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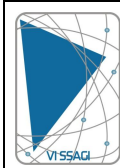
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## TECTONO-THERMAL EVOLUTION OF THE SE SÃO PAULO STATE PRECAMBRIAN TERRANES

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**Keywords:** Tectonic domains, shear zone, U-Pb and K-Ar geochronology, cooling rate

### Abstract

Aiming at the characterization of the thermal history of Pre-Cambrian terranes of the southeastern São Paulo state, specific geochronological studies were carried out on mylonitic and granitic rocks.

The southeastern Ribeira Belt, in the Mantiqueira Province, consists of four major tectonic domains limited by significant shear zones, associated with Neoproterozoic events.

The Embu Domain, north of the Cubatão Shear Zone (CSZ), is composed of metasedimentary rocks, and peraluminous granites, that yielded U-Pb ages of ca. 790 Ma, 620 Ma and 600Ma. Gneiss-migmatitic rocks, which yield U-Pb zircon ages in the 640 - 620 Ma range, and intrusive granites of 580 Ma predominate in the Mongaguá Domain, which is limited by Cubatão and Itariri shear zones. The Registro Domain, between Cubatão - Itariri Shear System (CISS) and the Serrinha Shear Zone (SSZ), is formed by metasediments and granitic rocks with migmatitic features and represents a Paleoproterozoic terrane (1.9–2.2 Ga) strongly deformed during the Neoproterozoic (750–580 Ma). Rocks of the Iguape Domain, limited to the north by the SSZ, include granites with U-Pb zircon ages at ca. 600 Ma, and low-grade metasediments.

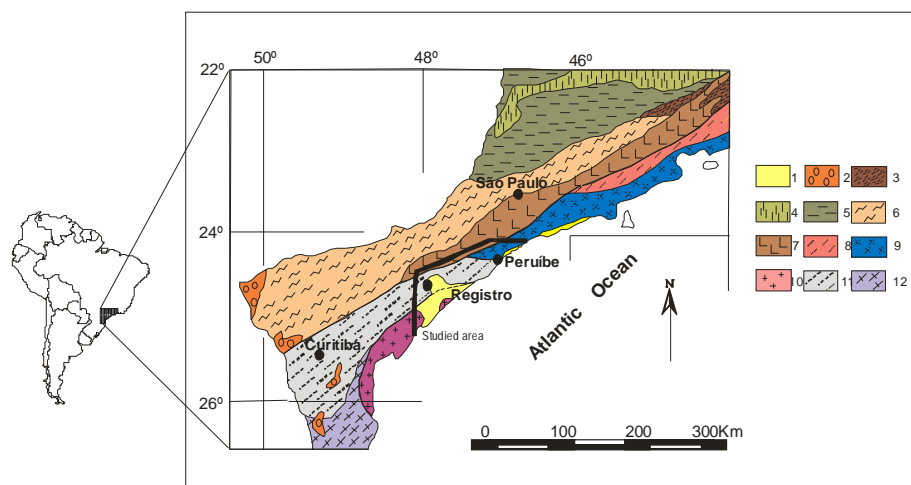
The Itariri and Cubatão mylonites occur as high- and low-temperature varieties, formed in amphibolite and greenschist facies conditions, respectively. Serrinha mylonites developed under amphibolite facies.

U-Pb zircon and monazite geochronological evidence indicates a short time interval at the end of Neoproterozoic for the juxtaposition of the blocks.

From the compilation of geochronological data, a temperature vs. time correlation diagram was obtained and both sequences of slower and faster cooling rates processes along the geological history could be identified.

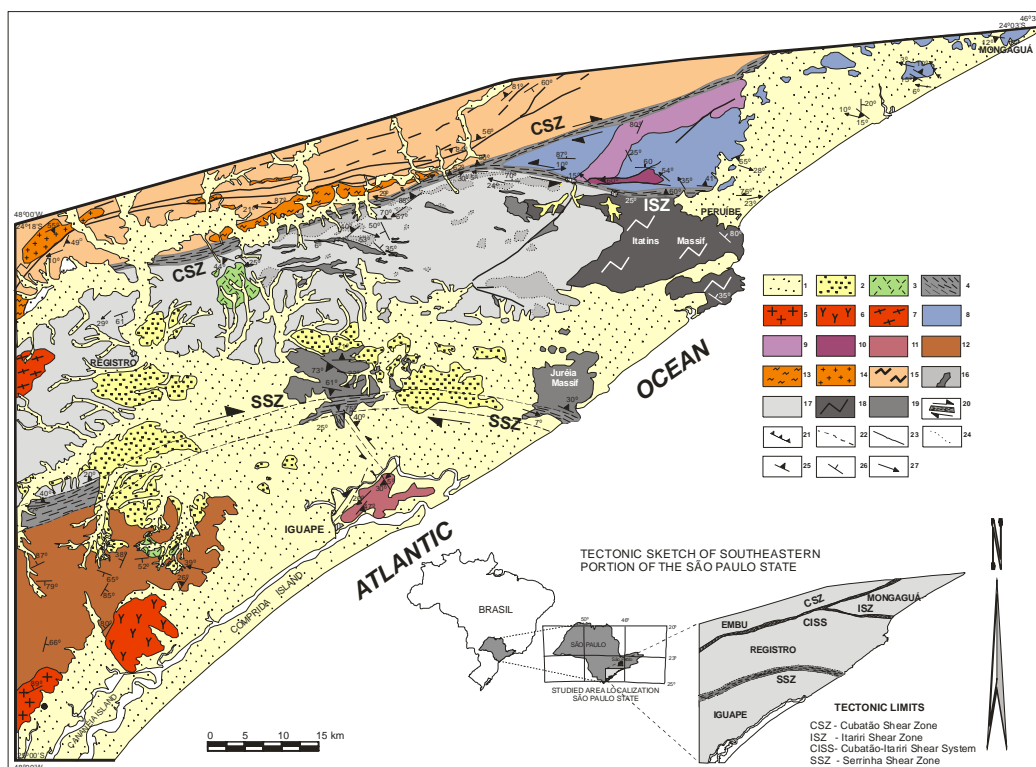
### Introduction

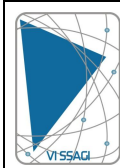
The southeastern sector of Ribeira Belt in the Mantiqueira Province (Almeida *et al.* 1981), SE Brazil, consists of tectonic domains limited by significant shear zones, related to Neoproterozoic tectonic events (Figure 1).



**Figure 1** - Outline of main tectonic domains of southeastern Brazil and localization of the studied area (modified from Campos Neto and 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.

Particularly in SE São Paulo State, four distinct tectonic domains delimited by major Neoproterozoic shear zones are defined. These are the Embu Domain, separated by the Cubatão-Itariri Shear System (CISS) from the Registro Domain southwards and the Mongaguá Domain eastwards, and the Iguape Domain, separated by the Serrinha Shear Zone (SSZ) from the Registro Domain northwards (Figure 2).





**Figure 2** - Geological Map of southeastern São Paulo State (modified from Passarelli 2001). 1. Quaternary sediments. 2. Tertiary sediments. 3. Juquiá Alkaline Complex (Cretaceous). 4. CISS and SSZ: mylonitic rocks. Serra do Mar Granitic Suite: 5. Itapitangui 6. Serra do Cordeiro 7. Serra do Votupoca. Mongaguá Domain: 8. Granite-gneiss-migmatitic Domain. 9. Areado Granite. 10. Ribeirão do Óleo Granite. Iguape Domain: 11. Iguape Granite. 12. Iguape Metasediments. Embu Domain: 13. Juquiá Granite. 14. Sete Barras Granite. 15. Metasediments. Registro Domain: 16. Granite-gneiss-migmatitic Domain. 17. Gneissic Domain. 18. Itatins Complex. 19. Cachoeira Sequence. 20. Transcurrent shear zones. 21. Fault with thrust component 22. Inferred Faults. 23. Lineaments. 24. Gradational geological contact. 25. Mylonitic foliation. 26. Principal foliation. 27. Mineral lineation.

The Embu Domain is composed of metasedimentary rocks, and peraluminous granites. Gneiss-migmatite rocks and intrusive granites predominate in the Mongaguá Domain, which is limited by the Cubatão and Itariri shear zones. The E–W oriented shortening in the CISS is consistent with a dextral and sinistral regime in the Cubatão and Itariri shear zones respectively, with mylonites developed under greenschist and amphibolite facies in that order. The Registro Domain is formed by metasediments and granitic rocks with migmatitic features. Rocks of the Iguape Domain, limited to the north by the SSZ, include granites and low grade metasediments. The SSZ in a dextral transpressive tectonic regime developed under amphibolite facies conditions.

## Results and Discussion

From igneous and metamorphic petrographic studies, basic structural analysis, U-Pb geochronology on zircon and monazite, K-Ar geochronology on minerals and fine fractions, and microtectonic analyses, relevant information has been obtained on the evolution of these SE São Paulo State Precambrian terranes, as well as the metamorphic-deformational evolution of the shear zones that bound them.

The Embu Domain garnet-bearing two-mica granite (Juquiá Granite) yields U-Pb zircon concordia age of  $793 \pm 3$  Ma interpreted as the crystallization age. The genesis of these granites is associated with melting of supracrustal rocks in a convergent tectonic environment (Passarelli *et al.* 2004, Vlach 2001, Silva *et al.* 2005). Monazite U-Pb ages of ca. 620 Ma on Sete Barras Granite record a posterior thermal event affecting this domain.

The maximum age obtained for the movement of CISS was  $\sim 598$  Ma (U-Pb zircon ages for the granitic protomylonite; U-Pb allanite ages for the Embu Domain Cryogenian peraluminous granite – Juquiá Granite). In the northern portion of the Embu Domain (São Paulo State), north of the Taxaquara Fault, compressive tectonic-associated granites yield ages that corroborate with the ages obtained in this work, between 610–595 Ma (Hackspacher *et al.* 2004). For a continuity of the Cubatão Shear Zone (CSZ) in the Rio de Janeiro State (RJ) – the Além Paraíba Shear Zone – a maximum age of  $590 \pm 8$  Ma was defined by U-Pb dating of titanite and monazite for the WNW thrust (Machado *et al.* 1996).

The Mongaguá Domain (São Paulo State) gneissic-granitic rocks yield U-Pb zircon ages of 620 and 640 Ma. These rocks may have been intensely deformed during the juxtaposition of the other domains (Embu and Registro), with possible generation of intrusive granites around 580 Ma.

Similar to the Mongaguá Domain, in the central part of Ribeira Belt, Costeiro Domain (terrane SE of the Além Paraíba Shear Zone, Rio de Janeiro State), rocks characteristic of magmatic arcs that perfectly correlate with gneissic rocks and Itariri-type granitic rocks of the Mongaguá Domain yield U-Pb zircon ages of ca. 630 Ma (Tupinambá *et al.* 2000, Dias Neto *et al.* 2002). In these regions, Paraíba do Sul and Costeiro Domains, a metamorphic peak was defined at 580 Ma (Machado *et al.* 1996) and a granitoid emplacement in a syn-collisional setting between 590–550 Ma (Heilbron and Machado 2005).

The Registro Domain is correlated with the Curitiba Domain - Paraná State (Siga Jr. *et al.* 1995), as discussed by Basei *et al.* (1999) and Passarelli *et al.* (2004). Mostly composed of migmatitic granite gneiss rocks, it represents a Paleoproterozoic terrane (1.9–2.2 Ga) strongly deformed during the Neoproterozoic (750–580 Ma). 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.

The Iguape Domain is composed of granitic and metasedimentary rocks, being the northern limit the Serrinha Shear Zone (SSZ) and the south-southeastern limit the Atlantic Ocean (Fig. 2). This region is correlated with the Costeiro Granitic Belt (Basei *et al.* 1999). The Iguape Massif granites are peraluminous and present characteristics similar to the volcanic-arc or syn-collisional granites (Passarelli, 2001). Biotite-monzogranites yield U-Pb (zircon) ages around 600 Ma. The more alkaline granites that occur in this Domain and yield U-Pb ages around 580 Ma (Passarelli 2001) are correlated with the Serra do Mar Suite (Kaul and Cordani 2000).

The SSZ, which separates the Registro and Iguape Domains, had its major movement at 575 Ma, age defined by the U-Pb method applied to monazites of the granitic protomylonite, which represents the juxtaposition of the Registro and Iguape Domains. Likewise for syn-collisional granites south of the Além Paraíba Shear Zone (RJ) ages in the 580-560 Ma interval were obtained. The metamorphic peak was defined by monazite and titanite dating (Machado *et al.* 1996, Silva *et al.* 2003).

Thus, the juxtaposition of tectonic blocks by means of CISS and SSZ must have occurred in very close periods during the Neoproterozoic. The present tectonic scenario of SE São Paulo State results from collages associated with the formation of the Western Gondwanaland by the end of the Neoproterozoic (Almeida *et al.* 2000).

From the compilation of geochronological data obtained by the U-Pb and K-Ar methods applied to minerals and fine fractions, mineral dating and respective closure temperatures, a temperature vs time correlation diagram was obtained (Figure 3).

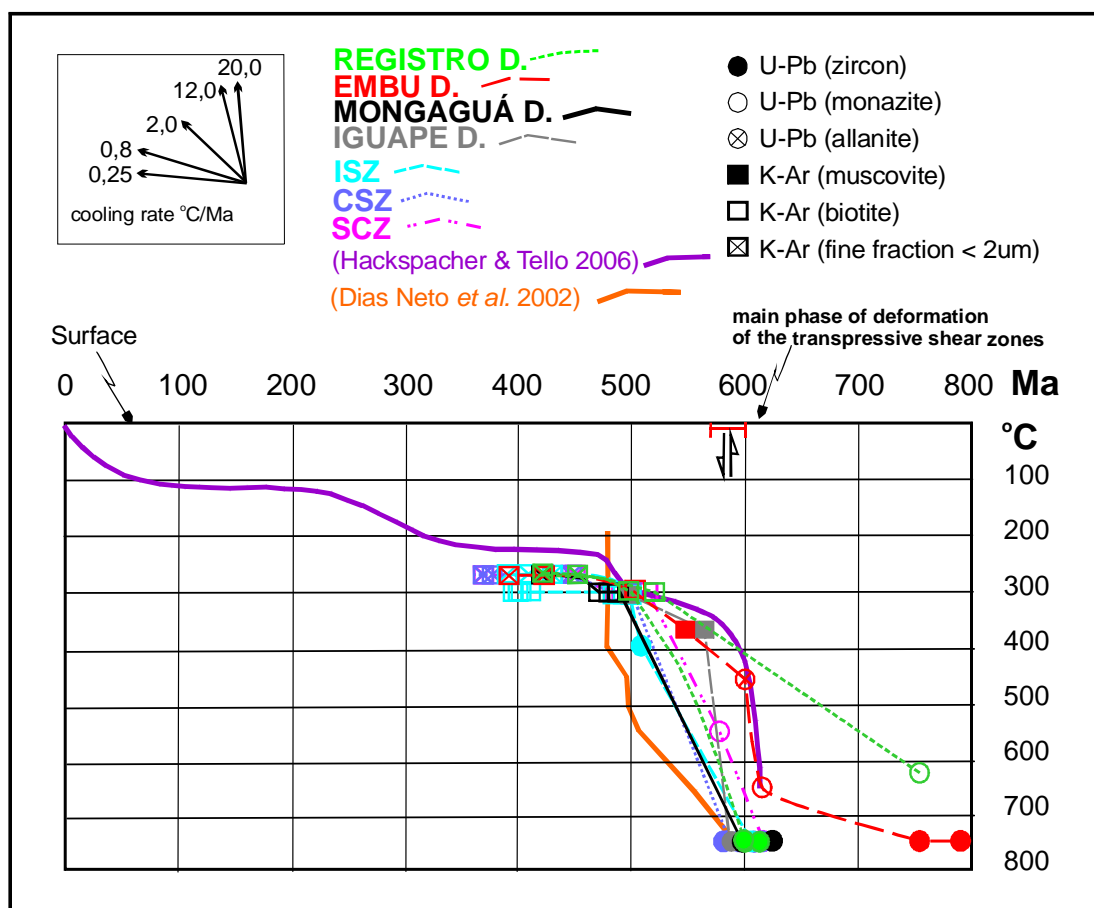
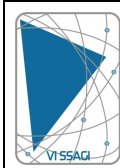


Figure 3 - Temperature vs time correlation diagram to the main tectonic domains and shear zones of the SE São Paulo State.



This diagram shows the cooling curves obtained from the data available for each tectonic domain and for the surrounding shear zones. Additionally for comparison of the evolution curves, cooling curves available for the Mantiqueira Ridge, mainly including the N portion of the Embu Domain (Hackspacher *et al.* 2004, Hackspacher and Tello 2006), and for the Costeiro Domain, south of the Além Paraíba Shear Zone in Rio de Janeiro State (Dias Neto *et al.* 2002), were also plotted.

### Final Remarks

In general terms, both sequences of processes with slower and faster cooling rates along the geological history can be identified. Some remarks can be pointed out:

- The tectonic domains present similar cooling rates, except for the Embu Domain and the Registro Domain metasedimentary rocks;
- The Embu Domain shows a cooling curve very similar to that of Hackspacher and Tello (2006);
- The tectonic domains show cooling curves very similar to the surrounding shear zones;
- From 600 to 500 Ma, the fastest cooling rates were recorded (up to 20°C/Ma), reflecting strong exhumation related to block tectonics, suggesting significant vertical dislocations during the movement of the shear zones;
- Between *ca.* 500 and 490 Ma the Costeiro Domain (RJ) shows extremely fast cooling rates (Dias Neto *et al.* 2002). This accelerated exhumation, not observed in the corresponding terranes south of CSZ in the study area, could explain the outcropping granulite facies terranes in the Além Paraíba Shear Zone (Rio de Janeiro State) and the outcropping greenschist facies terranes in the Cubatão Shear Zone (São Paulo State);
- A slow cooling rate is observed from the Cambro-Ordovician (a maximum of 0.8°C at 0.25°C/Ma) to the beginning of the Carboniferous (~350 Ma);
- The 450-350 Ma interval, defined by zircon fission track ages (TF ~240°C) and K-Ar fine fraction ages (TF ~270°C), is associated with the exhumation of tectonic blocks, correlated to the evolution of the Paraná Basin, at a slow cooling rate (~0.25°C/Ma) according to Hackspacher and Tello (2006).

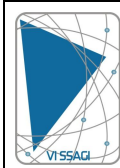
Highly important studies, such as zircon and apatite fission-track thermochronology, Ar-Ar geochronology, and compilation of the electron microprobe analysis data to geothermobarometry studies, are still to be carried out in order to better characterize the thermal and tectonic history of the shear zones and consequently of the terranes involved.

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