SOUTHERN BRASÍLIA BELT (SE BRAZIL): TECTONIC DISCONTINUITIES, K-AR DATA AND EVOLUTION DURING THE NEOPROTEROZOIC BRASILIANO OROGENY

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ABSTRACT This paper focuses the tectonic evolution of the southern Brasília belt, with emphasis on the Furnas segment, along the 21°S parallel. The uppermost structural unit (Passos Nappe - PN) comprises a highly deformed metasedimentary succession interpreted as a fragment of the Neoproterozoic passive margin of western São Francisco craton. An inverted metamorphic gradient ranging from greenschist to lower granulite facies of medium to high-pressure regime characterizes the PN as relict of a subduction zone. The External Domain displays a complex imbrication of basement rocks (Archean Piumhi greenstones, a turbiditic graywacke succession and a calc-alkaline granitoid suite) with undated siliciclastic low-grade metasedimentary rocks. The São Francisco Craton (SFC) comprises pre-1.8 Ga basement rocks covered by anchimetamorphic Neoproterozoic carbonatic shallow marine platform deposits of the Bambuí group. The Brasiliano thrust stacking generated a coarse clastic influx of molassic character on the foreland zone of São Francisco Craton, coeval with the exhumation of the External Domain thrust sheets. New K-Ar determinations on mineral separates are presented and interpreted among previous data. The SFC basement rocks display Paleo- to Mesoproterozoic cooling ages. The allochthonous units, in contrast, display K-Ar ages within the 560-675 Ma range. Brasiliano thrust stacking is therefore interpreted to have taken place onto a "cold" São Francisco craton foreland, in a thin-skinned style, as basement rocks were not heated enough to have their K-Ar systems reset during the allochthony.

Keywords: Brasilia Belt, K-Ar, Neoproterozoic, thrust tectonics, Brasiliano orogeny

INTRODUCTION

The Brasília belt is an important tectonic element of the Tocantins orogenic Province, developed during the Neoproterozoic Gondwana assembly, through convergence between the Amazonian, São Francisco and a third cratonic block presently covered by the Paraná Basin (Brito Neves *et al.* 1999). The southern portion of Brasilia belt (Fig. 1) has its eastern tectonic elements consistently thrusted eastwards towards the border of São Francisco craton (SFC). Southwards, the Ribeira belt, displaying NE-SW structural fabric along the Atlantic coast and a relatively younger tectonic development, with metamorphic peaks dating around 580 and 530 Ma (Machado *et al.* 1996) truncates it.

This article presents an overview of the tectonic organization of southern Brasilia belt, with emphasis on the Furnas segment, along the 21°S parallel. In that region, the Passos nappe displays low to high-grade Brasiliano metamorphism and was exhumed and thrusted at least 250 km onto a relatively cold foreland zone (eastern border of the São Francisco craton) as thin-skinned tectonic slices. K-Ar data help to constrain the timing and thermal conditions of allochthony.

TECTONIC ORGANIZATION OF SOUTHERN BRASÍLIA BELT

Three major imbricated tectonic domains contrast in structure, metamorphism and lithology (Fig. 1). The Internal Domain comprises the uppermost metamorphic nappes. They define three synformal structures, named from north to south Araxá, Passos and Luminárias nappes and are composed by Neoproterozoic passive margin metasedimentary successions with complex polyphase deformation, including distinct recumbent-style early folding. These nappes attained metamorphic conditions from greenschist to high-pressure granulite facies and thus have been regarded as tracers of a Brasiliano suture zone (Campos Neto & Caby 1999). In the Araxá nappe, an ophiolitic melange was identified by Brod et al. (1991), pointing to the involvement of oceanic assemblages in the Neoproterozoic allochthony. The Luminarias Nappe is covered by the Socorro-Guaxupé allochthon, composed by relatively lower pressure granulites. To the west, the Paraná basin covers the Internal Domain, so overlying tectonic domains are hidden. The External Domain is tectonically imbricated, composed of mainly greenschist facies siliciclastic metasediments related to proximal passive margin environments. Basement thrust-sheets are also present. The Cratonic Domain comprises basement outcrops of the São Francisco craton, of Archean to Paleoproterozoic age, and autochthonous low metamorphic grade sedimentary cover, of post-1.8 Ga ages, with varied degrees of deformation (Ribeiro *et al.*, 1995).

GEOLOGY OF THE FURNAS SEGMENT

Internal Domain (Passos Nappe)

In the Furnas segment (Fig. 2), the Internal Domain is represented by the Passos Nappe (PN), which displays a metasedimentary succession (Araxá group) containing abundant metabasic intercalations. A Lower Unit displays metapelites with marble lenses and quartzite beds, interpreted as prograding shelf sedimentation. A transitional contact with the Upper Unit, with paragneisses and feldspathic schists, probably marks reactivation of extensional stresses, which led to the erosion of granite-gneissic basement sources. Frequent intercalations of continental tholeiitic metabasalts are also characteristic. To the top of this transition, predominant metapelites with thin beds of paragneiss, calc-silicate rocks and spessartite-quartz metachert indicate deep marine environments. The geochemistry of intercalated metabasic rocks is indicative of progressive lithospheric extension, starting with the predominance of continental metabasalts, tending towards the top to a predominance of E-MORB type metabasalts (Valeriano & Simões 1997).

The PN displays a sole thrust always below the main quartzite level of the Lower Unit. Lithologic contacts (enveloping surfaces of the relict bedding planes) at map scale are subparallel to the basal thrust surface, regardless of pervasive tight intrafolial recumbent main phase folding. This feature played important role during the tectonic transport, in which the basal metapelites, overlain by relatively competent quartzite beds, acted as a crustal detachment zone. The internal deformation comprises early sin-metamorphic low angle shear processes, which originated tight to isoclinal folds with gently W to WNW dipping axes and penetrative axial plane foliations related to progressive refolding of early foliation. Associated stretching lineation is always subparallel to fold axes. Abundant shear sense indicators show unequivocal tectonic transport towards between E and SE directions. This main deformation is interpreted as the initial stage of crustal shortening related to a Neoproterozoic subduction zone, followed by the formation of the basal detachment zone and final thrust-emplacement onto the External Domain (Simões 1995). The thrust-driven ascension of the Passos nappe must have been relatively fast, indicated by the preservation of an inverted medium to high-pressure metamorphic gradient (Simões 1995), ranging from upper greenschist to lower granulite facies, with metamorphic zonation nearly parallel to bedding and basal thrust. The post-metamorphic peak deformations of the PN include two sets of gentle to open folds with steep axial planes, one with NW trending axes and a later phase with N-S axes.

External Domain

This tectonic domain is a foreland thrust-fold belt with four imbricated main lithologic associations (Valeriano *et al.* 1995), all displaying greenschist facies metamorphism (chlorite zone), that is:

i) **the Serra da Boa Esperança unit**, a siliciclastic succession of still undefined age. Typical lithology includes coarse orthoquartzites, sericitic phyllites and quartz-metaconglomerates with subordinated iron formation and carbonaceous metashales;

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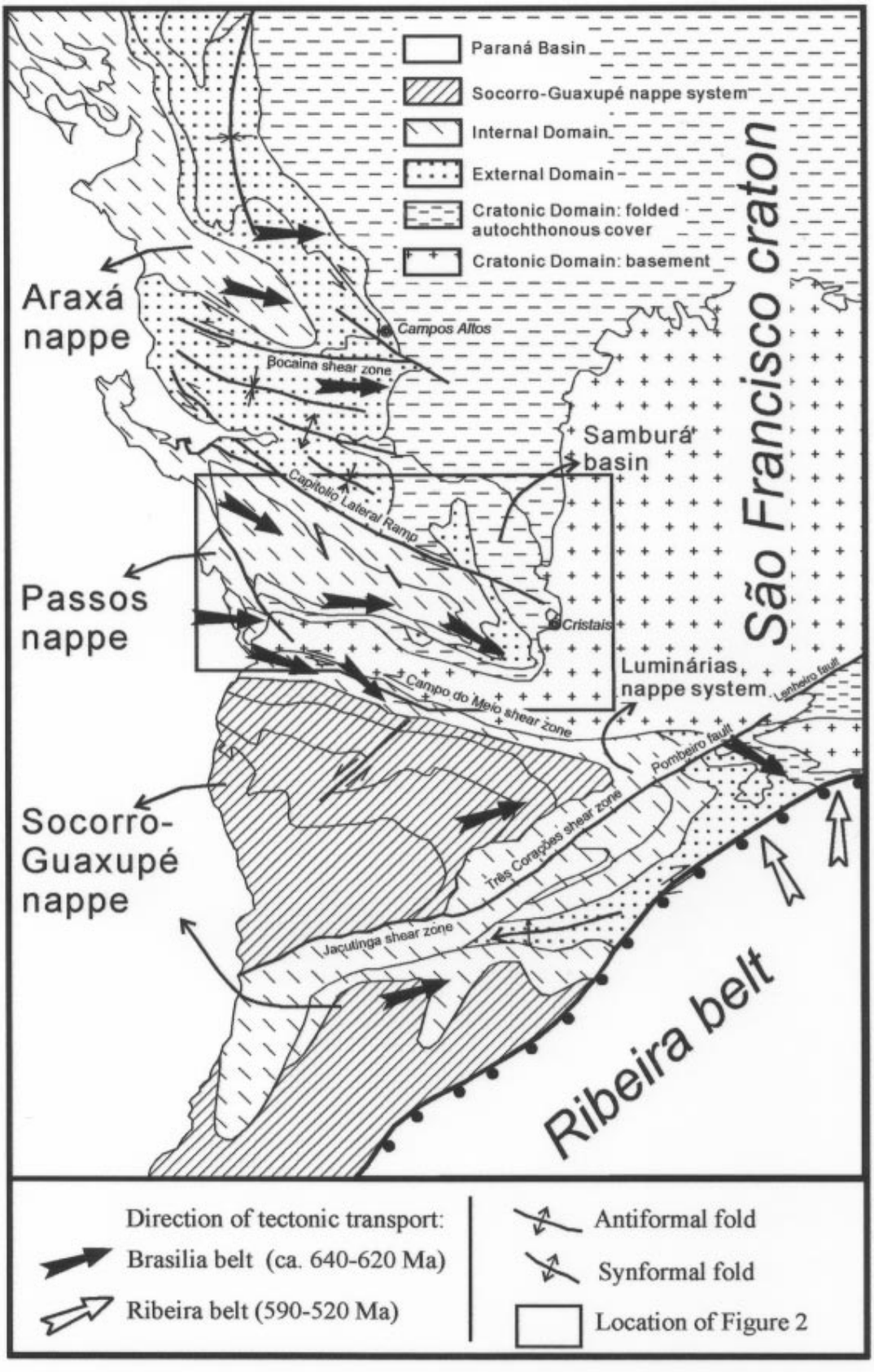

Figure 1: *Main structural elements of southern Brasilia belt and adjacent geotectonic units. Compiled from Schrank et al. (1990), Morales et al. (1993), Ribeiro et al. (1995), Valeriano et al. (1995), Seer (1999) and Simões (1995).*

ii) an Archean granite-greenstone association, with metakomatiites containing relict pillows and spinifex texture, in association with mafic to felsic metavolcanic and metasedimentary rocks (Schrank 1982). U-Pb zircon dating of a gabbro sill within the volcanic sequence yielded an upper intercept at 3116±10 Ma (Machado & Schrank 1989). At the Piumhi town area, granitoid rocks are clearly intrusive in the volcanic rocks. South of Piumhi, granitoid rocks predominate over the greenstones. South of Santo Hilario, an expanded deformed calc-alkaline granitoid suite predominates, ranging from gabbro to granite (Valeriano 1992);

iii) a thin-bedded turbidite sequence of low metamorphic grade, and

iv) minor thrust slices of the Bambuí Group slates.

In addition to the main continuous exposures under the Passos nappe, eleven small klippen were also mapped overlying the Cratonic Domain. The structural evolution of the External Domain contrasts with that of the other tectonic domains. Individual thrust sheets display a deformational fabric due to an intense N-verging low-angle shear tectonic transport marked by a stretching lineation and associated shear sense indicators. Valeriano *et al.* (1995) suggest that this fabric could be a relict of a pre-Brasiliano crustal shortening event. These previously deformed rock were involved in the Brasiliano east-vergent thrust stacking, at shallow crustal levels, on top of the Cratonic Domain. The Brasiliano deformation produced upright chevron folds

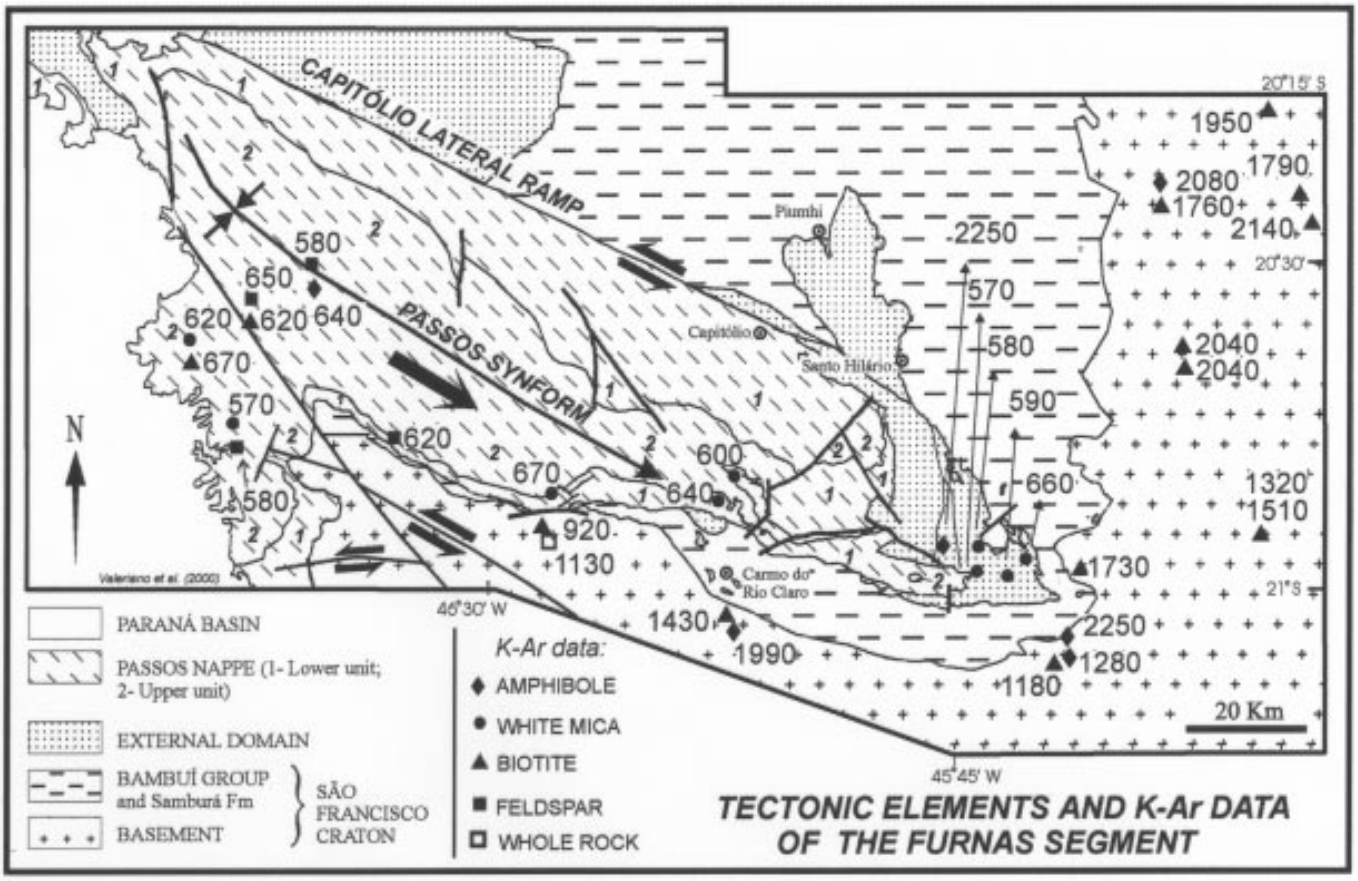

Figure 2 - Tectonic sketch of the Furnas segment of southern Brasilia belt. K-Ar data from Correia et al. (1982), Machado Filho et al. (1983), Teixeira (1982, 1985), Teixeira et al. (1989) and this paper.

Table 1 - Analytical data of new K-Ar determinations from the Furnas segment of the Brasilia belt, performed at the CPGeo-USP (Valeriano 1992).

Age (Ma)	Mineral	Rock type	Sample number	UTM coordinates	% K	rad.^{40}Ar x 10^{-6} (ccSTP/g)	% atm. Ar^{40}
595 ± 7	White mica	Quartzite	FU-3-C	363.20–7713.25	8.4555	231.72	5.98
600 ± 13	White mica	Quartzite	CRC-1-16	386.95–7694.70	8.2755	228.65	3.10
637 ± 17	White mica	Quartz-phyllite	CRC-2-33	383.30–7691.15	7.7239	228.84	5.65
673 ± 27	White mica	Quartz-mica schist	ALP-1	354.80–7693.60	7.3508	232.30	2.29
567 ± 7	White mica	Quartzite	BE-5-131	427.10–7680.80	7.9269	205.05	6.03
575 ± 11	White mica	Quartzite	CRI-C-62	426.40–7684.60	7.0482	185.18	8.25
588 ± 15	White mica	Quartz-phyllite	CRI-CL-4a	431.90–7679.60	7.2673	196.19	15.16
659 ± 8	White mica	Granitic phyllonite	BE-2-85	433.20–7682.10	7.0409	217.43	17.32
2251 ± 26	Hornblende	Dioritic gneiss	CRI-1090	419.80–7684.85	0.4973	86.50	4.16
1727 ± 100	Biotite	Granite	CRI-CWM-a	445.00–7680.30	0.6821	76.33	20.50

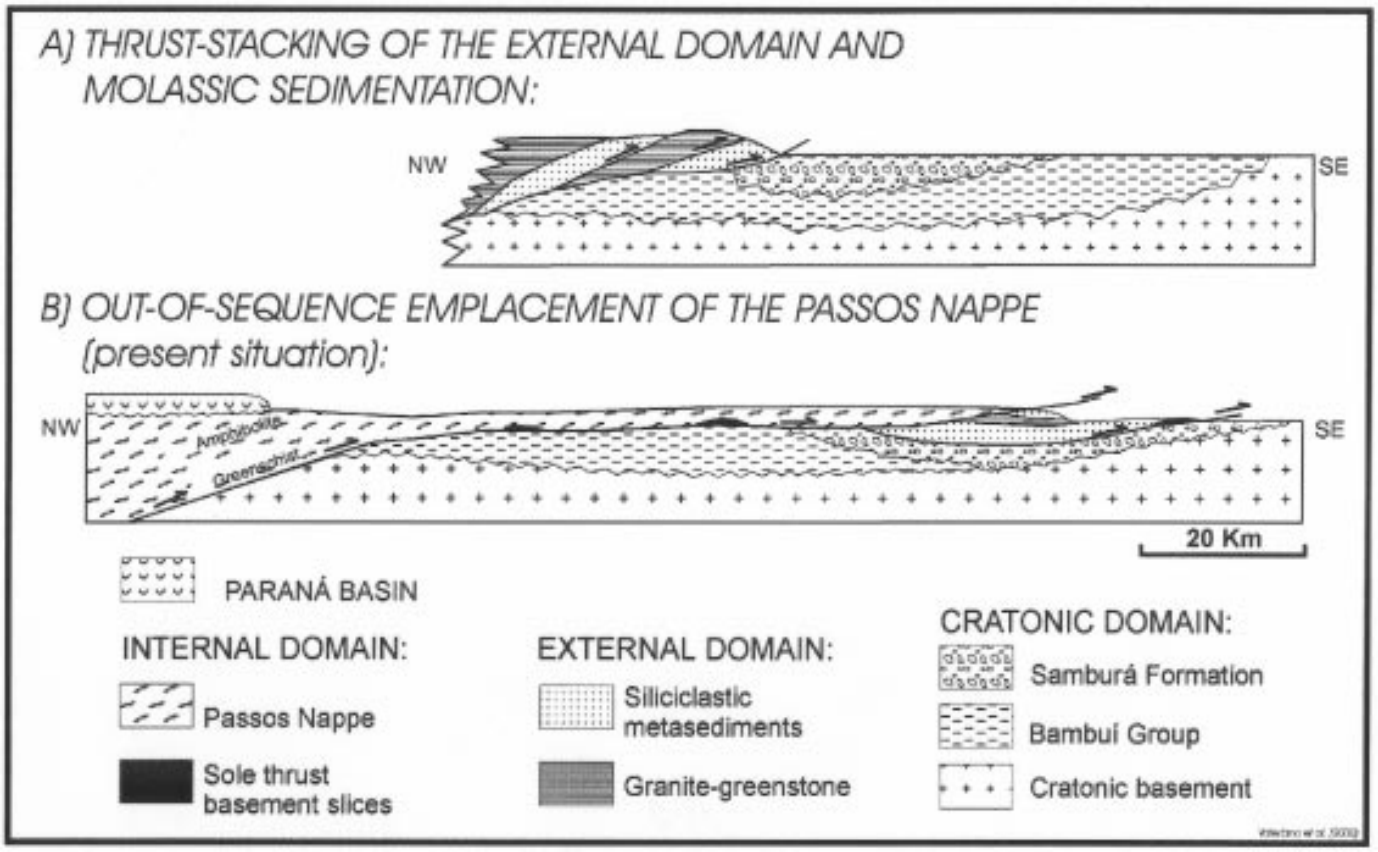

Figure 3 - Evolution of thrust-stacking events along the Furnas segment of southern Brasilia belt.

overprinting the previous subhorizontal foliation containing the N-S lineation. These folds are typically associated with brittle-ductile deformation, such as inverse and vertical faults, kink-bands, and intense jointing along axial surfaces. Overprinting of these N-S folds, by late and E-W to NW-SE folds, resulted in dome-and-basin interference patterns.

Cratonic Domain The autochthonous basement rocks, covered by the Bambuí group, extend continuously from the SW border of the SFC, along the southern limb of the PN (Fig. 2). This sector comprises an association of Archean to Paleoproterozoic migmatite-granite complexes with greenstone-belt remnants. South of the PN, moderate to high angle ductile and brittle shear zones overprint and obliterate previous structures, defining a major NW-SE sinistral strike-slip crustal discontinuity, referred to as the Campo do Meio Shear Belt by Morales (1993). The Bambuí group displays a deformational gradient from undisturbed subhorizontal beds on the craton, to highly sheared tectonites underneath the External Domain (Alkmin *et al.* 1989). As in the overlying domains, the overprinting of two sets of late open folds and kinks, on the slaty cleavage, is also registered. A Brasiliano sin-compressional foreland basin is represented by the Samburá Formation, which overlies discordantly the Bambuí Group and is tectonically covered by the external allochthons. The most representative lithotype is a polimict metaconglomerate that occurs along the basal portion of repetitive erosive upward-fining sedimentation meter thick cycles, interpreted as sub-aqueous fan deposits related to the erosion of the advancing thrust front of the Brasília belt (Valeriano 1992, Castro & Dardenne 1996). Clast compositions show clear provenance from the External Domain and Bambuí group rocks.

K-Ar DATA AND TECTONIC IMPLICATIONS New K-Ar determinations (Table 1) in addition to pre-existing data indicate that the regional cooling pattern constrains the timing of exhumation of the allochthonous domains, with implications regarding the thermal state of the foreland during orogeny.

In the External Domain, white mica from three samples of Serra da Boa Esperança quartzites (Table 1) yield a relatively narrow range of 588 ±15 to 567±17 Ma apparent ages, related to the Brasiliano tectonic imbrication. A significantly older white mica age of 659 ± 8 Ma from a basement granitoid-phyllonite thrust sheet (sample BE-2-85, Table 1), is interpreted as a mixed age, due to the presence of non recrystallized coarse primary mica. Hornblende from an orthogneiss sample (CRI-1090) within the granite-greenstone thrust slice yielded a 2251±26 Ma age. Although isolated, this value is compatible with the chlorite zone metamorphism in the External Domain, which was not high enough to reset older K-Ar hornblende systems.

In the Passos Nappe, available K-Ar age determinations (Correia *et al.* 1982, Machado Filho *et al.* 1983, Valeriano 1992) constrain its regional cooling within the 674-640 and 673-566 Ma time intervals obtained from hornblende/biotite and white mica, respectively. It is noteworthy that the youngest white mica ages from the NP are closely coincident with those of the External Domain (ca 570 Ma). This may be interpreted as the cooling age of the allochthons under 350±50°C, which is the estimated closing temperatures of argon in white mica (Hanes 1991).

Teixeira (1982, 1985) has studied the K-Ar cooling pattern of basement rocks from the Cratonic Domain of the southern SFC area in detail. The widespread apparent ages at ca. 1.8 Ga led the author to interpret them as the result of a conspicuous uplift and cooling event at the end of the Transamazonian collage (2.2-1.9 Ga). In the gneisses south of the Passos nappe, Teixeira *et al.* (1989) detected Mesoproterozoic isotopic Rb-Sr rehomogenization (1404±54 Ma) and K-Ar hornblende ages related to the Transamazonian event (2254±39 and 1988±29 Ma), possibly related to thermal influence of the hot allochthons of the Varginha-Guaxupé nappe (Figure 1). However, relatively old K-Ar ages indicate that, during the Neoproterozoic orogenic stage, the Cratonic Domain basement rocks were not heated enough to have their K-Ar systems reset, yielding pre-Brasiliano ages. Allochthony is therefore interpreted to have taken place onto a “cold” São Francisco craton foreland, resulting from thin-skinned nappe emplacement.

CONCLUDING REMARKS As recorded by the main deformation/metamorphism in the Internal Domain of the Passos nappe, crustal shortening took place first at medium to lower crustal levels. Through correlation with the adjacent Araxá nappe, where Seer (1999) obtained Sm-Nd whole mineral isochrons, this metamorphic event took place at ca 630 Ma. With initiation of thrust stacking and exposure of the External Domain thrust sheets (Fig. 3a), coarse clastic influx of molassic character (Samburá Formation) took place in the foreland zone.

The late "out-of-sequence" character of thrusting and emplacement of the Passos Nappe caused the truncation of the contacts between the External and Cratonic domains (e.g., north of Carmo do Rio Claro, Figs. 2 and 3b) and between the Bambui Group and basement rocks (west of Carmo do Rio Claro). The timing of emplacement of the Passos nappe and of the External Domain, onto the Cratonic Domain, is loosely constrained by the K-Ar data on white mica ranging 673-566 Ma and 588-567 Ma, respectively.

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