GEOCRONOLOGY AND ISOTOPE GEOLOGY OF THE PRECAMBRIAN TERRANES OF SOUTHEASTERN SÃO PAULO STATE, BRAZIL

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Tectonic domains limited by significant shear zones compose the southeastern part of São Paulo State, and their interpretation is fundamental to the regional geotectonic picture (Fig.1). The present tectonic situation, where four major tectonic domains were defined (Fig.2), is the product of *collages* related to the formation of West Gondwanaland, which ended in the Neoproterozoic (Almeida et al., 2000).

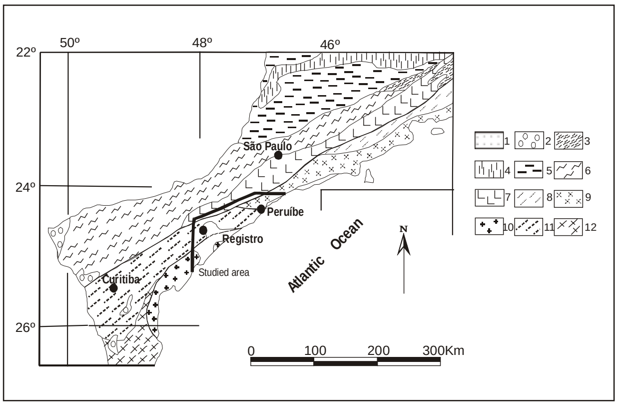

Figure 1. Outline of main tectonic domains of southeastern Brazil and localization of the studied area (mod. Campos Neto & Figueiredo, 1995; Basei et al., 1999). 1. Phanerozoic cover (Paraná Basin). 2. Neoproterozoic/Eo-Paleozoic Basins. 3. Juiz de Fora Infracrustal Terrane. 4. Alto Rio Grande Belt. 5. Socorro-Guaxupé Nappe. 6. Apiaí Folded Belt. 7. Embu Supracrustal Terrane. 8. Paraíba do Sul Terrane. 9. Serra do Mar Microplate. 10. Paranaguá Domain. 11. Curitiba Domain. 12. Luis Alves Terrane.

The Embu Domain occurs north of the Cubatão Shear Zone (CSZ), and it is mainly composed by metasedimentary rocks of medium to high metamorphic grade, locally migmatized, intruded by peraluminous granites which were controlled by E-NE shear zones (Cubatão - Itariri Shear System - CISS). Despite the analytical errors, the U-Pb monazite age of Sete Barras Granite (631 ± 23 Ma, Fig. 3A), is associated to the syn collisional stage of this sector of Ribeira Belt (RB) at around 620 Ma, (Janasi, 1999; Hackspacher et al., 2000) responsible for significant calc-alkaline magmatism. U-Pb (monazite) age of the Juquiá Granite (598 ± 8 Ma, Fig. 3B) dates the formation of these rocks from a crustal source and reflects the late collisional stage of this sector of RB which is characterized by lateral escape tectonics (NE-SW shear zones - formation of the CISS) and emplacement of granitic bodies. In addition, the Juquiá Granite has a model Nd T_{DM} age around 2.0 Ga.

The U-Pb zircon ages around 760 Ma (Figs. 3A and 3B) might reflect isotopic inheritance, but the possibility that represents the crystallization age of these granites and the monazite age (ca. 600 Ma) a later thermal event cannot be discarded. The peak of metamorphism in this domain at around 760 Ma was identified by Fernandes (1991), and reached high grade and anatexis. In addition, this phase was related to convergent tectonics (Vlach, 2001). Mylonitic orthogneisses of Embu Complex present a WR Rb-Sr isochron with an age of 770 Ma, and $(Sr^{87}/Sr^{86})i$ of 0.722 (Cordani et al., 2000), similar to the U-Pb zircon ages and $(Sr^{87}/Sr^{86})i$, found in this work (0.727). Nevertheless, the SHRIMP measurements reveal a very heterogeneous zircon population, with ages around 2,000, 800 e 660 Ma, indicating inherited, magmatic and metamorphic zircons respectively. The Nd and Sr isotopic data indicate that the granitic magmatism of this domain was produced from crustal source reworked in the Neoproterozoic.

The Mongaguá Domain is bounded to the northwest by CSZ, to the west by Itariri Shear Zone (ISZ) and to the east by the Atlantic Ocean (Fig. 2). It corresponds to undifferentiated migmatites of the Costeiro Complex (Gimenez Filho et al., 1987), to the Gneiss-migmatite Terrane of the Serra do Mar Microplate (Campos Neto & Figueiredo, 1995; Campos Neto, 2000), and to the Costeiro Granite Belt (Basei et al., 1999, 2000). The main rock type is gneiss-migmatite with granitic and dioritic compositions, in close association, and related granites. Passarelli (2001) defined three main groups of granite: the Itariri (IT), with gneiss migmatitic features, the Areado (A) with local gneissic features, and the Ribeirão do Óleo (RO) type with well-characterized magma mingling features. The main trend is E-NE, with the exception of the Itanhaém Gneiss (NW-SE structure and sub-horizontal dip).

For gneiss-migmatitic rocks conventional multicrystal zircon U-Pb dating provides an age of 612 ± 3 Ma (Fig. 4) interpreted as the crystallization age. Analyses of zircon indicate crustal inheritance in IT and RO Granites, and vague lower intercept U-Pb (zircon) ages around 580 and 620-630 Ma respectively (Passarelli, 2001). In this context, the A and RO granites are syn-kinematic to CISS since the ISZ movement conditioned the final phases of magmatic flow of IT Granite.

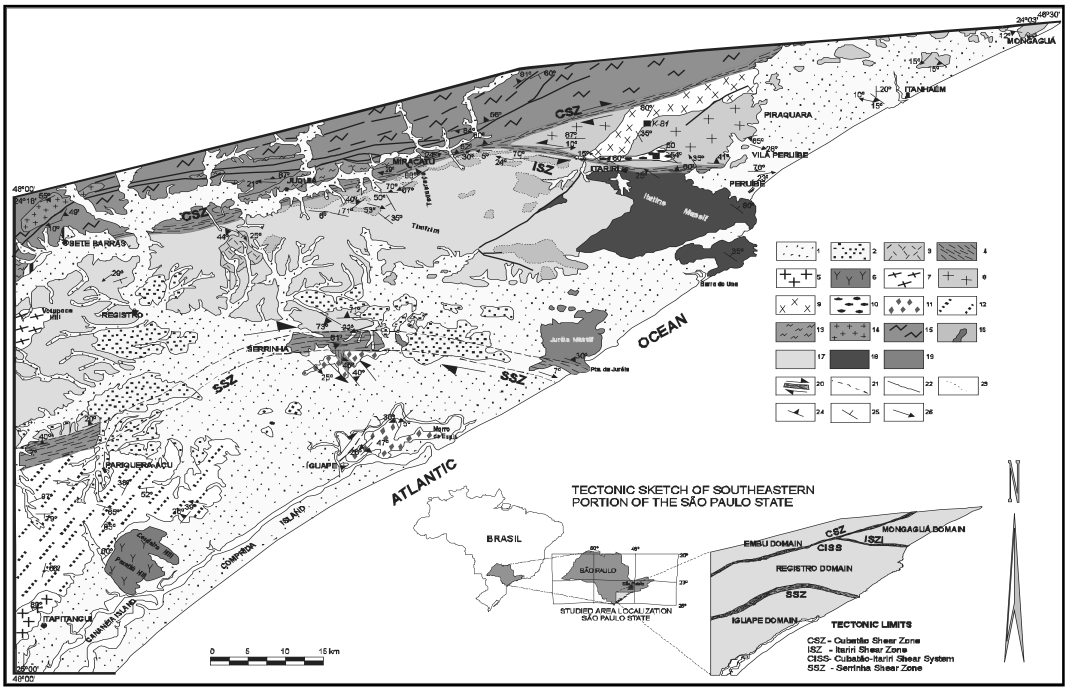

Figure 2. Geological map of southeastern São Paulo State. 1. Quaternary sediments. 2. Terciary sediments. 3. Juquiá Alkaline Complex (Cretaceous). 4.CISS and SSZ: mylonitic rocks (600-570 Ma). Serra do Mar Granitic Suite (c. 580 Ma): 5. Itapitangui; 6. Serra do Cordeiro 7. Serra do Votupoca. Mongaguá 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.Juréia (> 750 Ma). 20. Transcurrent shear zones. 21. Infered Faults. 22. Lineaments. 23. Gradational geological contact. 24. Mylonitic foliation. 25. Principal foliation. 26. Mineral lineation.

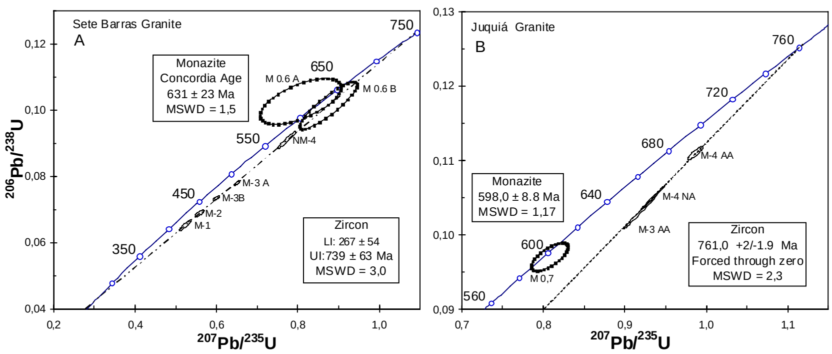

Figure 3. Concordia Diagram $^{207}Pb/^{235}U$ x $^{206}Pb/^{238}U$ (zircon and monazite). Embu Domain. A) Sete Barras Granite; B) Juquiá Granite

The similar TDM ages (1.7-1.8 Ga), negative ε_{Nd} values and $(Sr^{87}/Sr^{86})i$ around 0,708, of the granitic and dioritic portions of the Mongaguá and Itanhaém rocks may indicate efficient mixing kinematics, as discussed by Perugini et al. (2002). The Sr and Nd isotopic compositions for the granites, demonstrate that differentiation of the different crustal sources from the mantle occurred during different paleoproterozoic events (1.7 Ga - RO and 2.2 Ga - IT).

The structural evidence provides a compressional setting to the generation and emplacement of the Mongaguá Domain rocks, and the recorded deformation is possibly related to the emplacement of these rocks and associated to the juxtaposition of the Mongaguá Domain to the others.

The Registro Domain, between the CISS and the Serrinha Shear Zone (SSZ) (Fig. 2) comprises granitic rocks with different degrees of assimilation by dioritic material and migmatitic features, and metasediments. Represents a paleoproterozoic domain (1.9–2.2 Ga) intensely affected in Neoproterozoic times (750 – 580 Ma), being correlated to Atuba Complex (Siga Jr. et al., 1995) of Curitiba Domain. The domain has a NW-SE structure, which swings to E or NE under the influence of the CISS.

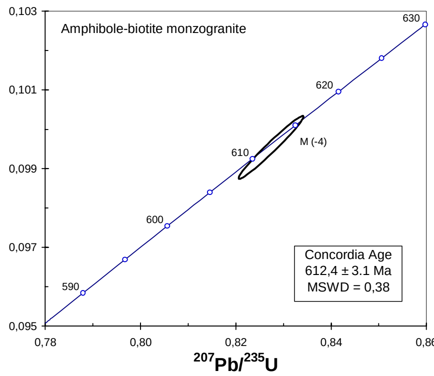

Figure 4. Concordia Diagram $^{207}Pb/^{235}U$ x $^{206}Pb/^{238}U$ (zircon) – Mongaguá Domain.

The migmatitic granites present evidence of extensional processes in the form of syn-plutonic dykes and enclave swarms. Mixing and mingling between the granitic and dioritic materials probably occurred between 2.2 and 1.9 Ga as shown by U-Pb (zircon) ages. The rocks were intensely affected by the Brasiliano tectono thermal event, as shown by the lower intercept U-Pb (zircon) ages of about 580 Ma in gneisses which have model Nd T_{DM} ages concentrated in the 2.7 - 2.9 Ga interval. The gneiss-migmatitic rocks present strongly discordant zircon U-Pb ages as a result of recrystallization during high grade metamorphism.

An upper intercept age of 1,894 ± 26 Ma was obtained in amphibole-biotite granodiorite (Fig. 5A) where ruptured syn-intrusive mafic dikes occur together with rounded enclaves. This result is interpreted as the minimum age for the crystallization of the granodiorite, and the mingling between granodioritic and dioritic magmas.

A record of paleoproterozoic and neoproterozoic ages is observed where hybrid rocks occur with gneissic and migmatitic features and with partially assimilated dioritic enclaves. An example is the mesocratic biotite-monzogranite with an upper intercept age of 2,197 ± 43 Ma interpreted as the probable age of crystallization of its protolith. The lower intercept age of 580 ± 23 Ma, in spite of being inaccurate, dates an important thermal / migmatitic event that caused neoformation of zircon crystals (Fig. 5B).

The mylonitic paragneiss from the Juréia Massif has a concordant U-Pb (monazite) age of 752 ± 4 Ma (Fig. 5C), that dates the amphibolite-grade metamorphism.

The Votupoca granite (Serra do Mar Suite, Kaul & Cordani, 1994) intruded into the gneiss-migmatites, has an age of 582 Ma (Passarelli, 2001).

Two distinct periods to mantle differentiation of the granitic rocks protolith are defined: 2.7-2.9 and 2.4 Ga.

The Sr and Nd isotopic compositions are clearly controlled by the hybridization degree of dioritic and granitic magmas. Where the mixing predominates both rocks present similar $(Sr^{87}/Sr^{86})i$ around 0.717 and negative εNd values. In some areas, the mixing was not so efficient, and the end members are isotopically different.

Rocks of the Iguape Domain, limited northwards by the SSZ and south-southeastwards by the Atlantic Ocean, include granites and metasediments with a dominantly NE structural orientation (Fig. 2). It is correlated to the Paranaguá Batolith (Basei et al., 1990) and Costeiro Granitic Belt (Basei et al., 1999, 2000).

The metasediments are mostly in low metamorphic grade, while the granites comprise three separate geochronological and geochemical groups. Protomylonitic granites of the Iguape massif have ages around 600 Ma (Fig. 6), and have geochemical signatures of volcanic arc or syncollision granites. The granites of the Paratiú - Cordeiro and Itapitangui hills are 580 Ma intraplate granites, similar to the Serra do Mar Granitic Suite (Kaul & Cordani, 1994). The SSZ has a dominantly E-W direction and dextral sense, but an important SE-oriented branch is sinistral.

Two distinct phases of mantle differentiation of the granitic rocks protolith are defined: 2.2 Ga and 1.8 Ga, and similar ε_{Nd} values that suggest similar crustal contributions to the generation of these rocks. $(Sr^{87}/Sr^{86})i$ between 0.711 and 0.714 corroborate this.

The studied rocks were originated and/or significantly affected by the Brasiliano Orogeny, and the oldest domains in the area (Embu and Registro) register an early thermo-metamorphic event at around 750 Ma.

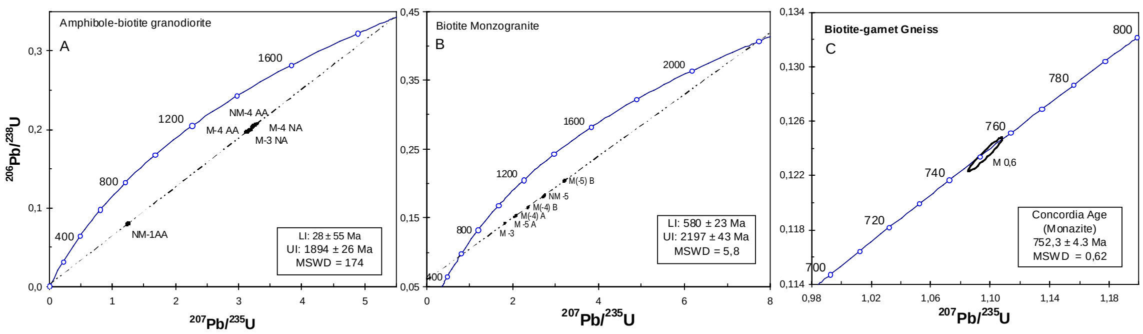

Figure 5. Concordia Diagram $^{207}Pb/^{235}U$x$^{206}Pb/^{238}U$ (zircon). A) Oliveira Barros; B) Serra Timirim; C) Juréia Massif–Registro Domain.

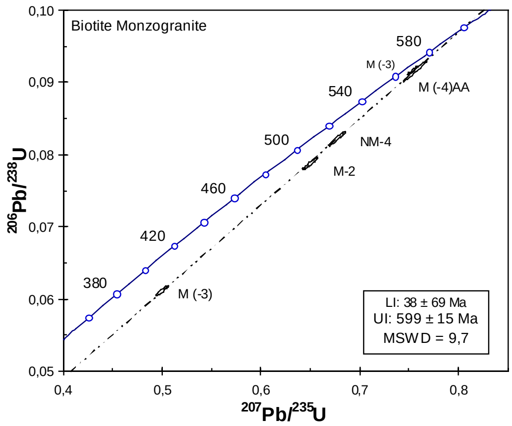

Figure 6. Concordia Diagram $^{207}Pb/^{235}U$ x $^{206}Pb/^{238}U$ (zircon) Morro do Espia – Iguape Domain.

It is likely that all these tectonic blocks were juxtaposed during a short time interval at the end of Neoproterozoic. The joining of the Registro and Embu Domains occurred at about 606 Ma along an E-W shear zone (Passarelli, 2001). The 598 Ma peraluminous granites (Embu Domain) may register the arrival of the Mongaguá Domain against the newly formed Registro-Embu Domain through E-W compression. The generation and emplacement of granite-gneiss migmatitic rocks of Mongaguá Domain (612 ± 3 Ma) might be associated to compressive regimes, possibly related to the juxtaposition kinematics of this domain to the others. The welding of the Iguape and Registro domains probably occurred between 580 and 570 Ma, as suggested by the U-Pb (monazite) age of the protomylonitic granites of the SSZ.

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