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Crustal Framework of the Southern Part of the São Francisco Craton, Brazil, Based on Airborne Geophysical Data

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Abstract

Systematic mapping in the southern part of the São Francisco Craton (SFC) is cumbersome due to the lack of continuous outcrops in the region. Deep soils and weathered rocks obscure the relationship between key metamorphic complexes and supracrustal sequences that occupy such terrains. This poses a problem for reconstruction of tectonic settings and the understanding of the geodynamical history of this region.

The high-resolution airborne survey acquired during the Pitangui- Ipatinga- São João Del Rey project is now providing a set of geological information in the SFC previously unavailable for any geologist in the field. The survey was acquired using 250m spaced flight lines with orthogonal tie lines flown every 2.500m. In this work, these data was interpolated in a regular grid, using 100m on a side, resampled at 50 m. Microlleveling and decorrugation techniques were further applied to the data, producing several geophysical products for geologic analysis and interpretation.

Images derived from the Pitangui-Ipatinga São João Del Rey project provided new insights about the tectonic assembly of the SFC throughout the Precambrian. Combined gamaspectrometric-magnetic images portrayed the lateral continuity and the internal structure of several terranes, particularly the location and geometry of terrane boundaries.

Introdução

The southern portion of the São Francisco Craton (SFC), located in the southeastern part of Brazil (Minas Gerais State), is considered one of the most prominent tectonic environments in Brazil, including rocks and structures ranging from the Mesoarchean up to the late Neoproterozoic. This area comprises thondjemitic-tonalitic-granitic suites, greenstone belts, granitoid plutons, mafic/ultramafic intrusions and ductile structures that both shape the geometry and cross-cut Archean and Paleoproterozoic geologic units. Early petrographic, geochemical and geochronological investigations defined several metamorphic complexes and metamorphic equivalents of volcano-sedimentary sequences in this region. Teixeira *et al.* (2000) summarized the available

data on composition, structure and geochronology for the southern SFC, providing regional distinctions among Archean and Paleoproterozoic lithological associations. However, the boundary relationships of several regional units are often obscured in the field, thus limiting current tectonic interpretations. Information yielded from airborne geophysics are useful in this scenario for their ability to overcome shallow covers and to provide information on deep, sub-surface rock packages and structure. In particular, there is a good correlation between patterns in the radiometric data and non-weathered rocks or in areas of poor outcrops.

In this paper, an integrated interpretation of airborne magnetic and gamma-ray plus geological data is achieved and used to portray the actual and detailed arrangement of crustal blocks in the southernmost part of the SFC.

Geological Setting

The southern portion of the SFC is composed of Archean thondjemitic-tonalitic-granitic (TTG) complexes; greenstone belts (Rio das Velhas, Barbacena, Fortaleza de Minas, Piumhi, Congonhas and Rio Paraúna); Paleoproterozoic (Minas Supergroup and Itacolomi Group) and Paleoproterozoic-Mesoproterozoic (Espinhaço Supergroup) supracrustal units, as well as mafic-ultramafic and mafic intrusives (Figure 1). Data concerning the earliest events that generated the continental crust in this region are fragmented. Many lithotypes that constitute the sialic crust of the southern part of the SFC have been dated by different radiometric methods (Machado and Carneiro 1992, Noce *et al.* 1997, Teixeira *et al.* 2000), yielding evidence for an Archean crustal evolution older than 3.1 Ga (U/Pb and Sm/Nd data). The Rio das Velhas orogeny (2.78 Ga, Carneiro *et al.* 1997) fostered terrane assembly concomitantly with regional amphibolite facies metamorphism. Neoproterozoic tectonics are linked to major, regional extension episodes, leading to the emplacement of the Ribeirão das Molas mafic-ultramafic intrusives and gabro-noritic dykes, with simultaneous late tectonic granitic emplacement and cratonization (Teixeira *et al.* 2000). The Transamazonian Orogeny (2.16-2.0) developed at the margins of the Archean continent in the southern part of the SFC. Linked to this orogeny are the evolution of the Mineiro mobile belt and the Minas Supergroup (Teixeira *et al.* 2000). The Brasiliano Orogeny (650-470 Ma) is related to a compressional tectonics.

The Pitangui-Ipatinga São João Del Rey airborne project used in this study was surveyed with two Cessna aircrafts at a constant ground clearance. The airborne data were acquired using 250 m spaced flight lines with orthogonal

tie lines flown every 2.500 meters at 100 meters above the ground surface. The survey was carried out in two different blocks with different flight- and tie-line directions, keeping data acquisition perpendicular to the main structures of the surveyed area.

The Oasis Montaj software, version 5.07 of GEOSOFT™, was used in the processing and visualization steps applied to this data. The data was interpolated in a regular grid, using 100m on a side, resampled at 50 m. Microllevelling and decorrugation techniques were further applied to the data, producing several geophysical products (individual and composite thematic maps) for geologic analysis and interpretation.

The analysis of the variation of the anomalous magnetic field was aided by its linear transformations principally that dealing with the amplitude of the analytic signal (orders 0, 1, and 2), which are a critical products to locate the spatial distribution of magnetic sources in low latitudes. The uses of derivatives, principally the first vertical, helped to determine the spatial positions of these sources, and were also extremely useful to characterize linear features. The horizontal derivatives further allowed the mapping of lateral limits of these same sources. All of these steps were guided by the analysis of the radial power spectra of the anomalous magnetic field.

The methodology used in the interpretation of gamma-spectrometric data (channels TC, K, U, and Th) involved: a) comparison of each microlleveled grid with digital terrain data, verifying zones where topography influenced the gammaspectrometry response; b) analysis of the total count channel and other individual channels to define major gamma-spectrometric domains; c) K, Th, and U channels displayed as RBG and CMY false-color maps (ternary images), optionally merged with digital terrain data; and d) computation of U/Th, Th/K, and U/K ratios and analysis of their correlation with gammaspectrometric domains.

Results

The integration of information generated by the interpretation of the magnetic and gamma-spectrometric data allowed the discrimination of three broad geotectonic domains. Each domain was analyzed and compared with the available overall geological data for the SFC, which are found at smaller scales than that of the airborne survey. This implies that the information derived from the geophysical data contains much more detail than the existing maps.

The best interpretations of the southernmost part of the SFC were achieved from visual analysis of the ternary radioelement map (Figure 2), the thorium channel map and the analytical signal amplitude map (Figure 3). These maps highlighted key crustal blocks of the SFC and their unique inter-relationships. The first geotectonic domain encompasses the oldest rocks that illustrate the Archean sialic crust of the Southern São Francisco Craton and are represented by three different complex with different age: a) Campo Belo Metamorphic Complex (3.2, SHIRIMP U/Pb zircon, A in the image); b) Bonfim Metamorphic

Complex (2.92-2.7 Ga, U/Pb zircon, B in the image); c) Passa Tempo Metamorphic Complex (2.66 Ga, U/Pb zircon, C in the image). The second one consist of rocks strongly reworked in the Transamazonic termo-tectonic event and encompasses the Paleoproterozoic Mineiro mobile belt (2.2-2.0 Ga, D in the image) and the Paleoproterozoic supracrustal of the QF (E in the image). A pervasive Brasiliano tectonics characterize the easternmost domain, expressed by a Neoproterozoic marginal mobile Belt that include the Dom Silvério shear zone (Araçuaí Belt). The Dom Silvério shear zone represents a suture of Brasiliano age.

Several structural features are well enhanced in these images, mainly inner in the Archean domain. A dominantly EW trend in the Campo Belo Metamorphic Complex is evidenced against a NW oriented structures in the Itapecirica and Bonfim areas. Also, complex fold interference pattern are displayed in this area and NE trending shear zones cross cut the oldest structures.

1.7 Ga and 960 Ma northwest –trending mafic dyke swarms intruded into the Archean nuclei and the Mineiro Belt. They are poorly exposed on the surface, but are prominent in the high-resolution aeromagnetic images. They change their direction, when cut the different domains with different reological properties (Figure 3).

Conclusions

Images derived from the Pitangui-Ipatinga São João Del Rey project provided powerful insights about the tectonic assembly of the SFC throughout the Precambrian, reflecting distinct episodes of crustal accretions and/or crustal reworking. The gamma-ray response over the study area shows broad correlation with rock units. However, subtle compositional variations and different structural patterns were outstandingly assessed through gamma-spectrometric images. Combined gamaspectrometric-magnetic images portrayed the lateral continuity and the internal structure of several terranes, particularly the location and geometry of the terrane boundaries. The clearest boundary is that between the Archean core and the Mineiro Belt. By geophysical contrast, it was possible to separate another block in southeastern portion of the study area. The geologic meaning of this block and its relation to neighbor units is yet unclear and further work is needed to clarify it. The magnetic images highlighted a clear distinction between the QF and surrounding areas, as a function of the fundamental contrast between highly frequency/amplitude magnetic anomalies of the QF and the generally less magnetic crust of the other accreted terranes in the SFC.

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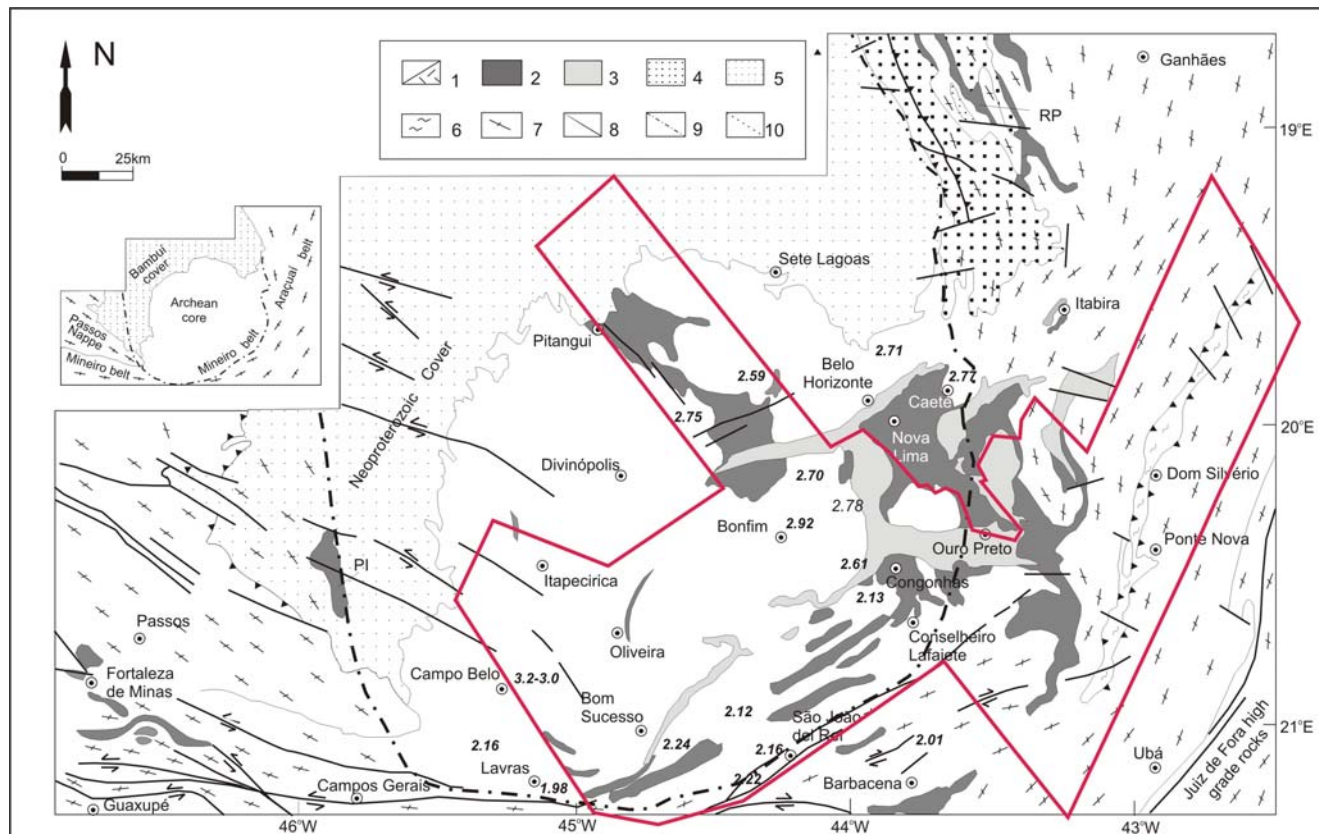


Figure 01- Geological sketch map of the southern part of the SFC, showing the Archean and Paleoproterozoic terranes, as well as the Neoproterozoic, marginal orogenic belts (modified from Teixeira *et al.* 2000). The red polygon is the area covered by the Ipatinga São João Dey Rey Airbone Geophysical Project. 1 – granitoid-gneiss-migmatite rocks and granulite, partially reworked in the Paleoproterozoic (Archean); 2- Greenstone Belts; 3-Minas Supergroup (Paleoproterozoic); 4-Espinhaço rift system (Paleo to Mesoproterozoic); 5-Bambuá Cover (Neoproterozoic); 6-Shear zone/shear belt; 7-Brasiliano structures of the marginal belts (Araçuaí, southern Brasília and Passos nappes), partly overprinting crystalline basement rocks (>1.8Ga), 8- major faults; 9-Limit of the Craton; 10- Gneiss foliation. Keys: PI, RP, FM, CO= Piumhi, Rio Paraúna, Fortaleza de Minas and Congonhas Greenstone belts; DS-Dom Silvério Group (Neoproterozoic).

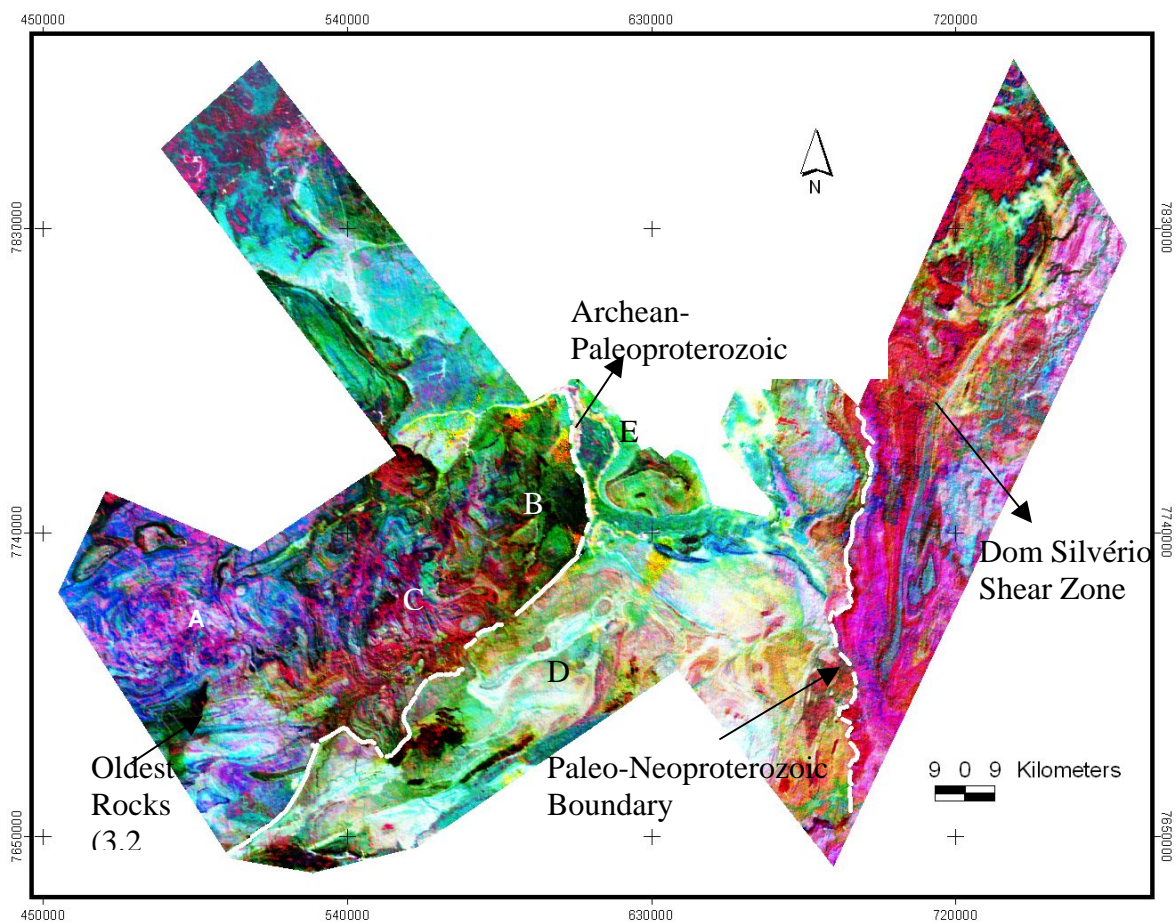


Figure 2- Enhanced three band CMY gamma-ray spectrometric image (KthU). A) Campo Belo Complex; B) Bonfim Complex; C) Passa Tempo Complex; D) Mineiro mobile belt; E) Quadrilátero Ferrífero, F) Araçuaí Belt.

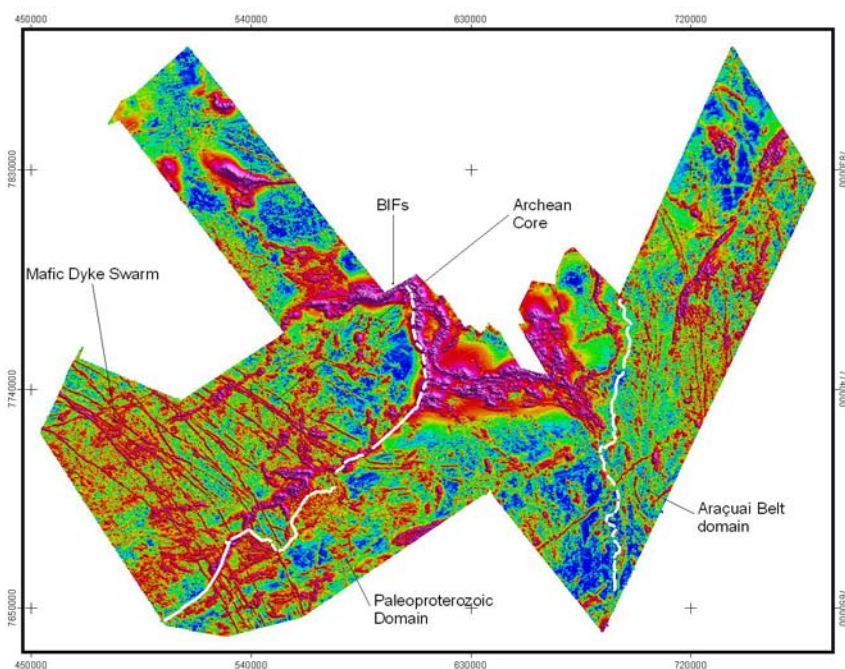


Figure 3- Analytical signal amplitude image of the southernmost part of the SFC.