Geological and geophysical data integration in the study of tectono-structural features in the region of Jequitaí - Minas Gerais

Cláudia D. Teixeira[1], Mônica G. Von Huelsen[1], Farid Chemale Júnior[2] , Vitor do Sacramento[1], Victor Botelho Perez Garcia[1]
[1]Observatório Sismológico - Universidade de Brasília
[2]Universidade do Vale do Rio dos Sinos

This paper was prepared for presentation during the 16th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 19-22 August 2019.

Abstract

The integrated geophysical and geological data of the Jequitaí region - Minas Gerais, Brazil, provided a powerful group of tools for analysis that allowed the understanding of the Jequitaí region's subsurface. The results show the presence of high gravity anomalies in the southern part of the study area. Depth estimation techniques, such as Euler deconvolution, allowed the identification of continuous structures up to 400 m depths and showed differences in the basement's depth in the northern and southern portions of the study area.

Introduction

Integrated geophysical and geological data analysis in the region of Jequitaí - Minas Gerais, Brazil, allow a better understanding of the tectono-structural context of the region of Jequitaí, where a reservoir will be constructed. Studies of this nature, during the previous stages of the construction of large hydroelectric projects, are highly important because the regional geology understanding associated with geophysical data interpretation can help to prevent damage in the physical structure of the reservoir, which will aid in its preservation.

This investigation is a contribution with regards to geological and geophysical data and interpretations to assist in the understanding of the structure of the subsurface in the Jequitaí region.

Geophysical data (gravimetric and magnetic) were integrated into the structural data collected in the field, and through information obtained from satellite images in order to correlate existing features, to better interpret the structural framework of the region.

Geological setting

The study region is located in the eastern portion of the São Francisco Basin, southeast of the São Francisco Craton, between the São Francisco River and the Espinhaço Range, and includes the Serra da Água Fria, Serra das Porteiras and the northern Serra do Cabral.

The São Francisco Craton is bordered by mobile belts that verge toward the interior of the craton. The studied segment occurs in the foreland compartment of the eastern portion of the São Francisco craton (Figure 1), deformed by the W-vergent Araçuaí Belt (Almeida, 1977; Chemale et al., 1993; Alkmim et al., 1993) during in the Brasiliano Event.

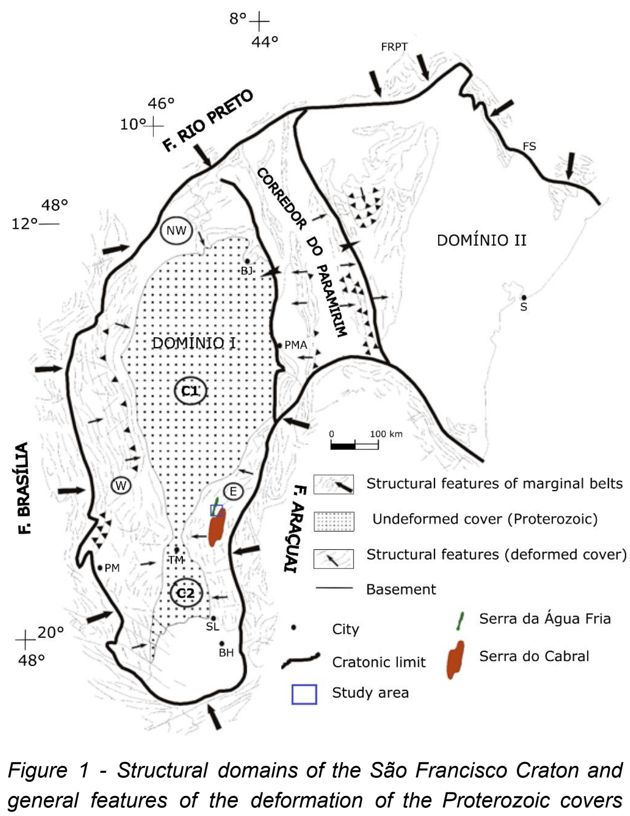

Figure 1 - Structural domains of the São Francisco Craton and general features of the deformation of the Proterozoic covers (Modified from Alkmim et al. 1993).

These folds in the Brasiliano occurred in the syn-collisional stage, in the interval between 580 and 560 Ma (Pedrosa-Soares et al., 2007), where the occurred collision on the opposite sides of the basin promoted the propagation of pushes to the cratonic zones, as well as the uplift of the mountain range (Alkmim et al., 2001). In the region, Late Paleoproterozoic to Neoproterozoic units appear on the Espinhaço and São Francisco supergroups, as well as Phanerozoic coverages belonging to the Areado Group. There are also surface deposits, mostly unconsolidated. (Chaves et al., 2011).

The Araçuaí Belt defined by Almeida (1977), is a belt of Neoproterozoic folds and thrust faults with westward vergence, towards the São Francisco craton, originated during the Pan-African / Brasiliano Orogeny. In general, the boundary between the Araçuaí Belt and São Francisco craton is marked by an inverse fault that involves the basement of the deformation of the cover. (Alckmin et al. 1993). In the east compartment, rocks of the Espinhaço and São Francisco supergroups outcrop, superimposed in some places by Meso-Cenozoic sedimentary successions, with the Areado Group (Cretaceous).

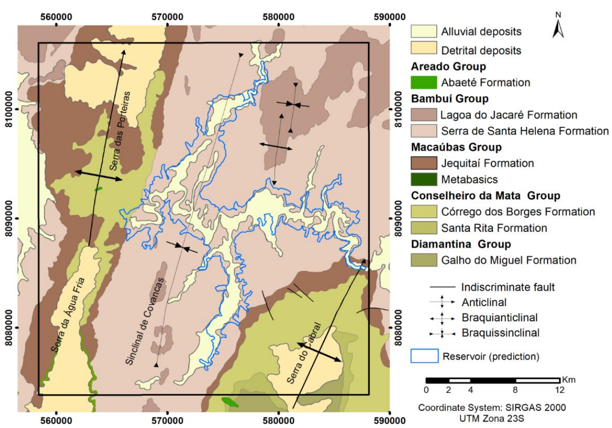

Figure 2 - Simplified geological map of the Jaquitaí region (partial and modified by Chaves et al. (2006)).

The metasediments of the Espinhaço Supergroup appear in the nucleus of the anticlinorium of the Serra da Água Fria and Serra do Cabral. In the Serra do Cabral the formations are recognized as the Galho do Miguel, Santa Rita, and Córrego dos Borges (Chaves et al, 2006, Santos et al., 2015; Figure 2).

The metasediments of the São Francisco Supergroup occur in the region as sand-diamictite deposits of the Jequitaí Formation - Macaúbas Group (Hercos et al., 2008) and rocks of the Bambuí Group, identified by the Serra de Santa Helena and Lagoa do Jacaré formations (Chaves et al., 2011) deposited in discordance on the previous units, composing the sedimentary cover on the craton (Figure 2).

In a different way, Hercos et al. (2008) describe the studied segment in a compartment where the basement was involved by the deformation of the rocks of the cover (thick-skinned tectonics), naming it Pirapora Salient.

Method

The magnetometric data used in this work were provided by Companhia de Desenvolvimento de Minas Gerais (CODEMIG) and are part of Minas Gerais State Aerogeophysics Survey Program – 2008/2009 (Area 13 Ubaí - Pirapora - Joaquim Felício).

For the processing of geophysical data, the Oasis Montaj software version 9.1 Geosoft ™ was used. The main procedures are described in the flowchart in Figure 3. Then, a database was created using the program ArcGis 10.3.

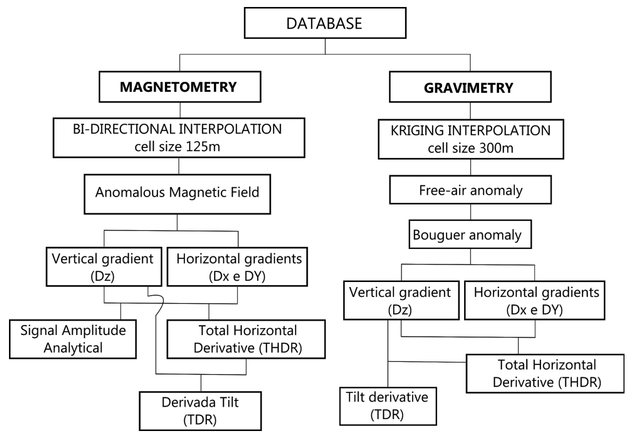

Figure 3 - Simplified flow charts illustrating the steps of processing of the magnetic data.

In October 2015, a field survey was carried out, producing 273 gravimetric stations with a spacing of approximately 500 m in the region near the future reservoir of Jequitaí, and every 1 km in the most distant areas. This data was complemented with terrestrial gravimetric data that represented a compilation of works developed in the region, provided by the Department of Geophysics of the Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG - USP). The Suturing Method was used for joining existing grids.

In the survey of the structural data, measures of the ruptile structures were made, besides the analysis of satellite images that served for better visualization of features recognized in geophysical images, and in the field. The format of measures is written in this paper as (true dip direction azimuth) / (dip angle of the plane of the structure with the horizontal plane).

Results

The interpretation of the magnetic data was based on the qualitative analysis of the compartmentalization of the local crust by means of the variation of the magnetic measurements. The study of the anomalous magnetic field (Figure 4) was used together with its linear transformations due to its difficult horizontal delimitation of anomalous sources.

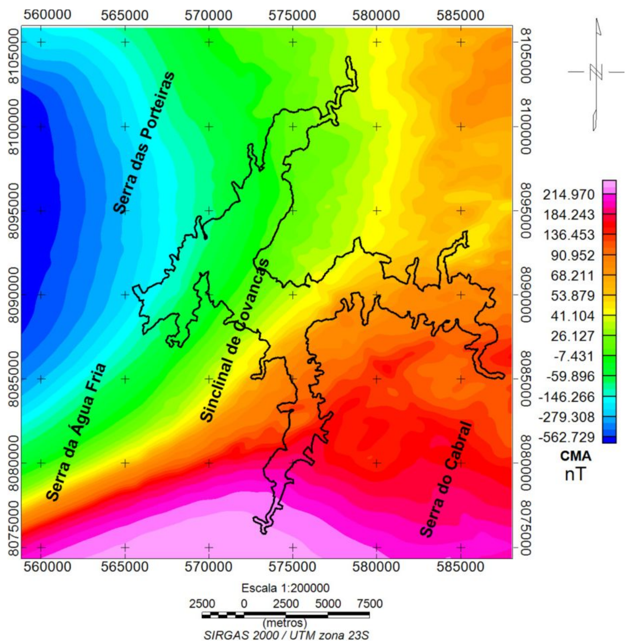

Figure 4 - Anomalous Magnetic Field Map

Figure 5 shows the attitudes of the magnetic lineaments with the dominant lineaments oriented N40° - 50° E and N40° - 50° W direction lines corresponding to the Riedel structures of the Araçuaí Belt fold-thrust systems, which was controlled by a tectonic transport from east to west. Strong orientations in the NE and SW directions were observed and associated with the swarms of dikes that occur in the region Silva et al. (1995).

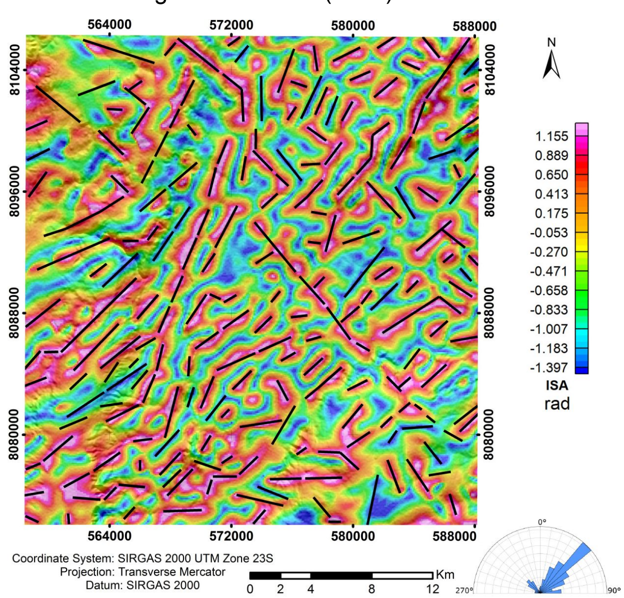

Figure 5 - Map of the Tilt derivate showing the magnetic lineaments and main lineaments trend.

Map of Bouguer anomalies (Figure 6) shows distinct gravimetric zones that correlate directly with the tectonic features, as a rise of the crystalline basement to the areas of the Serras da Água Fria and Serra do Cabral.

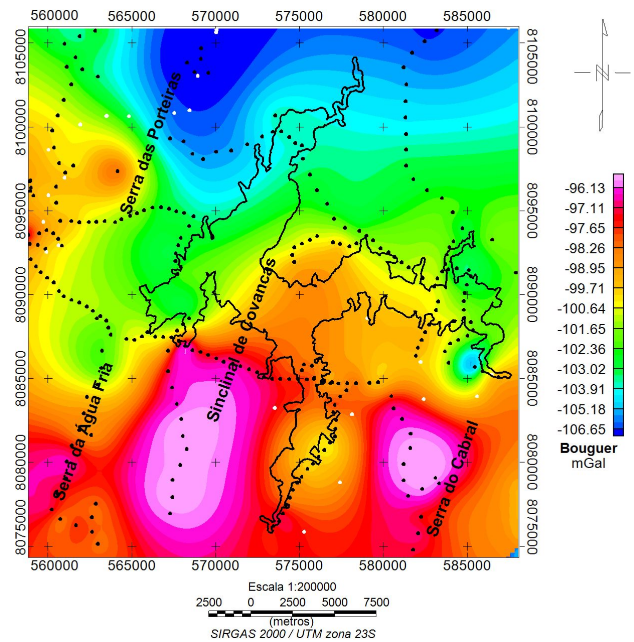

Figura 6 - Bouguer anomaly map and location of the data used. Data collected in this research (black points) and provided by IAG-USP (white points).

The most evident anomalies are located to the south of the area, where a high gravimetric in the southeast would be related to the structural elevation of the crystalline basement. Another region of high gravimetric, located in the center-south of the area, inside the Covancas syncline, would be related to the existence of an intrusive body. This region has a higher density than the sedimentary cover and probably a little higher than the basement density, with no apparent surface features. It is possible that small hills composed of calcilutite and metargillite of the Lagoa do Jacaré Formation also contribute to the high gravimetric measured (Chaves et al., 2011).

The high gravimetric located to the southwest coincides with the beginning of the Serra da Água Fria and was also interpreted as a structural rise of the basement. The gravimetric anomaly indicates higher values in the Serra do Cabral region in relation to the Serra da Água Fria, which suggests that the basement is situated shallower in the Serra do Cabral region. According to Hercos et al. (2008) this region had an uplift of greater magnitude, probably suffering a greater shortening in response to tectonic compression. This uplift which decreases to the west would have resulted in less shortening of the Sierra Fria region, and consequently a lower uplift.

The maps for locating the magnetic causative sources, obtained with the Euler deconvolution method, were then examined feature by feature. These solutions indicate an increase in depth for the southwest portion of the area, suggesting a difference in depth of the basement, since in the northeast region solutions occur up to approximately

500 m, while in the southwest of the area, these depths can reach around 7000 m (Figure 7).

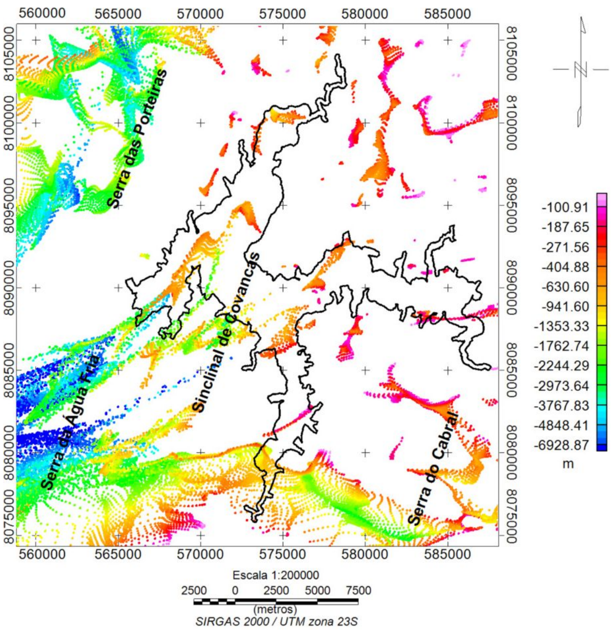

Figure 7 - Euler deconvolution solutions (Structural Index =0) residual magnetic field.

The solutions clustering from the gravimetric data (Figure 8) shows parallel N-S orientations in the south center portion of the area and have been interpreted as discontinuities/faults that would be in depth delimiting intrusive bodies that have higher density than the surrounding rocks that would be approximately 2 km in depth and would extend for about 4 km.

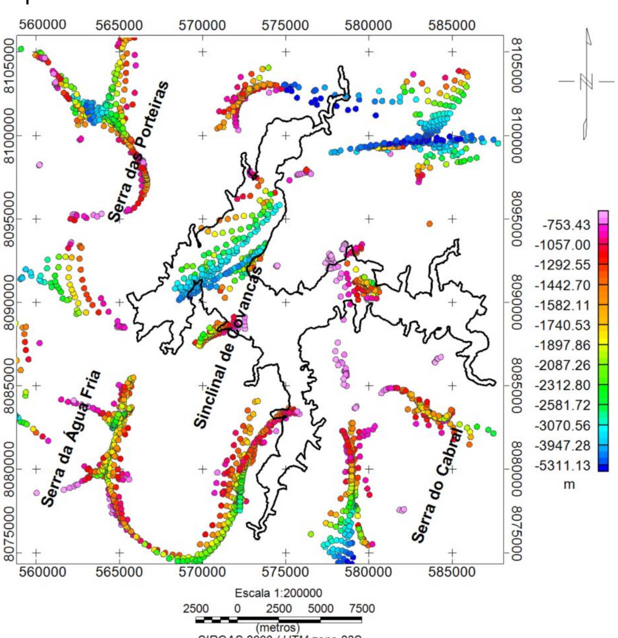

Figure 8 - Euler deconvolution solutions (Structural Index =0) Bouguer anomaly.

These solutions showed structures with greater depths to the southwest region of the area. Solutions clustering in the southwest portion with approximately N-S orientation, coincide with the approximate limit of the region where the influence of these bodies ends, to a region where the solutions are dispersed, suggesting the presence of a fault in that direction that would be delimiting the bodies to the north.

The Bouguer map combined with the Digital Elevation Model (Figure 9) shows three anomalies with high gravity, located in the southern portion of the area. Within the Covancas syncline there is a region with a higher density than the sedimentary cover and probably a little higher than the density of the basement, showing no apparent surface features. This anomaly suggests the existence of intrusive bodies of cylindrical shape, oriented in the direction N-S, and north would be about 2 km below the surface and extend for 4 km deep. The body of the southern syncline Covancas would extend at lower depths reaching approximately 2 km.

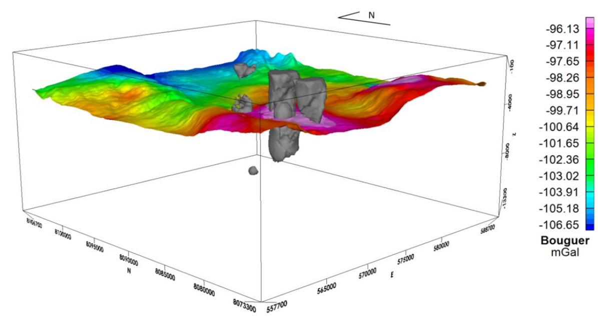

Figure 9 - Approximate format of the intrusive bodies on the Bouguer anomaly map.

From the integration of geophysical and structural data, it was possible to divide the studied segment into three structural domains: Western, Central and Eastern (Figure 10) defined based on the decrease of tectonic intensity, which occurs from east to west.

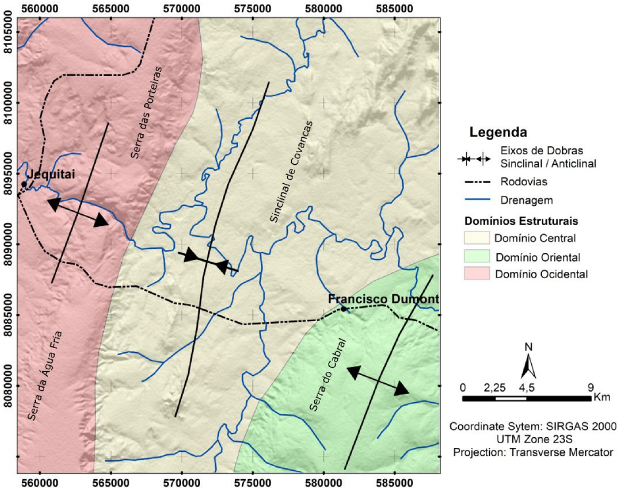

Figure 10 - Map of structural domains.

A comparison between linear data indicates that they are not always spatially associated. However, there are sectors where magnetic data exhibit good correspondence with field survey data.

A fact to be considered about the presence of magnetic lineaments that do not correspond directly with the field data can be related to: (i) deep structures that do not affect the sedimentary units; and/or (ii) the deep structures may have generated different deformation styles on the sedimentary cover, which could have attenuated the effect at small depths generating smaller structures that are not necessarily positioned at the same point on the surface. Magnetic lineaments are reflections of deeper structures related to 1st order structures. However, the lineaments referring to the data obtained in the field record the local stress fields or the 3rd and 4th order structures.

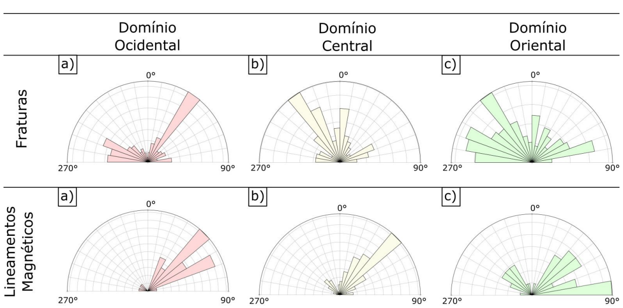

Figure 11 - Rose diagrams interpreted for each structural domain.

The Western domain was marked by directions approximately N60° W and N30° E. In addition, regions of a strong analytical signal accompany these lineaments emphasizing directions N40° - N70° E (Figure 11 (a)) - Western domain). The data analyzed in the Central domain, have a large scattered surface. The orientations of fractures and magnetic lineaments indicated tendencies N30° W and N40° E; and subordinate directions N10° E (Figure 11 (b)) - Central domain).

In the Eastern domain the fracture measurements showed good correspondence with magnetic lineaments, indicating directions between N30° - 70° W (Figure 11 (c)) - Eastern domain).

In the Western and Eastern domains, where quartzitic sediments occur, several patterns are observed, due to the greater variety and complexity of structures (3rd and 4th order). Shear fractures and associated conjugate structures (332° / 18° and 033° / 86° direction), normal faults have a preferential 083° / 20° direction and inverse faults were features described in this anticlinorium, generated by the regional crust tensions.

Conclusions

The methodology used showed an excellent result that helps to better understand the tectono-structural context of the Jequitaí region. By means of the integrated final products, it was possible to delimit more accurately the main structures, providing regionally and detail information about the structural framework in the region.

The pattern and shape of the gravimetric anomaly suggest that the basement rocks are arranged in staggered blocks limited by faults and the presence of possible bodies of higher density than the surrounding rocks and of little magnetism, limited to NW by an inferred fault in the NE-SW direction. This feature is very clear using Euler deconvolution.

From the magnetic and gravimetric causative sources derived from the Euler deconvolution method, it was possible to assume that these bodies would be in a maximum depth of 4 km and a difference in the depth of the crystalline basement from the southwest and northwest portion, being the southwest more shallow and structured in horst and graben.

Structural data provided information on 3rd and 4th order structures, which presented general orientation N30° - 40° W. However, the domains described, show a variation in orientation indicating a decrease in tectonic intensity, which occurs from east to west.

These results corroborate previous observations made by Hercos et al. (2008), which propose a tectonic compartment for this region that constitutes a protuberance within the foreland zone, called "Pirapora Salient ", where the basement was involved in the deformation of the cover rocks, which constitutes a thick-skinned tectonic.

Acknowledgments

The authors would like to thank Companhia de Desenvolvimento Econômico of Minas Gerais (CODEMIG) for providing the aerogeophysical data, and also Desenvolvimento Tecnológico (CDT/UnB) for the logistic support.

References

Alkmim, F. F., Brito Neves, B. d., and Alves, J. C. (1993). Arcabouço tectônico do Cráton do São Francisco-uma revisão. O Cráton do São Francisco, 1:45–62.

Alkmim, F. F. and Martins-Neto, M. (2001). A bacia intracratônica do São Francisco: Arcabouço estrutural e cenários evolutivos. A bacia do São Francisco. Geologia e recursos naturais: SBG/Núcleo MG, SBG/Núcleo MG, pages 9–30.

Almeida, F. F. M. d. (1977). O cráton do São Francisco. Revista Brasileira de Geociências, 7(4):349–364.

Chaves, M., Benitez, L., Egger, V. A., Henrique, L., Magalhães, G., Silva, C. J. E., and Andrade, K. W. (2006). Folha Jequitaí 1: 100.000. Brasília, Programa Geologia do Brasil, Convênio CPRM-IGC/UFMG, Relatório Final, 45p.

Chaves, M. L. d. S. C., Andrade, K. W., and Benitez, L. (2011). Geologia integrada das Folhas Jequitaí, Bocaiúva e Montes Claros (1: 100.000), norte de Minas Gerais. Revista Geonomos, 19(2).

Chemale Jr., F, Alkmim, F. F., and Endo, I. 1993. Late Proterozoic tectonism in the interior of the São Francisco craton. In: Findlay, Urung, Banks & Veevers (eds.), Balkema, Rotterdam: 29-41.

Hercos, C. M., Neto, M. A., and Danderfer Filho, A. (2008). Arcabouço estrutural da Bacia do São Francisco nos arredores da Serra da Água Fria (MG), a partir da integração de dados de superfície e subsuperfície. Revista Brasileira de Geociências.

Pedrosa-Soares, A. C., Noce, C. M., de Alkmim, F. F., da Silva, L. C., Babinski, M., Cordani, U., and Castañeda, C. (2007). Orógeno Araçuaí: síntese do conhecimento 30 anos após Almeida 1977. Revista Geonomos, 15(1).

Santos, M. N. d., Chemale, F., Dussin, I. A., Martins, M. d. S., Queiroga, G., Pinto, R., Santos, A., and Armstrong, R. (2015). Provenance and paleogeographic reconstruction of a mesoproterozoic intracratonic sag basin (Upper Espinhaço Basin, Brazil). Sedimentary Geology, 318:40–57.

Silva, A. M., Chemale Jr, F., Kuyumjian, R. M., and Heaman, L. (1995). Mafic dyke swarms of Quadrilátero Ferrífero and Southern Espinhaço, Minas Gerais, Brazil. Brazilian Journal of Geology, 25(2):124–137.

Teixeira, C. D.; Von Huelsen, M. G.,Chemale Jr, F., Sacramento, V., Garcia. V. B. P.