# ARCHEAN AND EARLY PROTEROZOIC CRUSTAL EVOLUTION IN THE SOUTHERN PART OF THE SÃO FRANCISCO CRATON

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The São Francisco Craton (Almeida, 1977) corresponds to a fairly large, ancient and tectonically stable geotectonic unit, surrounded by late Proterozoic mobile belts of the Brasiliano cycle (Figure 1). All of these mobile belts are ensialic and show typical polarities towards the craton, such as metamorphic zonation and tectonic vergence. This is especially true for the younger mobile belts (Ribeira and Brasília) in which most of the suprastructure was preserved. In the Canastra mobile, belt, a policyclic metamorphic basement is identified, including relicts of greenstone belts.

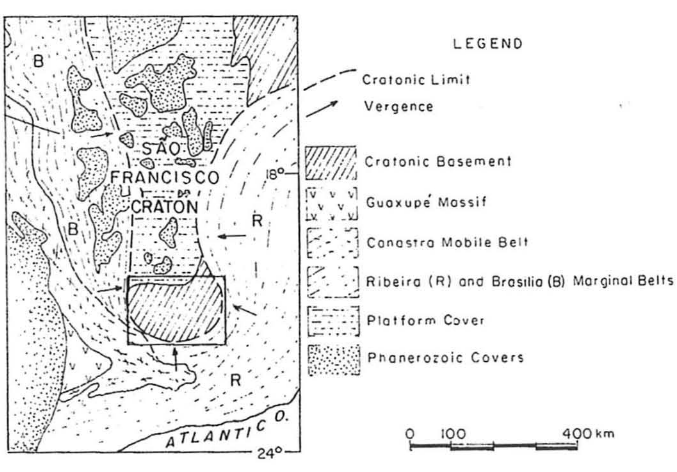


**Figure 1.**
The São Francisco Craton

The complex and diversified basement of the São Francisco Craton is well exposed in two main areas of Bahia and Minas Gerais States. On the other hand, large portions of the unit are covered by platform sequences of late Proterozoic age, named Bambui and Una Groups, slightly to strongly deformed by tectonism at the borders of the geotectonic unit. These sedimentary deposits also overlay in part the Espinhaço folded system, an elongated intracratonic unit of mid-Proterozoic age, and its contemporaneous cratonic cover, the Chapada Diamantina Group (Brito Neves et al., 1980; Cordani and Brito Neves, 1982), in central Bahia.

The investigated area (Figure 2), is located at the southern most portion of the São Francisco Craton in Minas Gerais State. The metamorphic complexes (mainly amphibolite facies) are characterized by gneissic-granitoid rocks which can be separated, in age, in at least two main crustal provinces, the oldest formed in the Archean, and the youngest in the Lower Proterozoic. The Archean rocks are better described in the Quadrilátero Ferrífero region, and include gneisses of tonalitic and granodioritic composition, migmatites, granitoids, amphibolites, and some granulites. The associates supracrustals are related to the Rio das Velhas Supergroup, a typical greenstone sequence with tight folding, complex structure and low to medium grade of metamorphism (Schorscher, *et al.,* 1982; Ladeira *et al.,* 1983).

On the other hand, the early Proterozoic basement complex was detected based on geochrnological control Teixeira, 1982; Teixeira, 1985) and is characterized by medium to high grade metamorphism and extensive granitization. Small cratonic remnants of Archean crust were identified within the Lower Proterozoic province. The supracrustal equivalents are related to the Minas Supergroup, which contains very large banded iron formations and manganes deposits. It reached amphibolite facies metamorphism during the so-called Minas diastrophism.

Some clearly intrusive bodies of granitic composition are found throughout the investigated area. Pegmatoid dykes have been also identified, cutting through the basement complex (Machado Filho *et al.,* 1984; Teixeira, *et al.,* 1985). Anorogenic basic dyke swams occur, especially to the north of Pará de Minas and to the south of Oliveira. The geologic scenary is completed by the occurrences of the Espinhaço and Canastra epimetamorphic rocks, as well as the Bambui cratonic cover, which overlay the basement complex in the western and northern parts of the area (Figure 2).

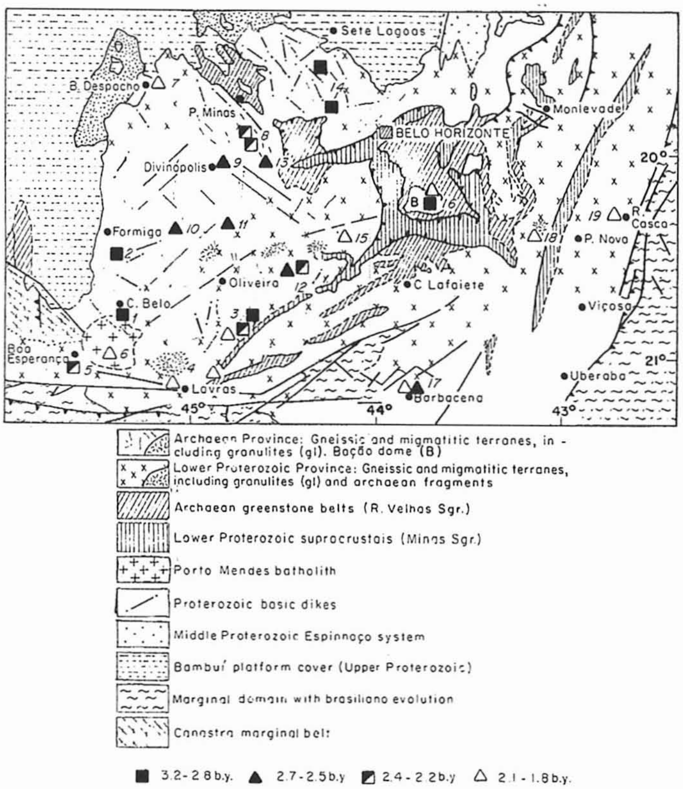


**Figure 2.**
Geologia outline of the Southern part of the São Francisco Craton.

The knowledge of the basement crustal evolution is complicated further by a tectono-thermal overprint related to the late Proterozoic marginal belts, in special towards the southern and eastern borders of the São Francisco Craton. In this respect, the interpretation of the available radiometric data has demonstrated the importance of an integrated treatment in order to elucidate the geotectonic evolution of ancient terranes (Teixeira, 1985; Cordani et al., 1985). Geochronological studies by different methodologies – Rb/Sr and Pb/Pb whole rock isochrons, U-Pb Concordia diagrams and K-Ar determinations on separated minerals – demonstrate a long period of crustal evolution for the southernmost part of the São Francisco Craton, with a final tectonic stabilization at the end of the Transamazonian orogenic cycle, at about 1.8 Ga.. In fact, the about 300 available age determinations over the investigated area are in a generally good agreement, and a coherent picture can be presented (Table 1 ). In general, the geochronological results by Rb-Sr, Pb-Pb and U-Pb methods show Sr initial ratios well correlated with the U/Pb $u_1$ values. The only exception seems to be the Boa Esperança granitoid (Figure 2), in which a high Sr initial ratio is opposed by a low model $u_1$ value.

As indicated by Figure 3, two important periods of crustal development are clearly defined.

The main period of crustal formation was late Archean (3.0-2.6 Ga.) and corresponds to a geochronological province with about 10.000 km², situated in the western part of the studied area. The analysed units (ortho-gneisses, migmatites, granulites, granitoids) are characterized by low $^{87}Sr/^{86}Sr$ initial ratios (0.700-0.703), model $u_1$ values appropriate to rocks newly derived from upper mantle sources ($\sim$8.0) and essentially concordant Rb-Sr and U-Pb age results (Table 1).

In turn, rock units with apparent age values in the range 2.4-2.0 Ga. defined $^{87}Sr/^{86}Sr$ initial ratios in two intervals: 0.702–0.703 and 0.706 to 0.761 (Table 1). The last one is related to early Proterozoic reworking of Archean crustal material, also confirmed by the respective model $u_1$ values in the range 8.2-8.9. On the other hand, the lower values for the initial ratios suggest some contribution from mantle-derived material. The pattern is consistent with the partition of the area into two age provinces, of which the younger one slightly overlaps the older domain. The younger province seems to be related to a development of a mobile belt of Transamazonian age, whose principal tectonic

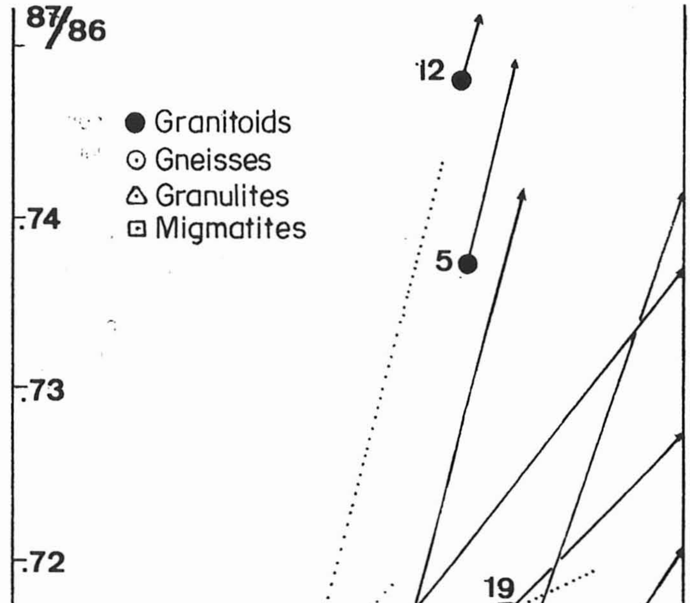


**Figure 3**
Sr isotopic evolution for the crustal provinces.

## GEOCHRONOLOGICAL DATA OF THE CRATONIC BASEMENT ROCKS

| AREA | Rb-Sr | I.R. | Pb-Pb | $u_1$ | U-Pb (Upper Intercept) | ROCK TYPE |
|---|---|---|---|---|---|---|
| 1 | 3,275 ± 125 | 0.7000 | $3,076 \pm^{85}_{91}$ | 8.18 | | ORTHO-GNEISS |
| 2 | 2,814 ± 65 | 0.7053 | $2,595 \pm^{30}_{30}$ | 8,31 | | GRANITOID |
| 3 | 2,793 ± 78 | 0.7000 | | | | MIGMATITE |
| | 2,228 ± 76 | 0.7020 | | | | GRANITOID |
| | 2,413 ± 70 | 0,7031 | | | | MIGMATITE |
| 4 | 2,137 ± 123 | 0,7026 | | | | ORTHO-GNEISS |
| 5 | 2,183 ± 83<br>2,329 ± 109 | *0.7372<br>*0.7162 | $2,332 \pm^{162}_{182}$ | 7.85 | | GRANITOID |
| 6 | 2,178 ± 85 | 0.7043 | $1,821 \pm^{102}_{109}$ | 8.05 | | GRANITE |
| 7 | 2,092 ± 135 | 0.708 | | | | ORTHO-GNEISS |
| 8 | 2,410 ± 34 | 0.7064 | | | | ORTHO-GNEISS |
| | 2,233 ± 96 | 0.7064 | | | | ORTHO-GNEISS |
| 9 | 2,754 ± 48 | 0.7105 | | | | MIXED-GNEISS |
| 10 | 2,556 ± 59 | 0.7606 | $2,645 \pm^{179}_{204}$ | 8.24 | | GRANITOID |
| 11 | 2,612 ± 123 | 0.7042 | $2,521 \pm^{261}_{319}$ | | 2,625 ± 10 | MIGMATITE |
| | 2,078 ± 78 | 0.7156 | | | | PEGMATOID |
| 12 | 2,674 ± 48 | 0.7037 | $2,673 \pm^{44}_{45}$ | 8.23 | | GRANITE |
| | 2.192 ± 78 | 0.7482 | $2,297 \pm^{90}_{96}$ | 8.99 | | GRANITOID |
| 13 | 2,727 ± 117 | 0.7002 | | | | ORTHO-GNEISS |
| | 1,870 ± 18 | 0.7108 | | | | PEGMATOID |
| 14 | 2,803 ± 70 | 0.7000 | | | | GRANITOID |
| 15 | 1,900 ± 108 | 0.7095 | | | | GRANITE |
| 16 | 2,750/2,100 | 0.703/0.704 | | | 2,750/2,820 | GRANITOID |
| 17 | 3,000/2,200 | 0.702/0.710 | | | 2,100/2,550 | ORTHO-GNEISS |
| 18 | 1,990 ± 42 | 0.7061 | $2,017 \pm^{538}_{854}$ | 8.64 | | GRANULITE |
| 19 | 2,064 ± 213 | 0.7171 | | | | MIGMATITE |

Obs.: Rb-Sr and Pb-Pb methods by whole rocks analysis; interpretation through isochron diagrams
I.R. = initial $^{87}Sr/^{86}Sr$ ratios.
K-Ar = Cooling ages along the area, by biotite (B) and amphibole (A), are between 1.7 and 2.1 GA.; restricted areas show a 2.5-2.2 GA. cooling patern.
* Isotopic system affected by younger events.

Table 1.

deformation, the Minas diastrophism, occurred at about 2.1 Ma.. Within this Lower Proterozoic mobile zone (see Figure 2), additional crustal thickening occurred by magmatization and associated plutonism (granitoids of granodioritic and granitic composition), and this very important plutonic event is characterized by either tectonic or intrusive contacts with the former granite – greenstone terranes. It includes batholiths, stocks, plugs, dikes and irregular bodies, the most important of which being the Porto Mendes intrusion. This large granitic massif is calc-alkaline, post-tectonic, locally porphyritic and includes basement enclaves. Pb-Pb isochron work in it indicated an age of about 1.8 Ga. (Table 1. Figure 2), and additonal Rb-Sr isochron results for intrusive pegmatoids, and for the Jacarandá granitic stock, yielded ages in the range 2.1-1.9 Ga. (Table 1).

From the available evidence, the following model for the geodynamic evolution of the southern part the São Francisco Craton can be suggested:

1. During late Archean times, a crustal fragment developed as typical granite-greenstone terrane, broadly comparable in evolution with ancient cratonic areas over the world. The granodioritic and tonalitic intrusives have characteristic ovoid structures, and sometimes are surrounded by supracrustal relicts. The largest known domic feature is the Bação complex in Quadrilátero Ferrífero, with $600km^2$, but dimensions of $50km^2$ (Pará de Minas and $150km^2$ (Formiga area) have been described.

2. In the region dominated by early Proterozoic tectono-thermal events, strongly developed EW to NE oriented structures are predominant. In that area, the substratum is made up of grano dioritic to granitic bodies, and the supracrustal units are mostly sequences of stable shelf characteristics, including BIFs. Crustal rifting of the Archean domain occurred along the period 2.2-2.0 Ga., immediately prior to and during the initial phases of deformation within the adjacent mobile zone, characterized by fissural anorogenic magmatism, essentially mafic dyke swarms. In this context , the age of the postectonic granites, followed by regional cooling of the basement rocks, is associated to the main period of cratonization for that area, corresponding to the southern end of the São Francisco Craton. Despite of the ensialic nature of the early Proterozoic mobile belt, the general tectonic scenario is consistent with some crustal shortening type processes, with some subduction to allow the granitic magma production, as described previously.

3. Finally, the geographic distribution of the geochronological provinces is consistent with different boundaries for the cratonic continental mass, in different periods of geological time. During the Brasiliano cycle (late Proterozoic to early Phanerozoic) the eastern part of the Lower Proterozoic domain was remobilized by extensive thrusting, progressive deformation and isotopic rejuvenation of K-Ar data (temperatures of at least of 300ºC), as recently described by Teixeira(1985) and Oliveira (1986). These features make extremely difficult the task of establishing the cratonic boundary for the Brasiliano Cycle (with the Ribeira and Brasília belts), if we consider that "tectonic stability" cannot be precisely defined, and the limits are always dependent on criteria which include a great dose of subjectivity.

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