domínios tectônicos da porção sul-oriental do Estado de São Paulo. Ph.D. Thesis. IGc-USP, São Paulo, SP, Brasil, 254 p.

PASSARELLI CR, BASEI MAS, CAMPOS NETO MC AND SIGA JR O. 2000. Geology and U-Pb geochronology of precambrian terranes of southeastern São Paulo State, Brazil. In: CONGRESSO BRASILEIRO DE GEOLOGIA 39, Rio de Janeiro, RJ, Brazil.

PASSARELLI CR, PRAZERES FILHO HJ, SIGA JR O, BASEI MAS AND CAMPOS NETO MC. 2003. Geocronology and Isotope Geology of the Precambrian Terranes of southeastern São Paulo State, Brazil. In: SIMPÓSIO SUL-

AMERICANO DE GEOLOGIA ISOTÓPICA IV, Salvador, Brazil. Short Papers II: 635–638.

PASSARELLI CR, BASEI MAS, CAMPOS NETO MC, SIGA JR O AND PRAZERES FILHO HJ. 2004. Geocronologia e geologia isotópica dos terrenos Pré-Cambrianos da porção sul-oriental do Estado de São Paulo. Geol USP Sér Cient 4: 55–74.

PICANÇO J, TASSINARI CCG, CORDANI UG AND NUTMAN AP. 1998. Idades U-Pb (SHRIMP), Sm-Nd e Rb-Sr em rochas do Maciço de Itatins (SP): Evidências de Evolução Policíclica. An Acad Bras Cienc 70: 139–150.

PIMENTEL M, FUCK RA AND BOTELHO NF. 2000. Granites and the geodynamic history of the Neoproterozoic Brasília belt, Central Brazil: a Review. Lithos 46: 463–483.

SATO K AND KAWASHITA K. 2002. Espectrometria em geologia isotópica. Geol USP Sér Cient 2: 57–77.

SATO K, NUTMAN AP, SIGA JR O, BASEI MAS AND SPRÖESSER WM. 2001. Mesoarchean orthogneiss in the Atuba Complex in a Neoproterozoic Brasiliano mobile belt in SE Brazil: An integrate idtims, evtims and shrimp zircon dating study. Gond Res 4: 775–777.

SIGA JR O, BASEI MAS AND MACHIAVELLI A. 1993. Evolução geotectônica da porção NE de Santa Catarina e SE do Paraná, com base em interpretações geocronológicas. Rev Bras Geoc 23: 215–223.

SIGA JR O, BASEI MAS, REIS NETO JM, MACHIAVELLI A AND HARARA OM. 1995. O Complexo Atuba: um cinturão Paleoproterozóico intensamente retrabalhado no Neoproterozóico. Bol IG-USP Sér Cient 26: 69–98.

SILVA ATSF. 1981. Tentativa de interpretação da gênese e evolução da infraestrutura arqueana exposta entre Peruíbe e Curitiba, SP e PR. In: SIMPÓSIO REGIONAL DE GEOLOGIA 3, Curitiba, PR, Brasil, SBG 1: 133–147.

SILVA ATSF, CHIODI FILHO C, CHIODI DK AND ALGARTE JP. 1978. Geologia Integrada das Folhas Cananéia e Iguape. In: CONGRESSO BRASILEIRO DE GEOLOGIA 30, Recife, PE, Brasil, SBG 1: 208–221.

SILVA ATSF, FRANCISCONI O, GODOY AM AND BATOLLA JR F. 1981. Projeto integração e detalhe geológico no Vale do Ribeira: Relatório Final – Integração geológica. Vol. 1, São Paulo, SP, Brasil, CPRM, 15v.

STEIGER RH AND JAGER E. 1977. Subcomission on geochronology: convention on the use of decay constants in geo and cosmochronology. Earth Plan Sci Lett 36: 359–362.

TUPINAMBA M, TEIXEIRA W AND HEILBRON M. 2000. Neoproterozoic Western Gondwana assembly and subduction-related plutonism: the role of the Rio Negro Complex in the Ribeira belt, South-eastern Brazil. Rev Bras Geoc 30: 7–11.

VIEIRA, SRSS AND TASSINARI CCG. 1988. Estudo petrológico e geocronológico das rochas da região de Embu-Guaçu, Estado de São Paulo. In: CONGRESSO BRASILEIRO DE GEOLOGIA 35, Belém, PA, Brasil, SBG 3: 1391–1399.

VLACH SRF. 2001. Microprobe monazite constraints for an early (*ca.* 790 Ma) Brasiliano orogeny: the Embu Terrane, Southeastern Brazil. In: SOUTH-AMERICAN SYMPOSIUM ON ISOTOPE GEOLOGY III, Pucon, Chile, Extended Abstracts, p. 265–268.