UNIVERSIDADE FEDERAL DA BAHIA

INSTITUTO DE GEOCIÊNCIAS

CURSO DE PÓS-GRADUAÇÃO EM GEOLOGIA

ÁREA DE PETROLOGIA, METALOGÊNESE E EXPLORAÇÃO MINERAL

TESE DE DOUTORADO

GEOLOGIA E TECTÔNICA DA ZONA DE SUTURA ENTRE OS BLOCOS ITABUNA-SALVADOR-CURAÇÁ E JEQUIÉ, BAHIA, BRASIL.

LUCAS TEIXEIRA DE SOUZA

Salvador

2019

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Tese de doutorado apresentada ao Programa de Pós-Graduação em Geologia da Universidade Federal da Bahia, como requisito para a obtenção do Grau de Doutor em Geologia, na área de concentração em Petrologia, Metalogênese e Exploração Mineral em 13/12/2019.

Salvador

2019

Ficha catalográfica elaborada pelo Sistema Universitário de Bibliotecas (SIBI/UFBA),
com os dados fornecidos pelo(a) autor(a).

Teixeira de Souza, Lucas
GEOLOGIA E TECTÔNICA DA ZONA DE SUTURA ENTRE OS BLOCOS ITABUNA-SALVADOR-CURAÇÁ E JEQUIÉ, BAHIA, BRASIL. / Lucas Teixeira de Souza. -- Salvador, 2019.
70 f. : il

Orientador: Luiz Cesar Corrêa-Gomes.
Coorientadora: Jailma Santos de Souza-Oliveira.
Tese (Doutorado - Geologia) -- Universidade Federal da Bahia, IGEO, 2019.

1. Zona de Sutura. 2. Aerogeofísica. 3. Petrogênese. 4. Cráton do São Francisco. 5. Granitogênese. I. Corrêa-Gomes, Luiz Cesar. II. Souza-Oliveira, Jailma Santos de. III. Título.

LUCAS TEIXEIRA DE SOUZA

"TECTÔNICA E GEOCRONOLOGIA (U-PB) DA ZONA DE SUTURA ENTRE OS BLOCOS ITABUNA-SALVADOR-CURAÇÁ E JEQUIÉ, BAHIA, BRASIL "

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Salvador – BA
2019

AGRADECIMENTOS

Em primeiro lugar, agradeço a meus pais, Vicente Fernandes de Souza e Georgina Conceição Teixeira de Souza, e à minha irmã, Liliane Teixeira de Souza, pelo apoio e confiança constantes, principalmente no momento em que me propus retornar à vida acadêmica. A confiança que me passam sempre me guiará a buscar melhorar e evoluir.

Agradeço muito aos meus orientadores Luiz Cesar Corrêa Gomes e Jailma Santos de Souza de Oliveira, que aceitaram o desafio de realizar o projeto em prazo reduzido, me ajudando muito na conclusão desta tese.

Um agradecimento especial à minha companheira, Larissa, que tanto me ajudou e aconselhou no desenvolvimento deste trabalho.

Agradeço também a todos os que sempre estiveram dispostos a me auxiliar e aconselhar na minha evolução como geólogo, sejam professores, amigos, colegas ou alunos.

Aos funcionários do IGEO, sempre solícitos a ajudar quando requisitados.

À Pós-Graduação em Geologia pelo apoio.

A CAPES pelo incentivo à pesquisa.

RESUMO

A área de estudo desta pesquisa localiza-se na porção central da maior feição tectônica do estado da Bahia, o Cráton do São Francisco (CSF). Mais especificamente nos limites entre dois dos principais blocos que compõem o referido cráton, os Blocos Jequié e Itabuna-Salvador-Curaçá. A pesquisa objetivou principalmente a reavaliação do limite entre os referidos blocos, utilizando mapas aerogeofísicos e dados geológicos, estruturais, características petrográficas, geoquímicas e dados bibliográficos de geocronologia U-Pb de rochas que afloram nesta região, de modo a contribuir com o conhecimento da evolução geotectônica que moldou as rochas ali aflorantes. Os mapas aerogeofísicos utilizados foram dos métodos radiométrico e magnetométricos, que permitiram a individualização de cinco domínios radiométricos e seis zonas magnetométricas. A análise estrutural identificou quatro fases de deformação, características de uma zona transpressional. A descrição petrográfica verificou-se que a mineralogia dos litotipos é bastante similar, tendo como características discriminantes os graus de deformação e a presença de alguns minerais índices da facies granulito. Os estudos litogeoquímicos mostraram que as rochas intrusivas na região da zona de sutura entre o BJ e BISC são de característica calcioalcalinas peraluminosas a metaluminosas com alto K e provenientes de ambiente tectônico de arco magmático. A geocronologia U-Pb utilizou dados bibliográficos de idades de cristalização para realizar interpretações a respeito às rochas do embasamento e estimar a data das intrusões. As idades utilizadas foram em torno de 2,7-2,6 Ga (U-Pb em zircão) e pico do metamorfismo em 2,07-2,06 Ga (U-Pb em zircão), com diferença de idade entre borda e centro dos zircões com um intervalo de 40-30 Ma, interpretados como o período entre o pico metamórfico e o colapso orogenético. O presente estudo propõe uma modificação do limite entre os blocos, baseando-se no conjunto de dados obtidos por esses métodos.

Palavras-chave: Zona de Sutura, Cráton do São Francisco, Petrografia, Litogeoquímica, Aerogeofísica

ABSTRACT

The study area of this research is located in the central portion of the largest tectonic feature of the state of Bahia, the São Francisco Craton (SFC). More specifically on the boundaries between two of the main blocks that make up the craton, the Jequié, and Itabuna-Salvador-Curaçá blocks. The research mainly aimed at the reevaluation of the boundary between these blocks, using airborne geophysical maps and geological, structural, petrographic, geochemical and U-Pb geochronology data of rocks that occur in this region, to contribute to the knowledge of the geotectonic evolution that shaped the rocks in this location. The airborne geophysical maps used were the radiometric and magnetometric methods, which allowed the individualization of five radiometric domains and six magnetometric zones. Structural analysis identified four phases of deformation characteristic of a transpressional zone. The petrographic description showed that the lithology mineralogy is very similar, having as discriminating characteristics the degrees of deformation and the presence of some index minerals of the granulite facies. The lithogeochemical studies showed that the intrusive rocks of the studied area are of high-K peraluminous to high-alumina calcine characteristic and classified as VAG. The U-Pb geochronology used bibliographic data of crystallization ages to perform interpretations about the basement rocks and to estipulate the ages of the intrusive granites. The ages used were around 2.7-2.6 Ga (Zircon U-Pb) and metamorphic peak at 2.07-2.06 Ga (Zircon U-Pb), with age difference between border and center of the zircons with a range of 40-30 Ma, interpreted as the period between the metamorphic peak and orogenetic collapse. The present study proposes a modification of the boundary between blocks, based on the data set obtained by these methods.

Keywords: Suture Zone, São Francisco Craton, Petrography, Geochemistry, Airborne Geophysical Maps.

SUMÁRIO

CAPÍTULO 1
INTRODUÇÃO GERAL

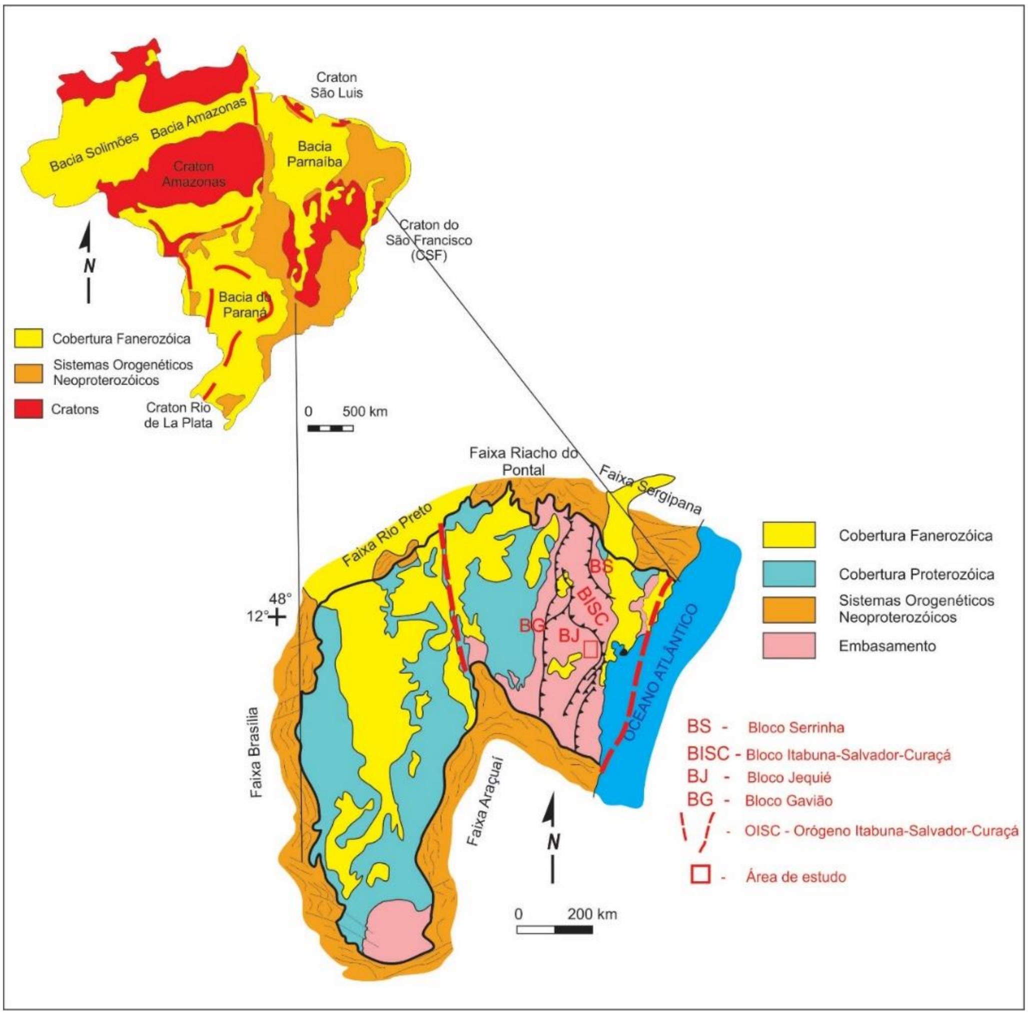
As zonas de sutura possuem grande importância em estudos geológicos, uma vez que são representantes da tectônica colisional em determinadas regiões. Além da sua importância geológica/científica, também são potenciais áreas de mineralizações, devido à possibilidade de ocorrência de ofiolitos e pela intensa atividade metassomática associada quando servem de conduto para remobilização de elementos móveis e formação de depósitos minerais.

Esta pesquisa buscou estudar uma significativa área na zona de sutura dos terrenos metamórficos de alto grau do sul da Bahia, a qual constitui uma das mais importantes províncias em fácies granulito e anfibolito aflorantes no mundo. Esses terrenos foram e são objeto de estudos petroquímicos, de química mineral e geocronológicos desde a década de 1980 e, em consequência, novas discussões sobre sua gênese, protólitos, condições termobarométricas e ambientes metamórficos atuantes, são amplamente estimuladas. Esses metamorfitos aflorantes no estado da Bahia fazem parte do Cráton do São Francisco (CSF) (ALMEIDA, 1977) onde ocorreu a colisão de quatro segmentos crustais, de idades arqueana e paleoproterozoica: i) Bloco Gavião (BG); ii) Bloco Jequié (BJ); Bloco Itabuna-Salvador-Curaçá (BISC); e iv) Bloco Serrinha (BS) (BARBOSA e SABATÉ, 2002, 2004). A geotectônica responsável pela aglutinação destes blocos ocorreu no Paleoproterozoico, em torno de 2,08 Ga, que resultou na formação do Orógeno Itabuna-Salvador-Curaçá (OISC) (BARBOSA e SABATÉ, 2002, 2004) (Figura 1).

O objeto principal desta tese é o estudo da estratégica porção da zona da sutura entre os Blocos Jequié e Itabuna-Salvador-Curaçá, na região de Milagres (BA), buscando auxiliar no entendimento da evolução tectônica Paleoproterozoica e reavaliando os limites destas unidades tectônicas, buscando definir como aconteceu a colisão entre os Blocos Itabuna-Salvador-Curaçá e Jequié e contribuindo para o entendimento da Orogenia paleoproterozoica responsável pelo aglutinamento desses blocos que compõem parte importante do Cráton do São Francisco. Os artigos foram/serão submetidos na revista Journal of South American Earth Sciences. Tem-se como objetivos específicos: (i) individualizar zonas radiométricas e magnetométricas com os mapas aerogeofísicos e utilizá-los na interpretação da localização da zona de sutura; (ii) observar os padrões estruturais e determinar como ocorrem as deformações dessas rochas na zona de sutura; (iii) caracterizar os litotipos locias, através da petrografia e identificar as paragêneses minerais das rochas intrusivas; e, (iv) determinar as características geoquímicas das rochas das intrusivas e interpretar as condições em que ocorreram essas intrusões.

O projeto se torna importante visto que a área selecionada não possui trabalhos anteriores dentro do tema proposto, de forma que foram obtidas informações inéditas que contribuíram para o entendimento geológico associado ao estudo de zonas de sutura e reavaliando o limite entre duas unidades geotectônicas que constituem de um dos sistemas cratônicos mais importantes no território brasileiro e mundial. Essa pesquisa trouxe também importantes contribuições científicas com a utilização de dados geofísicos, estruturais e litológicos no estudo de zonas de alta taxa de deformação, metamorfismo e atividade magmática.

Figura 1 – Principais crátons e sistemas orogenéticos neoproterozoicos do território brasileiro e mapa geológico simplificado do CSF.



Os trabalhos se concentraram na folha Milagres (SD-24-V-B-V) onde há grande ocorrência de inselbergs granulíticos ou graníticos, onde os afloramentos são de maneira geral de fácil acesso devido à BR-116 cortar a área de estudo na direção NE-SW. Detalhes acerca deste tópico são discriminados nos capítulos 2 e 3.

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CAPÍTULO 2

ARTIGO - REINTERPRETATION OF THE SUTURE ZONE BETWEEN THE ITABUNA-SALVADOR-CURAÇÁ AND JEQUIÉ BLOCKS, OF THE SÃO FRANCISCO CRATON, BAHIA, BRAZIL, USING STRUCTURAL AND GEOPHYSICAL DATA

Journal of South American Earth Sciences 96 (2019) 102353

Contents lists available at ScienceDirect

Journal of South American Earth Sciences

journal homepage: www.elsevier.com/locate/jsames

Reinterpretation of the suture zone between the Itabuna-Salvador-Curaçá and Jequié blocks, of the São Francisco Craton, Bahia, Brazil, using structural and geophysical data

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ARTICLE INFO

Keywords:
Suture zone
São Francisco Craton
Geophysics
Structural geology

ABSTRACT

The study area is located in the central portion of the São Francisco Craton (SFC), between two of the main blocks that compose this feature: the Jequié and the Itabuna-Salvador-Curaçá blocks. The main objective of this study was to reevaluate the transition zone between both blocks, employing airborne geophysical, geologic and structural data. The geophysical data are represented by gamma-ray spectrometry and magnetic surveys, which showed the structure of the lithotypes mapped and helped in the identification of their limits. The analysis of these images established five radiometric domains and six magnetic zones. The geophysical data interpreted along with mapping survey, with macroscopic description and structural data, allowed better identification of the suture zone between the referred blocks. The structural analysis identified four deformation phases, characteristic of a transpressional zone, uplifting the ISCB onto JB. The present study proposes the modification of the limits between these blocks to a more southern location and updates the regional geotectonic understanding of the central region of the state of Bahia.

1. Introduction

Suture zones are of great importance in geologic studies since they represent collisional tectonics in certain regions. In addition to their geologic/scientific relevance, they are potentially important for ore enrichment due to the possibility of ophiolites occurring and the intense metasomatic activity that is associated with them, which can act as a duct to remobilize mobile elements and form mineral deposits.

The present study aimed to analyze a significant area of high-grade metamorphic terrains in central-eastern Bahia, Brazil, which represents one of the most important outcropping high-grade metamorphic provinces in the world. These terrains were and still are the focus of petrochemical, mineral chemistry, and geochronological studies since the 1980s. Consequently, new discussions on their genesis, protoliths, thermobarometry conditions, and metamorphic environments in activity, are widely stimulated.

These metamorphites are part of the northern portion of the São Francisco Craton (SFC) (Almeida, 1977), where the amalgamation of four Archean and Paleoproterozoic crustal segments occurred: i) Gavião Block (GB); ii) Jequié Block (JB); Itabuna-Salvador-Curaçá Block (ISCB); and iv) Serrinha Block (SB) (Barbosa and Sabate, 2002; 2004). The tectonics responsible for the agglutination of these blocks occurred during the Paleoproterozoic, peaking approximately 2.08 Ga ago (Barbosa and Sabate, 2002; 2004; Peucat et al., 2011). This resulted in the formation of the Itabuna-Salvador-Curaçá Orogen (ISCO) (Fig. 1).

The main objective of the present study was to evaluate a strategic portion located between the Jequié and Itabuna-Salvador-Curaçá blocks, in the region of the municipality of Milagres, state of Bahia (BA). The aim was to improve the understanding of Paleoproterozoic tectonic evolution and re-evaluate the limits of these tectonic units. Therefore, a better definition of the location of the suture zone between these blocks is expected.

In order to achieve this objective, a methodology similar to that applied by Sampaio et al. (2017) to delimit the same blocks in the county of Valença (BA), located southwards from the present study site, was used. These authors used airborne geophysical data that allowed the identification of structural patterns and suggested the reinterpretation of both the geology of the region of Valença and the suture zone between the Jequié and Itabuna-Salvador-Curaçá blocks, therefore significantly contributing to the understanding of the São Francisco Craton.

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https://doi.org/10.1016/j.jsames.2019.102353
Received 8 July 2019; Received in revised form 5 September 2019; Accepted 5 September 2019
Available online 10 September 2019
0895-9811/

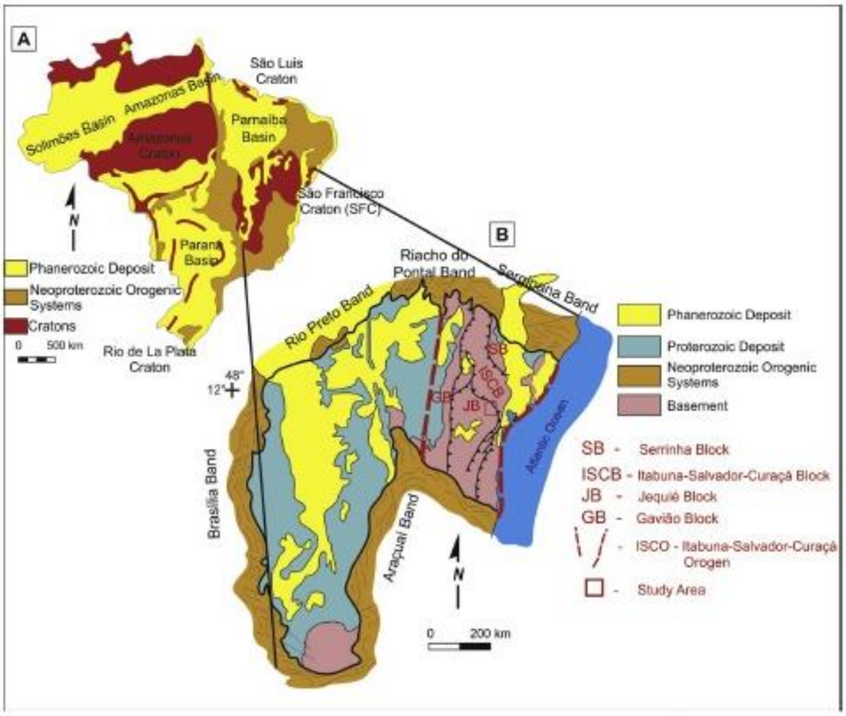

Fig. 1. (A) Main cratons and Neoproterozoic orogenic systems of the Brazilian territory; and (B) Simplified geologic map of the SFC.

2. Location of the study area

The SFC (Fig. 1A) is located in the South American Platform and is part of the most important tectonic unit of the central-eastern region of Brazil (Almeida, 1977). This craton is molded and limited by orogenic bands called: Riacho do Pontal, to the north; Brasília, to the west; Rio Preto, to the northwest; Araçuaí, to the south; and Sergipana, to the northeast, of which the largest outcropping extension is located in the state of Bahia (Fig. 2A).

The analyses concentrated within the limits of the Milagres chart (SD-24-V-B-V) (Fig. 2B) where there is a large occurrence of intrusive granitic inselbergs and/or inselbergs that originated from basement rocks, where outcrops are generally easily accessible from the BR-116 highway that cuts across the study area from NE to SW.

The access from the state capital (Salvador) is via the BR-324 highway, followed by the BR-116 until the municipality of Milagres (Fig. 2B), main municipality of the chart. Milagres is located 240 km away from Salvador.

3. Material and methods

This paper relied on the assistance of data obtained from previous campaigns, including structural measurements and macroscopic description of rocks (Barbosa and Sabate, 2002; Macedo, 2006; Nunes and Melo, 2007; Santiago, 2010; Teixeira, 1997).

The airborne geophysical maps were obtained from the digital library of the Geological Survey of Brazil (CPRM, 1976), on a single survey between latitudes −14°00′ and −12°00′ and longitudes −40°00′ and −39°00′.

During the field campaign, outcrops were described using the SIRGAS 2000 datum and the UTM (Universal Transverse Mercator) coordinate system, which since 2005 is the system used by IBGE (Brazilian Geography and Statistic Institute). Sample collection, photographic records, meso- and macroscopic analyses, and geologic sections were also conducted and, whenever possible, measurements were taken from structures found (metamorphic or magmatic foliations, faults, fractures, and lineations).

Interpretations related to making the geologic-structural map were treated in a GIS (Geographic Information System) interface using *Arcmap* software (version 10.3). The images used to conduct geophysical interpretations were also treated using *Arcmap* software (version 10.3) and were based on data and images provided by CPRM (1976) using gamma-ray spectrometry and magnetic methods. Combined with the geologic mapping and geophysical data, SRTM (Shuttle Radar Topography Mission) images were used. These images assisted in the delimitation of contacts, especially of intrusive bodies that compose the inselbergs of the studied region.

Figures and image editing were treated using *CorelDrawGraphicsSuite X7* software (version 7).

4. Regional geology

The present study area is located at the limit of two Archean and Paleoproterozoic crustal segments that compose the SFC: the Jequié Block (JB) and the Itabuna-Salvador-Curaçá Block (ISCB), respectively (Figs. 1 and 3).

JB is rebalanced on granulite facies and is mainly composed of enderbite-charnockite rocks dating approximately 2.7 Ga (U/Pb in zircons). Alternated felsic and mafic (with TDM Sm/Nd model ages of 3.2 Ga) bands that are sometimes migmatized occur associated with these granulites. Among the orthoderived granulites are supracrustal rocks with anatectic granites rich in garnet and cordierite (Barbosa and

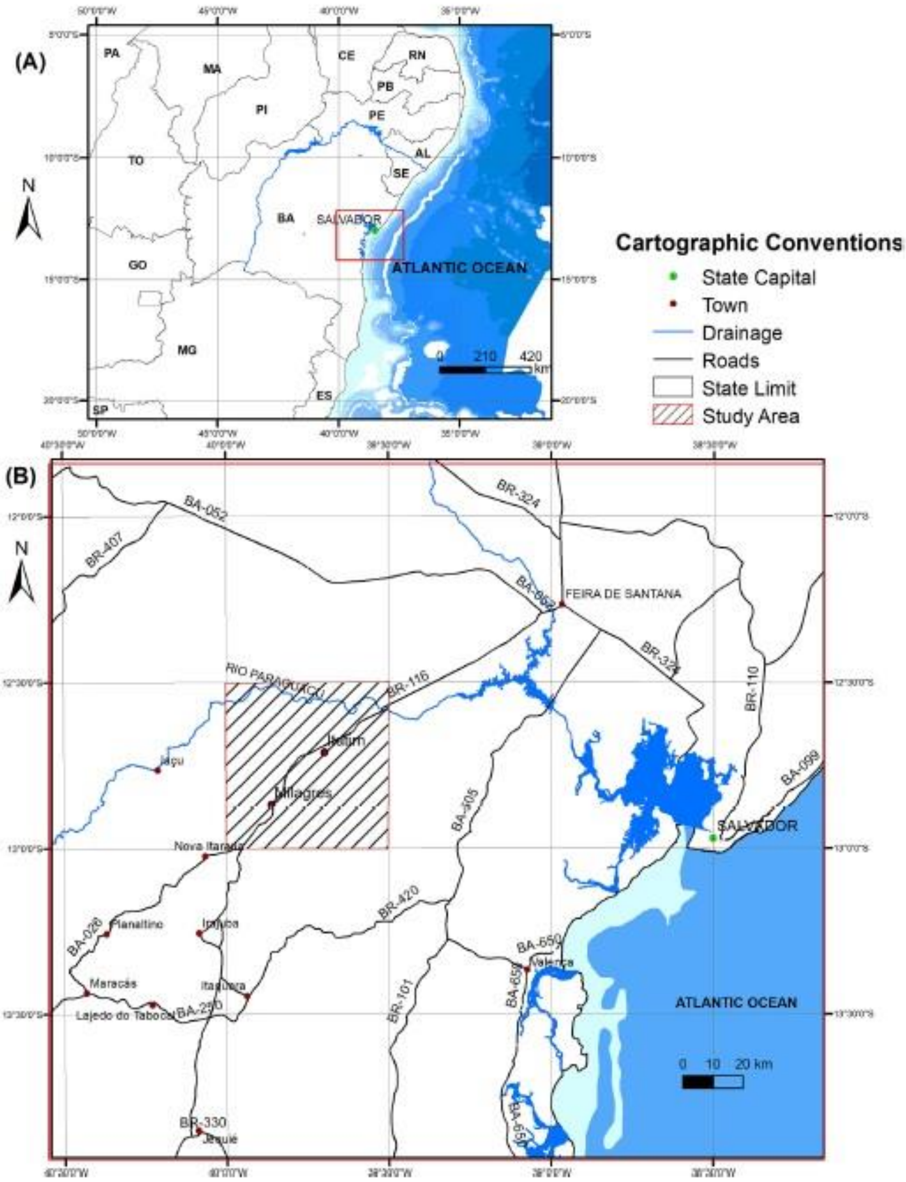

Fig. 2. Study area location map. (A) Study area location map within the Northeastern region of Brazil; and (B) Location within the state of Bahia, where the polygon that delimits the study area represents the Milagres chart (SD-24-V-B-V).

Sabate, 2002; 2004; Macedo, 2006). Charnockite domes and Paleoproterozoic granites and syenites, both deformed and non-deformed, are particularly relevant in this block. In turn, ISCB is composed of tonalite/trondhjemite rocks with ages of approximately 2.6 and 2.1 Ga (Barbosa and Peucat, 2006), charnockite bodies of 2.6 Ga, supracrustal rocks (quartzites, aluminium-magnesium gneisses, graphitites, and magnesium-rich formations), gabbros/basalts from the ocean floor and/or from mantle-source back-arc basin (Teixeira, 1997), and monzonitic/shoshonitic intrusions of 2.4 Ga (Ledru et al., 1993). All these units are rebalanced on granulite facies due to the Paleoproterozoic event (Barbosa, 1990).

The metamorphic lithotypes were deformed by at least three ductile deformation phases and rebalanced on granulite facies, under an intermediate-pressure (5–7 kbar) and high-temperature (850–870 °C) regime (Barbosa, 1990; Barbosa et al., 2012). The central portion of the granulitic terrains from eastern Bahia is excluded from this context (Ipiaú Band, Barbosa, 1996), since this portion is composed of rocks rebalanced on the amphibolite facies.

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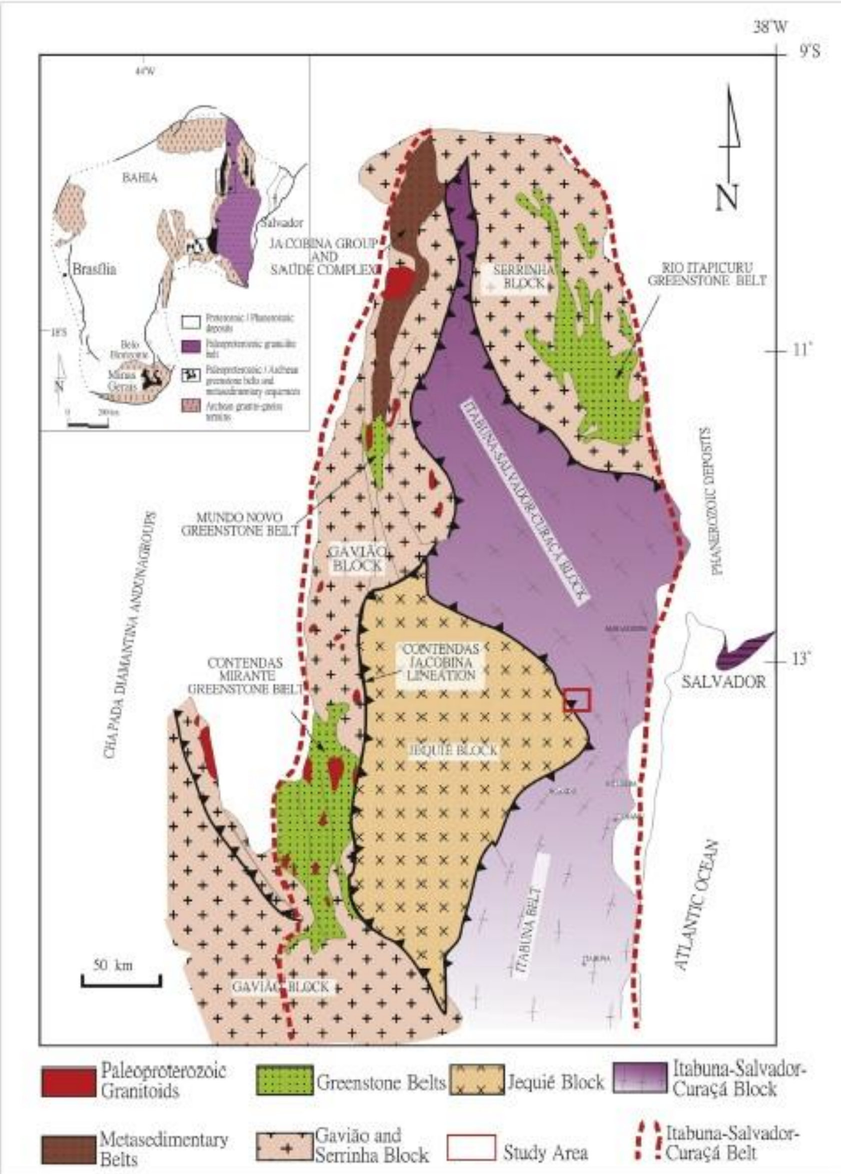

Fig. 3. Spatial arrangement of the main blocks that compose SFC. (A) Positioning in the state of Bahia; and (B) Representation of the limits between blocks, highlighting the present study area, at the limit between the Itabuna-Salvador-Curaçá Block and the Jequié Block.

In addition to petrology, structural geology, geochronology, and tectonics, metallogenesis has also been investigated in ISCB. This includes: (i) studies on mineral deposits and occurrences, highlighting those on manganese, barite, and copper; and (ii) studies on the occurrences of basic sulfides and platinum found in mafic-ultramafic rocks in the central portion of the area, near the municipality of Ipiaú. Mineral studies have also been conducted in occurrences of JB, such as those on nickel, close to the municipality of Boa Nova, and on iron, in Jequié (Sá, 2010).

The tectonic macro-features of this granulitic region of SFC, as mentioned above, are the Jequié Block (JB) and the Itabuna-Salvador-Curaçá Block (ISCB). In these blocks, the outcropping rocks are mainly represented by those of the Jequié Complex and the Caraíba Complex, respectively. These are the lithotypes that compose the basement of the region. Syn to late tectonic intrusive granitoids also occur in both blocks (Fig. 4) (Nunes and Melo, 2007).

The rocks of the Jequié Complex occur as ortho- and paraderived heterogeneous granulites, whose composition ranges between

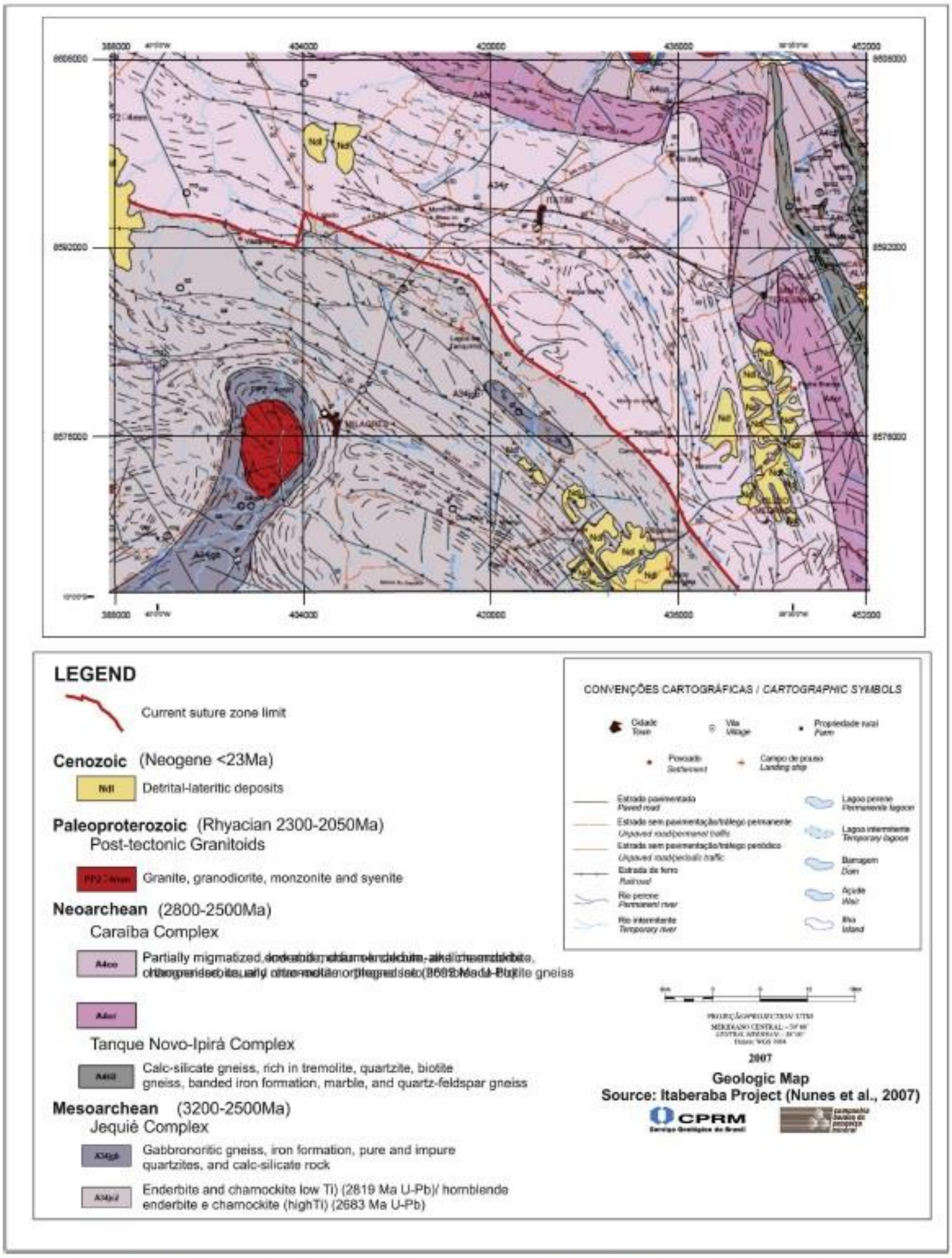

Fig. 4. Regional geologic map of the central portion of SFC, in the suture zone between the Jequié and Itabuna-Salvador-Curaçá blocks. Source: Adapted from Nunes and Melo (2007).

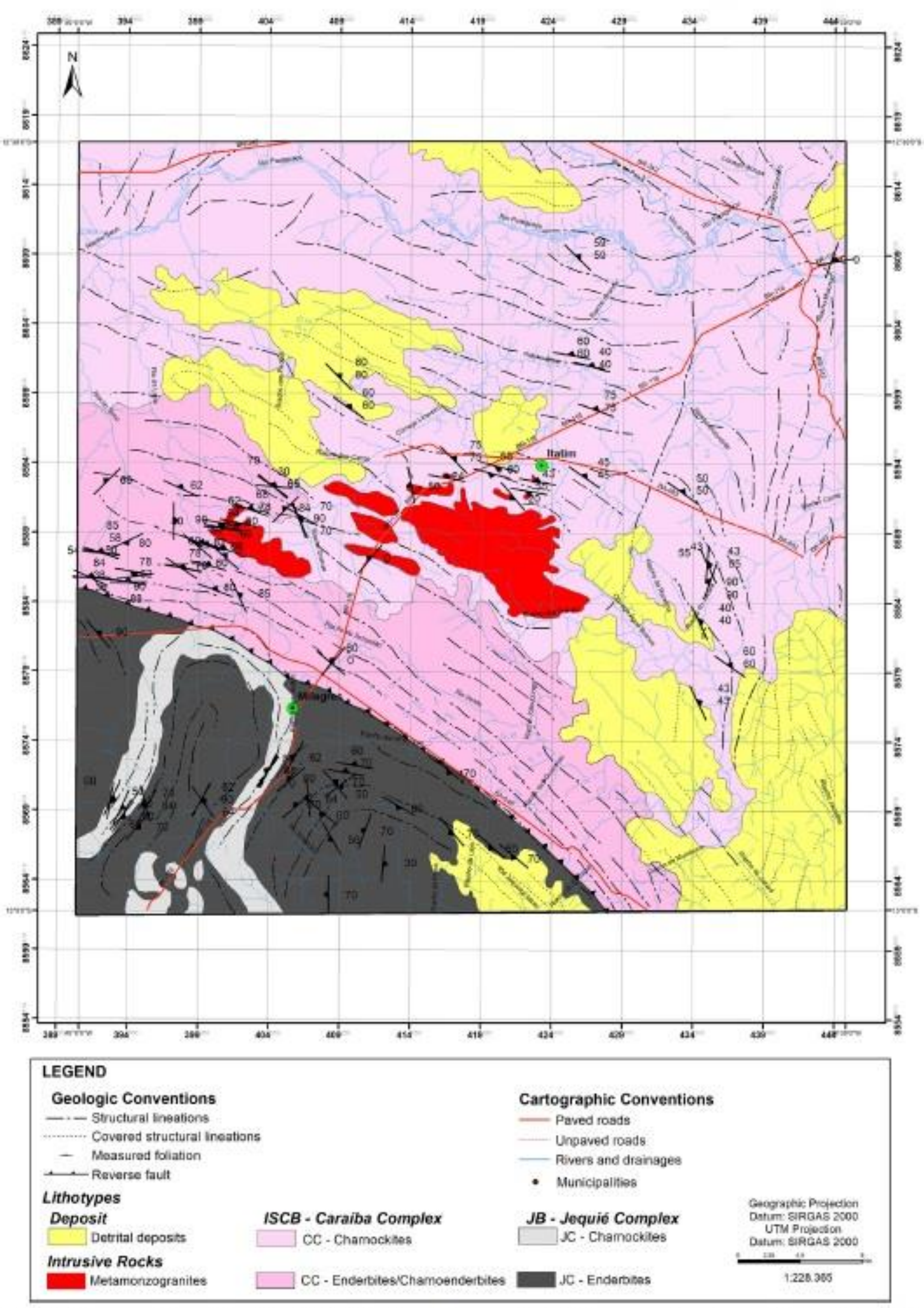

Fig. 5. Geologic map of the central portion of SFC, in the Itatim/Milagres region, which represents the suture zone between JB and ISCB.

enderbite-charnoenderbite-charnockite and augen-charnockite granulites, presenting colors ranging from gray to grayish-green, often reaching pinkish hues when altered (Nunes and Melo, 2007; Barbosa and Sabate, 2004; Macedo, 2006). These rocks generally present medium grain size and foliation mainly characterized by feldspars and micas. They commonly present mafic enclaves, often deformed along with the rocks of the complex. The composition of these enclaves is described as being rich in amphibole to norite, with metamorphic edges

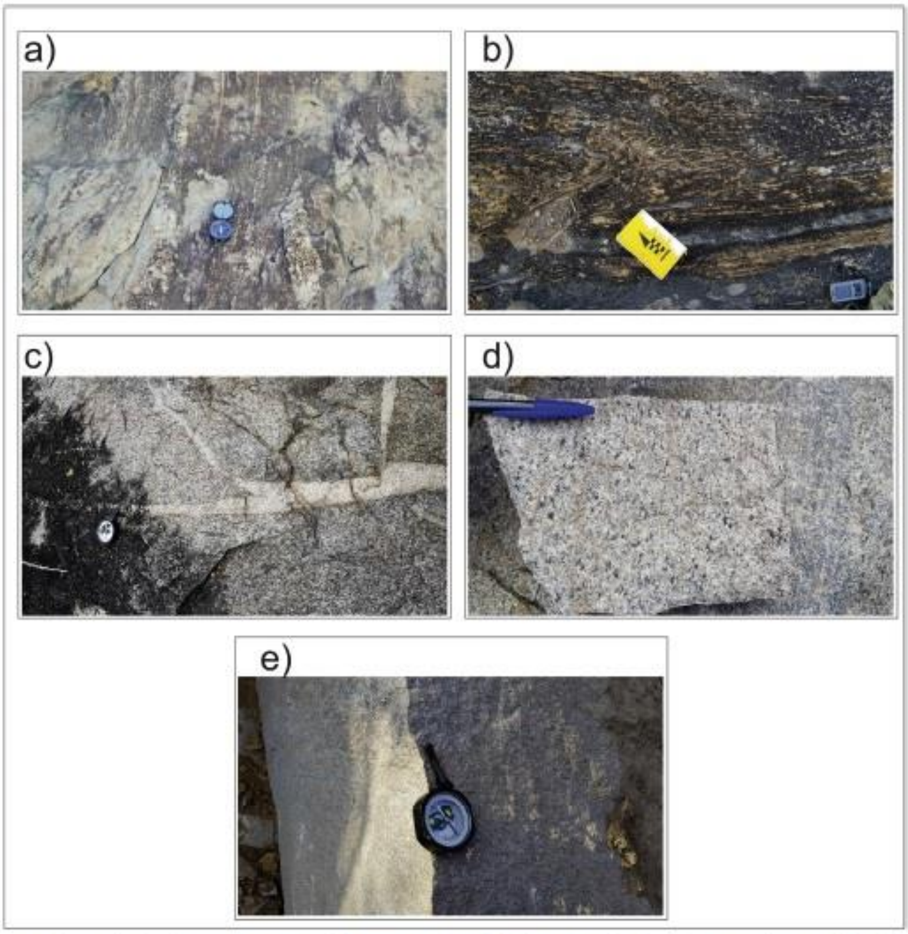

Fig. 6. (a) Migmatitic feature of rocks from JC presenting enderbite composition and thinly segregated bands; (b) Migmatitic feature of the rocks of the Caraíba Complex, mainly indicated by the variation in rock foliation, with little segregation of leucosomes and melanosomes; (c) Pegmatite vein discordant in relation to the foliation of the rocks of the Caraíba Complex. It is predominantly composed of Qz and Pl, filling a fracture oriented according to the direction N215; (d) Monzogranite with poorly visible foliation, presenting an inequigranular, phaneritic structure with medium to coarse grain size; and (e) Monzogranite presenting incipient visible foliation mainly resulting from the orientation of biotites. The block represents both the XY and the YZ planes, allowing direct visualization of plane direction and dip.

for the granulite facies (Barbosa and Sabaté, 2003).

The Caraíba Complex is represented in the study area as two lithofacies with mainly structural differences due to the intensity of deformation that reached these lithotypes (Nunes and Melo, 2007). The first lithofacies is in contact with rocks of the Jequié Complex and comprises greenish-gray enderbite, charnoenderbite, and charnockite orthogneisses, sometimes whitish and/or yellowish when altered by weathering processes. These rocks present medium to coarse grain size and well-defined foliation. The second lithofacies is represented by granulite-migmatite orthogneisses that underwent a more accentuated retro-metamorphic deformation, and are classified as migmatized hornblende-biotite gneisses, with strong deformation caused by shear zones (Santiago, 2010).

The intrusive rocks are associated with the Itaberaba Granite Suite, first described by Fernandes (1991). This author identified them as Paleoproterozoic rocks (2.1 Ga – Rb-Sr method). The suite is subdivided into four facies: (i) equigranular biotite-garnet granites; (ii) hornblende-biotite leucogranites; (iii) granites with biotite or garnet alternated with coarse to pegmatitic leucogranites; and (iv) aplitic fine-grained granites presenting gradational progression with the previous rock (Barbosa et al., 2012). According to Nunes and Melo (2007), the rocks that outcrop near the limits between the Jequié Block and the Itabuna-Salvador-Curaçá Block are granites, granodiorites, and syenites that are similar to types (ii) and (iii) described by Barbosa et al. (2012). This suite is considered by these authors as syn to late tectonic, which implies that its classification ranges from deformed to weakly deformed.

Therefore, the geologic investigations in the area of interest aimed to complement studies that had been conducted previously regarding this granulitic region of eastern Bahia, more specifically in the Milagres chart, increasing subsides to the knowledge of its petrology, tectonics, isotopic/geochronological geology and metallogenesis.

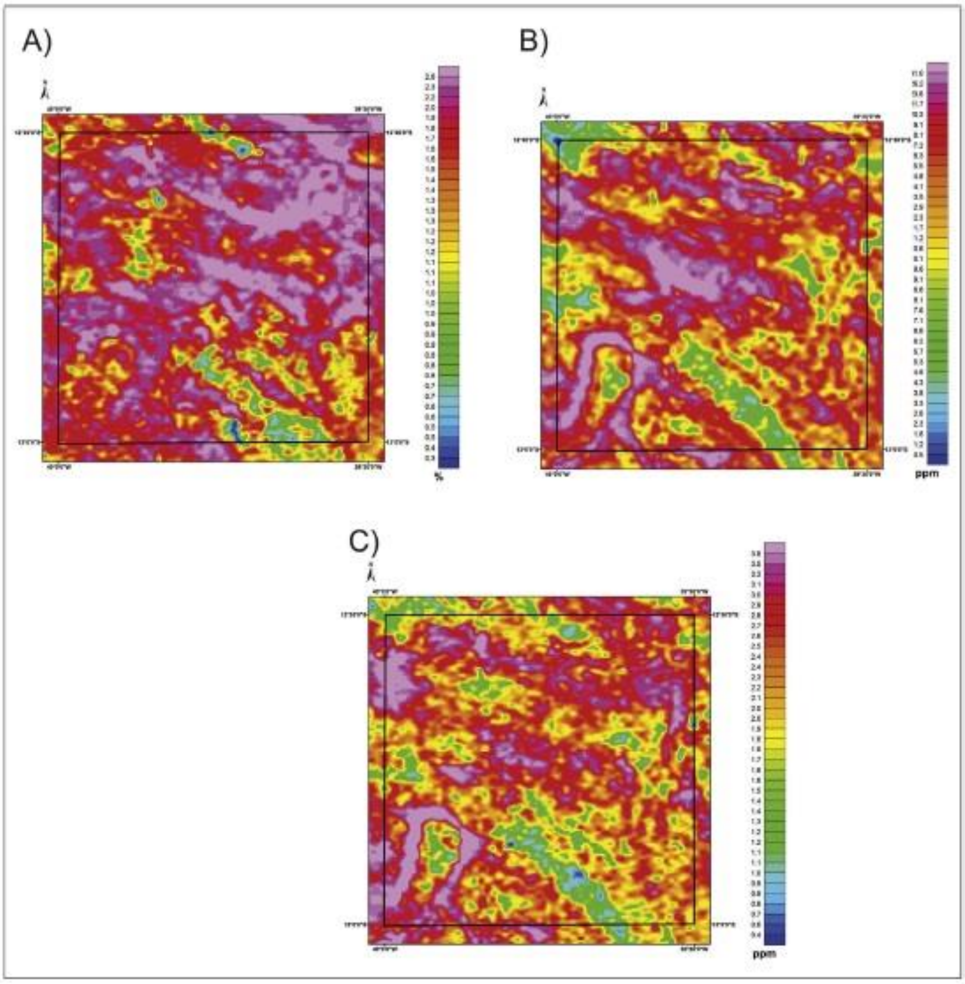

Fig. 7. Gamma-ray spectrometry airborne geophysical maps of the Milagres region. (A) K channel; (B) eTh channel; and (C) eU channel.

5. Results of macroscopic, geophysical and structural data

5.1. Macroscopic aspects

The region studied is represented by rocks of the Jequié Complex and the Caraíba Complex, with intrusive rocks of the Itaberaba Intrusive Suite, which present various granitic compositions. The outcrops of this suite are commonly highlighted by the relief, forming some of the inselbergs that predominate in the region. Detrital-lateritic colluvial deposits are found across the entire area, with deposits being more expressive in the southeastern portion of the chart (Fig. 5).

5.1.1. Jequié Complex (JC)

In the study area, the Jequié Complex is represented by orthoderived granulites classified by Nunes and Melo (2007) as enderbites, charnoenderbites, and charnockites. Paraderived granulites are found subordinately.

These rocks are meso-to leucocratic and present medium to coarse texture, rarely fine, and centimetric gneissic banding parallel to the regional deformation (Fig. 6a). The following features can be found in some outcrops: (i) mafic enclaves parallel to foliation; (ii) millimetric quartz veins discordant to foliation; and (iii) centimetric quartz veins concordant to foliation. These rocks commonly present signs of retrometamorphism, and often present mesopertite as the characteristic mineral of the granulite facies, since they do not always present orthopyroxenes in their composition. Several outcrops present porphyritic texture, with mesopertite as porphyries, often centimetric, and mylonitized levels (Fig. 6a). They present metasomatic alteration borders at the contact points with intrusive granitoids.

5.1.2. Caraíba Complex (CC)

The lithotypes of the Caraíba Complex are very similar to the rocks of JC because they are composed of charnockite and enderbite granulites. They predominantly present gneissic structure, and can also occur as migmatite, presenting thinly segregated leucosomes and melanosomes (Fig. 6b). They are grayish and present grain sizes ranging from medium to coarse, predominantly composed of plagioclase, mesopertite, quartz, biotite, and orthopyroxene. K-feldspar either occurs

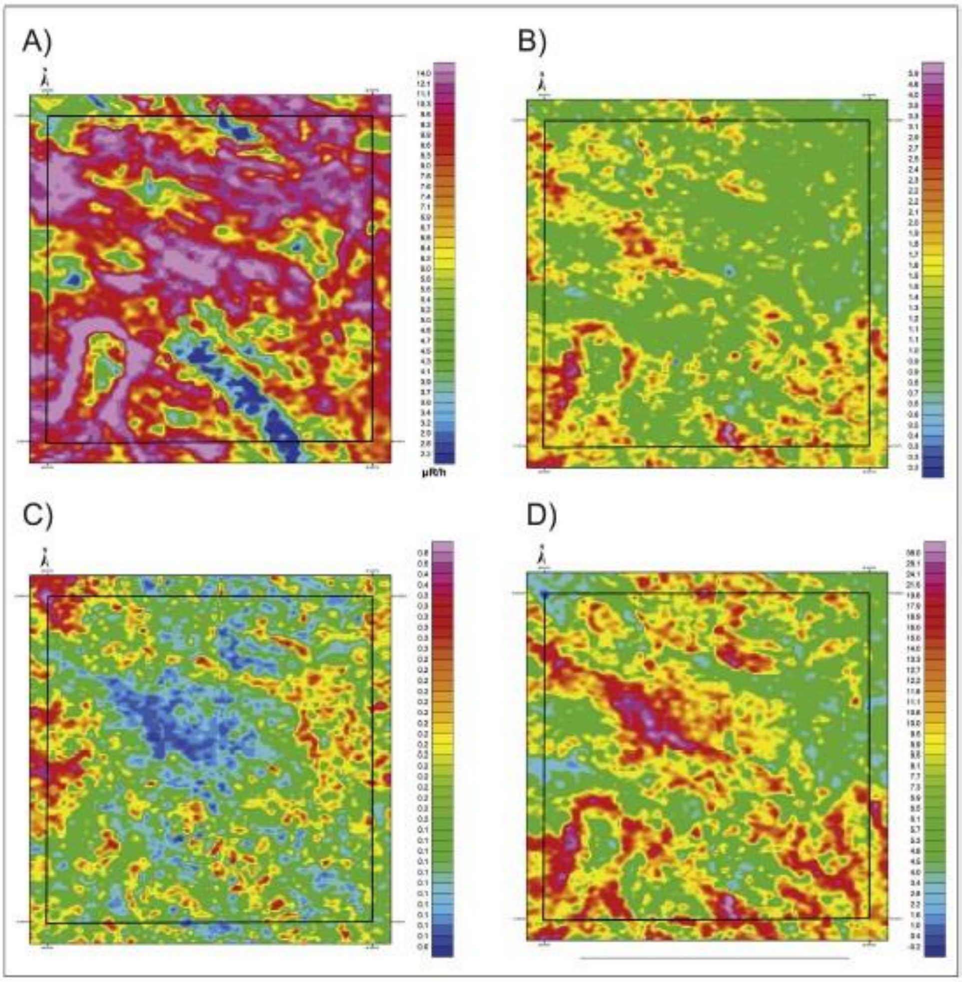

Fig. 8. Gamma-ray spectrometry airborne geophysical maps of the Milagres region. (A) Total count; (B) U/K ratio; (C) U/Th ratio; and (D) Th/K ratio.

subordinately or is not present in the rocks. Magnetite is sometimes present as a possible product of hydrothermal fluids.

The rocks of CC range from meso-to leucocratic, with centimetric to decametric gneissic banding thickness, similar to the deformation observed all over JB, however with varying directions.

The following features were observed in some outcrops: (i) mafic enclaves parallel to foliation; (ii) pegmatite veins with medium to coarse grain size, and predominantly composed of plagioclase and quartz (Fig. 6c), sometimes presenting magnetite; and (iii) quartz veins. Quartz veins can be observed both discordantly and concordantly in relation to foliation. The discordant ones mainly present NE-SW direction. Rocks occasionally presented porphyritic structure, with feldspar porphyries (either plagioclase or mesopertite).

5.1.3. Intrusive rocks

In the context of ISCB, there is a large incidence of positive relief, comprising rolling hills, ridges, and typical inselberg regions. A significant increase in the correlation between these inselbergs and intrusive rocks of the region was observed in the central portion of the study area. However, not all positive geomorphological features consist of magmatic rocks, since some of these inselbergs are composed of gneissified and/or migmatized granulitic rocks.

In order to individualize these intrusive rocks, a correlation was made between the outcrops, where these rocks were found and described, and the relief and geophysical images in order to identify the extension of these lithotypes.

The outcrops visited allowed classifying the rocks as monzogranites with phaneritic, inequigranular structure, presenting medium to coarse grain size (Fig. 6d), composed of plagioclase, quartz, potassium feldspar, and biotite, sometimes presenting garnet and magnetite. They presented various degrees of deformation and were classified in the present study as having a syn to late tectonic setting. More deformed outcrops presented foliation mainly characterized by the orientation of biotite (Fig. 6e), in which structures related to grain rotation were difficult to identify.

The foliation directions of these rocks, when observable, presented a similar pattern to that of the regional distribution, with a main NW-SE direction and a mild WNW-ESE trend in some outcrops, presenting a

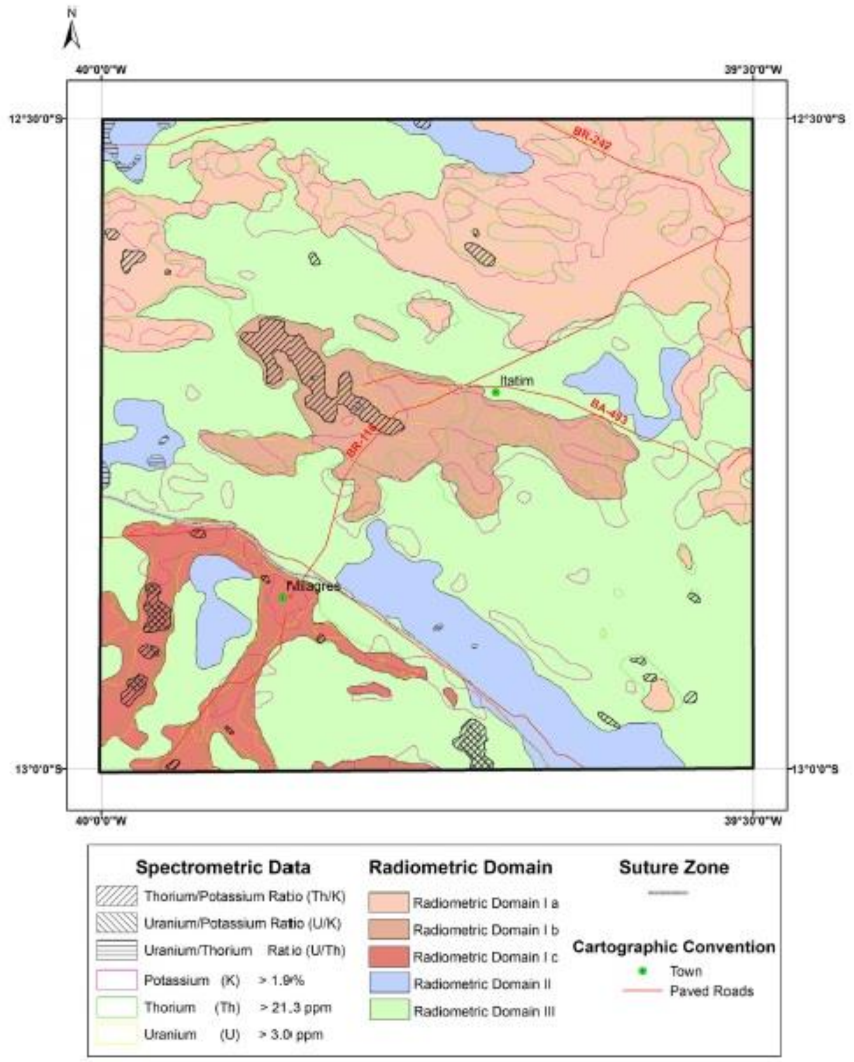

Fig. 9. Gamma-ray spectrometry data interpretation map of the Milagres region.

low to medium-angle dip (between 20 and 60°).

5.2. Airborne geophysical maps

Airborne geophysical maps were used in the present study to assist in marking the limits of the Jequié and Itabuna-Salvador-Curaçá blocks and, consequently, the suture zone. To do so, gamma-ray spectrometry and magnetic methods were used. These maps allowed the observation, in mega-scale, of the structural response from rocks that occur in the study region and, consequently, from part of the central portion of SFC. Different geophysical zones and domains were delimited based on individualizations of anomaly patterns and structural behavior, which helped in geologic mapping and identification of block limits.

5.2.1. Analysis of gamma-ray spectrometry maps

The concentration of radioisotopes K and U in the study region was, in general, within the average patterns of crustal rocks suggested by Killen (1979) and Dickson and Scott (1997): 2–2.5% K and 2–3 ppm U. The values of K, in the Milagres chart, ranged between 0.4 and 2.6%, with a predominance of values between 2.0 and 2.6%. In turn, the values of U were between 0.7 and 3.8 ppm, with high occurrences of variations between 2.6 and 3.8 ppm. Regarding the content of Th, the study area showed values higher than the variation between 8 and 12 ppm suggested by Killen (1979) and Dickson and Scott (1997), reaching values between 4.8 and 31 ppm, with most common occurrences between 20.3 and 31 ppm. These values are represented individually (Fig. 7A, B and C) and together in the total gamma-ray spectrometry count map (Fig. 8A).

According to these data, a large portion of the study area is

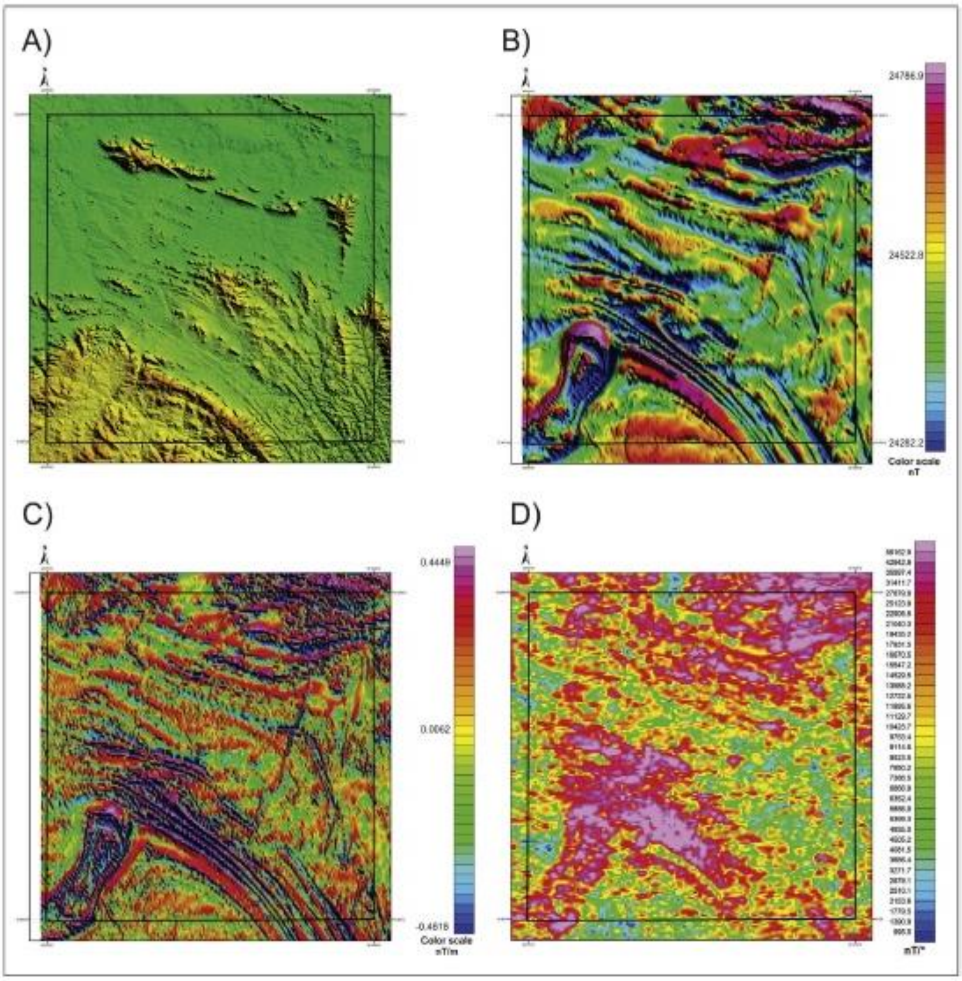

Fig. 10. (A) Digital terrain model map; (B) Total magnetic field intensity map; (C) Magnetic field first vertical derivative map; and (D) Analytical signal amplitude map.

represented by high values of radiometric elements and, since the content of potassium was within the average crustal values, ultrapotassic rocks are unlikely to occur. Combined with this, the strong anomalies of thorium indicate that there is a high occurrence of granitic rocks in the region and, because uranium values did not present negative anomalies, these rocks present a low degree of weathering, given that this element is more intensely weathered.

Fig. 8B, C, and D represent the maps of the U/K, U/Th, and Th/K radiometric ratios, respectively. They show that the highest radiometric activity in the area is due to thorium and uranium, the latter mainly occurring in the SW portion of the map. Thorium strongly predominates in the central portion, as indicated by the negative anomalies in U/Th ratios (Fig. 8C), and positive ones in Th/K ratios (Fig. 8D), considering that these are areas composed of charnockites. In turn, the low values obtained in the total count (Fig. 8A) can be associated with rocks with a less differentiated composition, forming enderbites.

The data analyzed from the maps in Fig. 7 along with K, U, and Th distribution maps (Fig. 7A, B and C) were integrated in order to interpret Fig. 9, where five radiometric domains were individualized (RD Ia, RD Ib, RD Ic, RD II, and RD III), and areas of positive anomalies of these elements were delimited. RD I comprises rocks with high contents of all three radiometric elements, therefore representing rocks with more differentiated and granitic composition. However, since there are a few individualities within these RD, they were separated onto three subdivisions, in which: RD Ia, represented on the northern portion of the map have high values of the radioelements but not of their ratios; RD Ib located on the central area also have high values of the radioelements individually, but also a large portion of Th/K ration anomaly, both of the domains also occur with a predominant NW-SE structure; RD Ic, located on the southwestern portion of the map, is represented by high values of the radioelements and by Th/K and U/K ratios, while also differing drastically in its structural direction, with a NE-SW direction. On the other hand, RD II comprises rocks with lower values in the gamma-ray spectrometry channels, associated with tonalites or enderbites. Finally, RD III comprises intermediate values.

The identification of these domains was not directly associated with

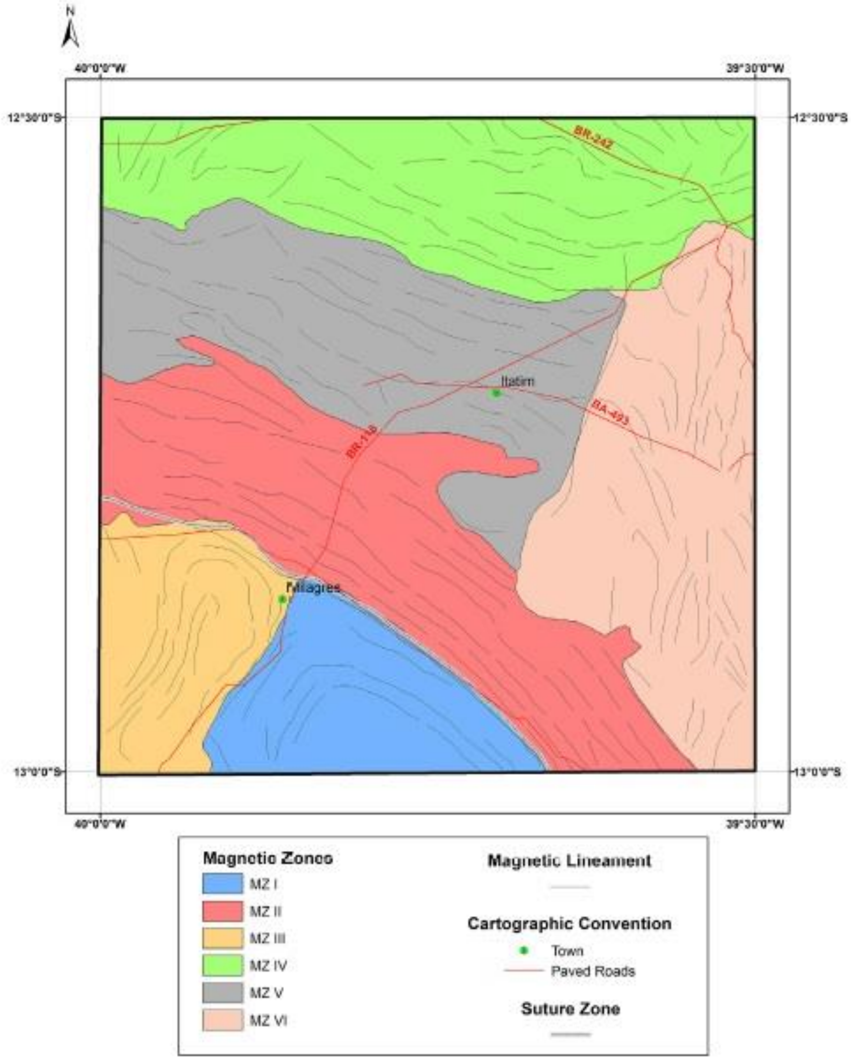

Fig. 11. Map showing the interpretation of magnetic zones and structural lineations derived from airborne geophysical magnetic data of the Milagres region.

portions of the crustal blocks that outcrop in the region due to compositional similarities among these blocks. However, these various domains occur with different stretching directions and structures, especially in the southern portion of the area, suggesting that the rocks found there present a unique rheological behavior. Therefore, the limit between JB and ISCB was interpreted in the present study as being between RD II and RD III, beginning in the SE and moving towards NW, between RD Ic and RD III (Fig. 9). Thus, the rocks that occur below this limit were associated with JB domains, and above it, with ISCB.

5.2.2. *Analysis of magnetic maps*

Magnetic maps were studied by using a total field intensity map (Fig. 10B), first vertical derivative (Fig. 10C), and amplitude of the analytical signal (Fig. 10D), assisted by a digital terrain model map (Fig. 10A). These were the maps provided by the CPRM digital data center, probably because the quality of data of the flight period wasn't enough to generate the magnetic anomaly map. These images are highly relevant and can be of assistance in geologic mapping efforts, especially when the first magnetic derivative map is analyzed (Fig. 10C). Structural behavior that is weaker in definition in radiometric maps is easily observed in these magnetic maps. Magnetic Zones (MZ) were individualized (Fig. 11) based on these products, considering mainly the predominant structural lineation directions originated from the anomalies represented in these images.

The main difference regarding magnetic behavior in the area occurs in the southern portion of the map, where there is a separation between the main NW-SE structuring (MZ II) and folded structures that vary in direction – NE-SW (MZ III) and NE-SW to NW-SE (MZ I). These results were therefore in accordance with the interpretation based on spectrometric maps, which placed the suture zone that separates the Jequié

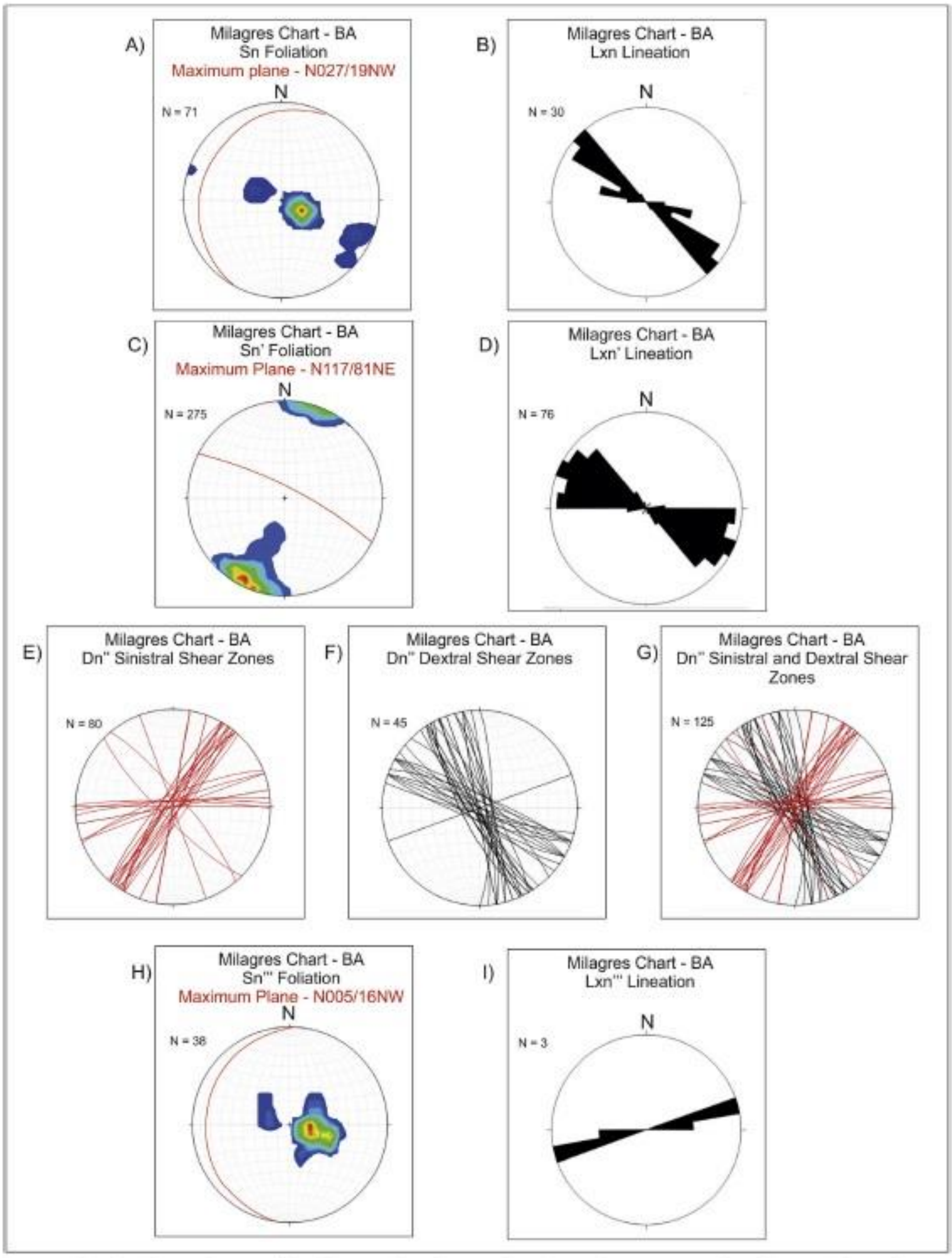

Fig. 12. (A, C, and H) Polar isodensity diagrams of the foliations in the study area. The maximum plane is represented in red. (B, D, and I) Rose diagrams for the mineral stretching lineations in the study area. (E, F, and G) Planar structure diagrams for sinistral (red) and dextral (black) shear zones. Lower hemisphere, N = Number of Measurements. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

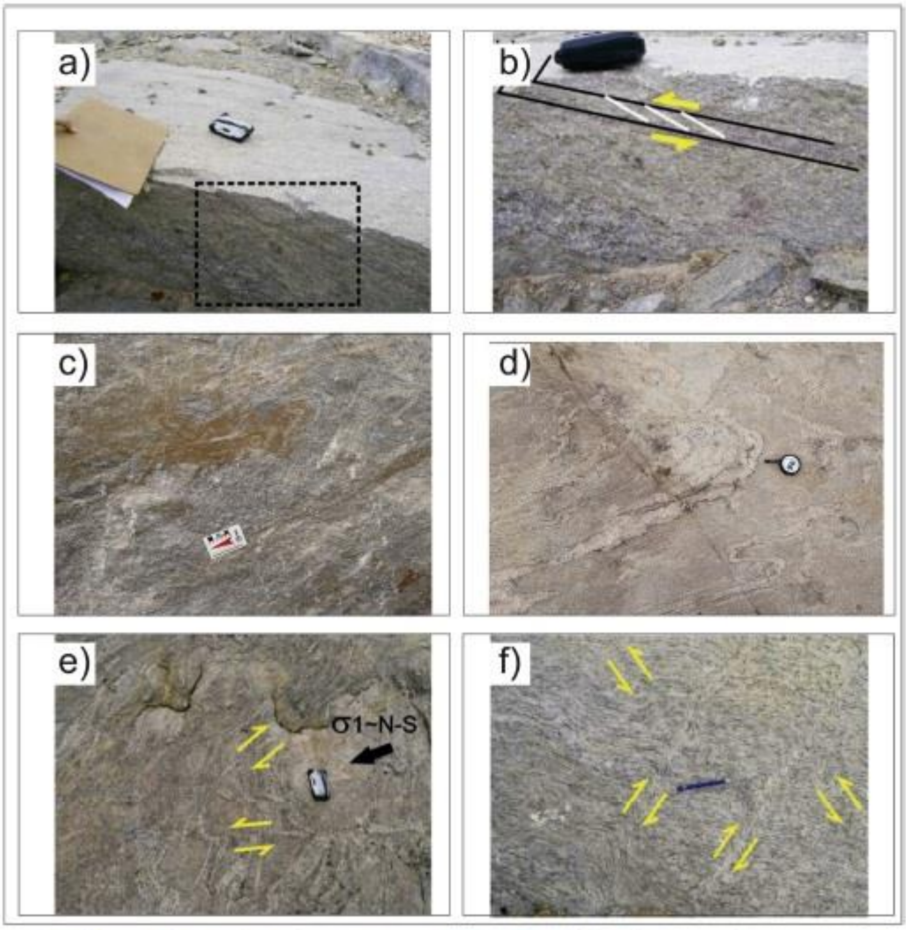

Fig. 13. (a) Low-angle Sn foliation with measured attitude N033/40SE. Source: Santiago (2010); (b) XZ plane showing the S/C structure representing a reverse movement. Source: Santiago (2010); (c) Mylonitic foliation of the rock highlighting the rootless intrafolial fold, a record of a deformational event that parallelized a previous structure in relation to the new flow plane; (d) Mylonitic foliation of the rock presenting asymmetric parasitic folds in M, W, S, and Z as a record of regional folds; (e) and (f) Shear zones in conjugated pairs representing Dn" deformation. They indicate an approximate N-S σ1 direction. Source: Santiago (2010).

and Itabuna-Salvador-Curaçá blocks between MZ II and MZ I + MZ III (Fig. 11), given that nearly the entire northern portion of the map presented structural behavior similar to MZ II, varying only in the intensity of magnetic anomalies (MZ IV and MZ V). Therefore, only MZ VI presented a different behavior from the others, with N-S structures, although it presents similar magnetic intensity to that of MZ V (Fig. 10B and C, and 11).

MZ II was considered in the present study as one of the most important zones in the region because of its structuring and strategic position for interpretations regarding the Suture Zone. The lineations of this zone, predominantly NW-SE oriented, that surround MZ I and MZ III in the southern and southwestern portions, respectively (Fig. 11), are visible in all three magnetic geophysical maps, and is more prominent in the first magnetic derivative map (Fig. 10C), where a high magnetic gradient was observed. This behavior can also be observed in the total magnetic field map (Fig. 10B), presenting again high dipolar magnetic contrasts and weak definition in the analytical signal map (Fig. 10D). The digital terrain model (Fig. 10A) also shows a large difference between the strongly positive reliefs of MZ I and MZ III, and the less accentuated ones of MZ II.

Fig. 10A also indicates the behavior of structural lineations in MZ VI, confirming the predominant N-S orientation. In turn, MZ IV and V present less accentuated relief, with small exceptions of higher altitudes, and structuring that is predominantly compatible with that observed in MZ I. This suggests that this entire region belongs to the same geotectonic domain, interpreted in the present study as ISCB.

5.3. Structures

The study area is composed of various types of ductile, brittle, and ductile-brittle structures that make the region highly complex to understand. The family of ductile structures is represented by foliations, folds, and mineral stretching lineations, while the brittle structures predominantly comprise fractures and pegmatitic or quartz veins. In turn, ductile-brittle structures occur as shear zones.

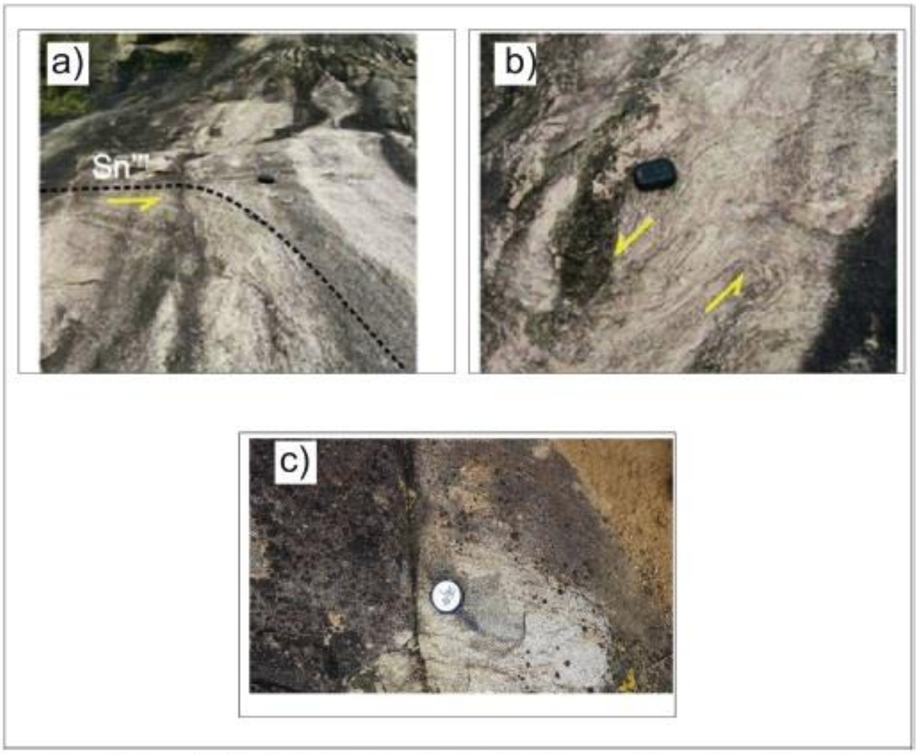

Fig. 14. (a) Representation of the low-angle Sn''' with drag folds that resulted from sinistral movement; (b) normal shear fold associated with the Dn''' phase, transposing the Sn'' foliation. Source: Santiago (2010); and (c) Rock of the Caraíba Complex presenting an unfilled fracture with a N020 direction.

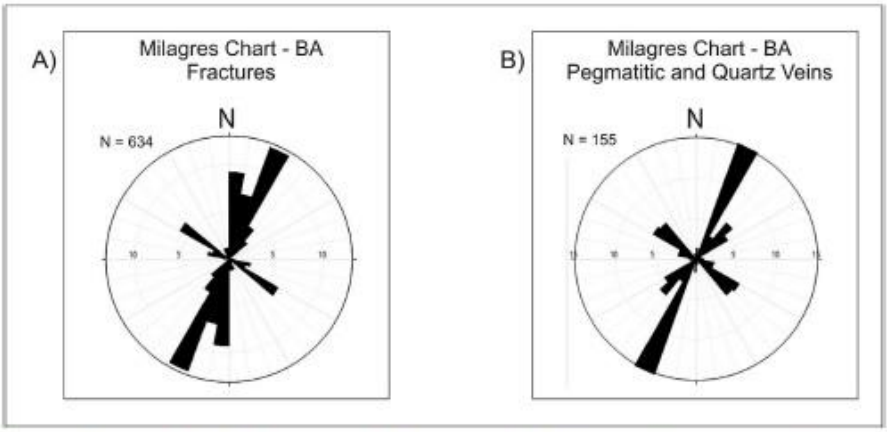

Fig. 15. Rose diagrams for brittle structures in the study area. (A) Fracture measurements; (B) Quartz and pegmatite vein measurements. Lower hemisphere, N = Number of Measurements.

5.3.1. Ductile structures

Ductile structures are predominantly marked by foliations characterized by preferential orientations particularly of minerals such as plagioclase, biotite, and quartz. They were hierarchized according to the interaction of both plane directions and the interaction with their mineral stretching lineations, therefore associating the nomenclature Sn, Sn', Sn''' with surfaces generated, and Lxn, Lxn', and Lxn''' with lineations.

Sn foliation has a predominantly NE-SW direction and represents the first deformation phase (Dn). It presents low-angle dips mainly towards NW (Fig. 13a), and maximum plane of N027/19NW (Fig. 12A). Lxn mineral stretching lineations are present in this plane and have an

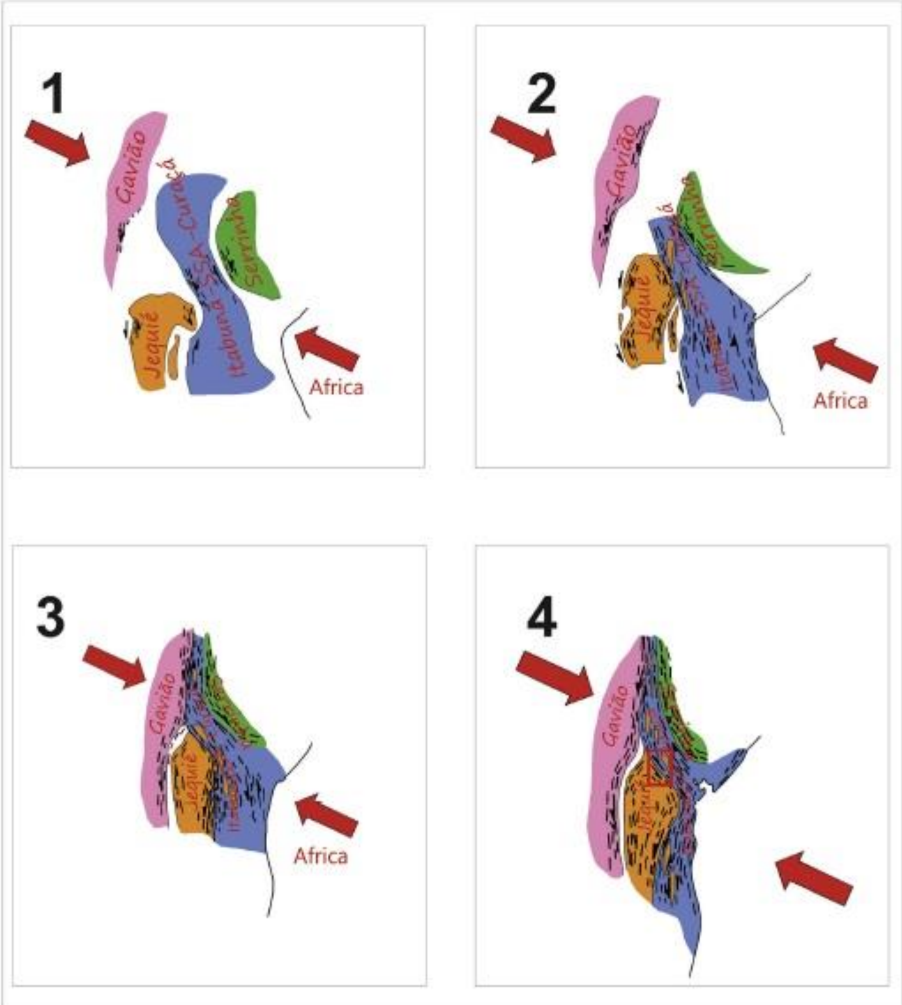

Fig. 16. Evolution model of the Paleoproterozoic collision responsible for the agglutination of the blocks that compose the São Francisco Craton. The figure shows how ISCB is more curved in its central-northern portion due to its collision with JB. The study area is highlighted by a red rectangle in stage 4. Source: Modified from Barbosa et al. (2012). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

orthogonal direction in relation to the Sn plane, maximum concentration of 24° Az305 (Fig. 12B), and reverse apparent kinematics, shown by a S/C structure (Fig. 13b).

The Sn′ foliation is the main type observed in the study area, composing the Dn′ phase. It is a penetrative well-defined foliation mainly observed through the alignment of biotite, but sometimes also of plagioclase and quartz. This foliation occurs varying between finely segregated to well-defined bandings. It is spaced, disjunctive, discontinuous, and parallel, sometimes presenting migmatitic aspects (Fig. 6a and b). Sn′ occurs as a planar structure that obliterated a previous foliation, becoming parallel to what is now the main foliation of the region, with rootless intrafolial folds as evidence (Fig. 13c). This foliation presents a main NW-SE structuring that predominates in the area and is identifiable in gamma-ray spectrometry airborne geophysical maps (Figs. 7 and 8), and even more expressively in magnetic maps (Fig. 10), presenting maximum plane of N178/81NE (Fig. 12C). Lineations are parallel to the foliation plane, presenting low angles and maximum concentration of 18° Az285 (Fig. 12D). They present dextral apparent kinematic movement, characterized by asymmetric folds and S/C relationships.

The dips of the planes vary towards north and south, which promotes folded structures varying between normal synforms and antiforms or presenting inverted limbs. Asymmetric parasitic folds in M, W, S or Z usually occur as fractals of these folds (Fig. 13d).

After these foliation planes formed, a ductile-brittle deformation associated with a Dn″ phase took place, represented by a conjugated pair of subvertical shear zones (Fig. 13e and f), with dextral zones presenting a main NW-SE orientation, and sinistral zones with a main NE-SW orientation (Fig. 12E, F and G).

A third foliation pattern was identified in the study area. It was

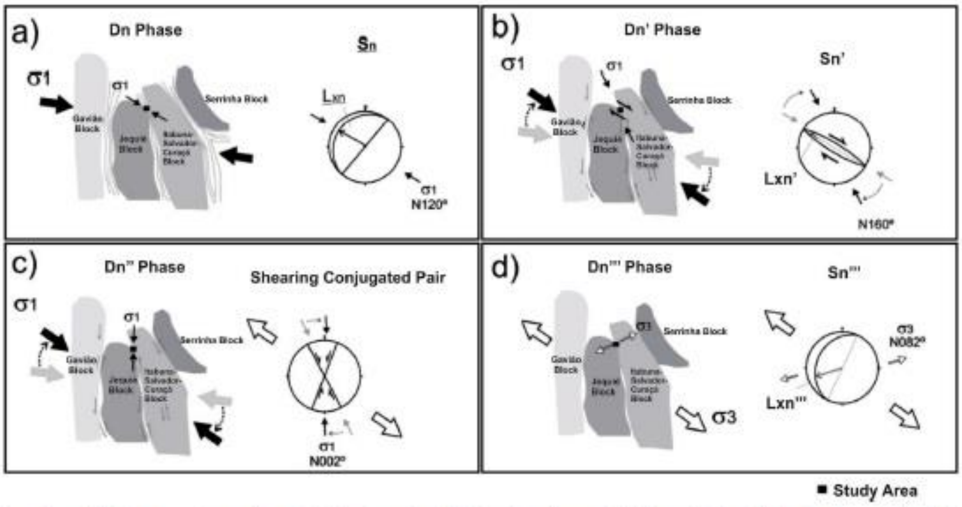

Fig. 17. Schematic model of the stress tensors that acted during the regional deformation phases, and their association with the structures described in the present study: (a) Dn; (b) Dn'; (c) Dn''; and (d) Dn'''. The rotation of the main σ1 paleo-stress tensors occurred progressively from (a) to (c). Small black arrows represent local comprehensive stress tensors, while gray ones are the local extensive stress tensors. Large same-colored arrows represent the regional stress tensors obtained by Sabaté (1996) and Corrêa-Gomes et al. (2005). Source: adapted from Santiago (2010).

called Sn''' and was associated with the Dn''' phase. These foliations present a predominant NE-SW plane direction, and maximum measured plane of N005/16NW (Fig. 10H). Its Lxn''' mineral stretching lineation is orthogonal to the foliation plane, with maximum concentration of 12° Az250 (Fig. 10I) and is characterized as high rake. These lineations result from normal-sinistral movement and are visible from drag folds (Fig. 14a and b).

5.3.2. Brittle structures

Brittle structures are observed in the study area mainly through fractures (Fig. 14c) that present a predominant NE-SW direction (Fig. 15A). However, they are also observed through quartz- or pegmatite-filled veins (Fig. 6c), also presenting a main NE-SW direction (Fig. 15B).

6. Discussions

6.1. Geologic mapping

As discussed in section 4, the study area presents high geologic complexity regarding its mineralogical macroscopic and structural context. Lithotype mapping and individualization were conducted using airborne geophysical images seeking to systematically integrate the methods applied for this purpose. The area of occurrence of JC could thus be redefined, pushing its limit further south, as opposed to where it was previously proposed by Nunes and Melo (2007).

As seen in section 5.1, JC comprises rocks with granite-granodiorite-tonalite composition that were metamorphosed within the granulite facies. They occur in the southern portion of the study area and were mainly identified as the magnetic zones I and II shown in the interpretation of magnetic maps (Fig. 11). The structural behavior in the central-northern portion of the area, where a folded structure and main foliation direction of N-S are observed particularly in the SW portion, is completely different from the predominant foliation of the rest of the area. In addition, this region also presents radiometric anomalies that stand out in relation to the rest of the area, as observed in the interpretation of spectrometric maps (Fig. 9). The nucleus of this SW portion, which presents lower-intensity radiometric and magnetic anomalies (Figs. 7, 8 and 10), was interpreted in the present study as being composed of enderbites, while its limits, which presented higher intensity in those maps, are composed of charnockites.

Although CC was macroscopically very similar to JC, since it is also composed of charnockites-charnoenderbites-enderbites, it presents structures and geophysical anomalies different from those observed in JC and could be associated with magnetic zones MZ II, IV, V, and VI (Fig. 11). However, specific mineralogical control justifying such anomaly patterns between radiometric domains was not observed (Fig. 9).

Mild positive anomalies in Th/K ratios occurred in the SE portion of the map (Fig. 8D), which are the result of colluvial deposits due to lower lixiviation of thorium. This interpretation was confirmed in the field during the geologic mapping. This was associated with darker portions in the total count gamma-ray spectrometry map (Fig. 8A) that refer to enderbites and charnoenderbites. These rocks can also be observed in the interpretation of magnetic maps as MZ II (Fig. 11). The central portion of the map was associated with charnockites due to the high concentration of radioisotopes (Fig. 8A) and magnetic anomalies with varying intermediate contents (Fig. 10).

However, this complex is mainly identifiable due to its structural behavior that, as previously mentioned, is significantly different from that observed in the lithotype classified as JC, presenting structural lineations mainly oriented according to an NW-SE direction, especially in the southern portion, near the contact zone between both complexes. The eastern portion of this unit presents different structuring compared with the overall pattern, with a preferential N-S direction and identified in the magnetic interpretation as MZ VI. However, regarding compositional responses, the eastern portion does not seem different from the central one. Therefore, only one difference in rheological response was interpreted in this region. The folds observed in CC are either normal synforms and antiforms or present an inverted limb. They did not show evidences of later refolding.

The rocks that compose the intrusive granitoids are mainly monzogranites with weak to inexistent deformation compatible with those observed in CC, lithotype in which they are intruded. Initially, the high

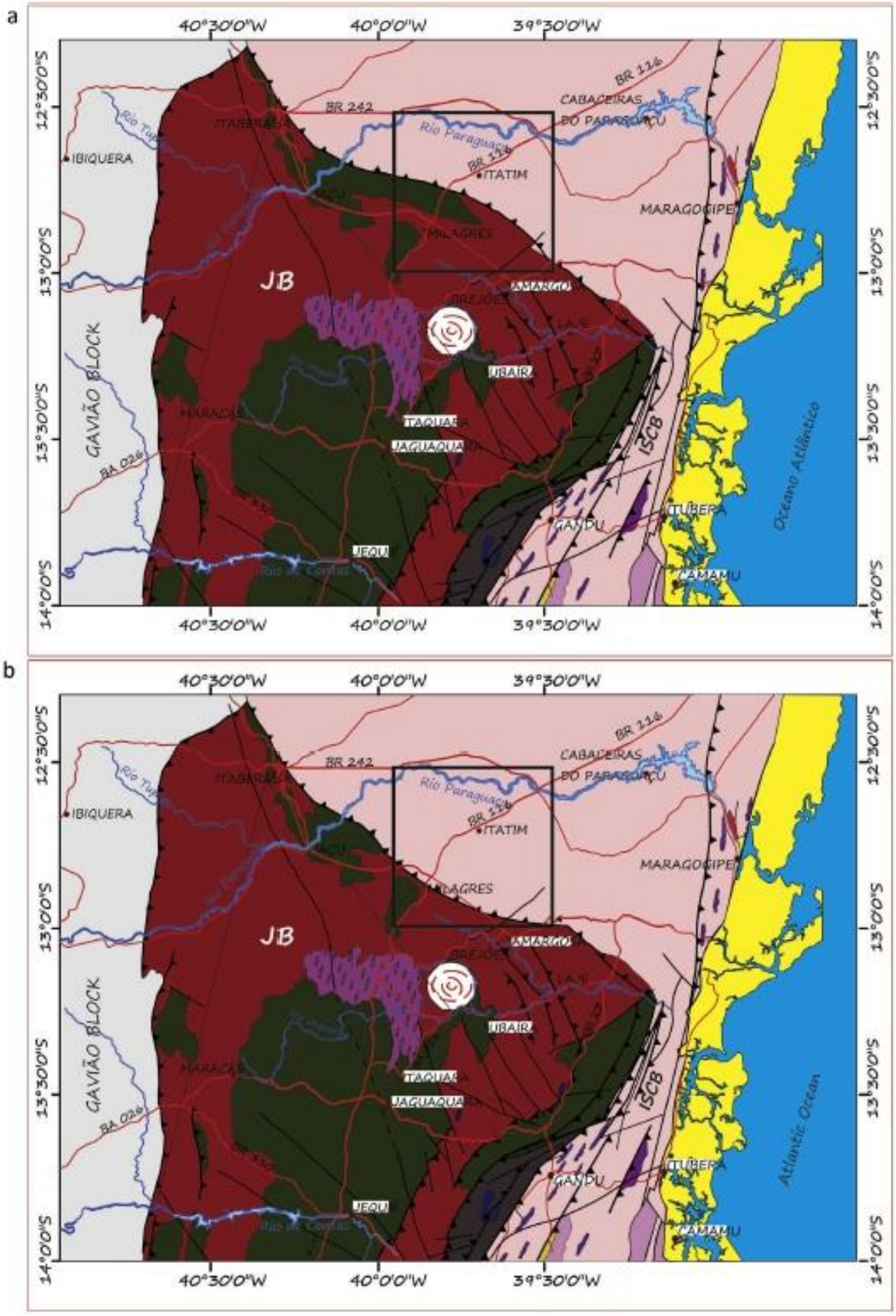

Fig. 18. Comparison between (a) the previous and (b) the new position of the suture zone between ISCB and JB proposed in the present study. Source: modified from Barbosa et al. (2012).

occurrence of inselbergs in the region was thought to be related to these intrusive bodies. However, this hypothesis was not corroborated in field campaigns, since a large portion of these positive reliefs is composed of rocks from either CC or JC. The use of airborne geophysical maps was extremely important to identify the limits of these bodies, especially the gamma-ray spectrometry maps (Figs. 7 and 8), since the rocks with this composition would probably be represented by pinkish anomalies in the map. However, similarities between the composition of granites and charnockites hampered the use of this method in the identification of these intrusive bodies. Thus, a correlative methodology using field descriptions and anomalies was adopted to delimit them. Therefore, only the intrusive bodies described in the field were individualized in the present study.

6.2. Tectonic evolution

The evolution of the deformation in the study area is considered mainly to have originated from Paleoproterozoic tectonics, and was interpreted in the present study as a progressive deformation process subdivided into four stages, ranging from ductile to ductile/brittle to, finally, exclusively brittle.

The first phase (Dn) was responsible for the generation of the Sn foliation with an orthogonal Lxn to the plane (Fig. 12A and B). This indicates dip-slip reverse kinematics, with a SE dip, therefore resulting from the beginning of the collision between the blocks.

The second deformation phase, also ductile, was more penetrative and responsible for the generation of an Sn' surface, which is the most easily observed foliation in the area, either using geophysical images (Figs. 7, 8 and 10) or during outcrop field visits. This phase presents a main NW-SE direction and strike-slip lineation (Lxn') parallel to the foliation plane (Fig. 12C and D), which resulted from a dextral shear associated with an evolution stage of collisional tectonics. Isoclinal folds and S/C structures occur associated with this phase. The dextral shear movement is associated with the geometry of the contact between blocks, locally resulting in an opposite movement to the regional one (Fig. 16 – stage 3).

The Dn" phase is the result of regional stress tensor rotation towards an N-S direction and was responsible for ductile-brittle deformation, which produced conjugated pairs of sinistral and dextral shear zones (Fig. 12E, F, and G). This phase was identified as a more advanced stage of the collision.

The last phase of ductile deformation was classified as Dn‴, in which an extensional situation occurred as the result of orogen collapse. This was shown by low-angle NE-SW foliation (Sn‴) and gently tilted lineation (Lxn‴) (Fig. 12H and I), also orthogonal to the plane, presenting normal movement as the result of the trans-extensive vector due to the gravitational stress tensor of the mountain range. This phase was also responsible for normal shear fold structures and brittle structures that resulted from the trans-extension (Fig. 15A and B), which sometimes were filled by pegmatite- or quartz-enriched material.

7. Conclusions

The area studied is clearly a geologic environment characterized by a transpressional zone, mainly represented by reverse faults that resulted from the collision between the Itabuna-Salvador-Curaçá and Jequié blocks, causing the superposition of ISCB over JB. This collision is also characterized by possible calcium-alkaline magmatism responsible for the syn to late tectonic granitic intrusions, given that the intrusive rocks described in this study presented incipient deformation, mainly characterized by micaceous minerals and plagioclases, compatible with regional deformation.

The structural patterns suggest a progressive deformation which is characteristic in collisional zones, presenting evidence of four deformation stages, mainly interpreted by analyzing the relationship between foliation surfaces and mineral stretching lineations. Some of the deformation stages resulted from the rotation of stress tensors until the final structures of the orogen collapse (Fig. 17).

The combination of data obtained in the present study allowed to reinterpret the limits between ISCB and JB, as observed in the gamma-ray spectrometry and magnetic geophysical images (Figs. 9 and 11). It also allowed to re-evaluate the occurrence of intrusive calcium-alkaline rocks in the central area, and the regional lineations observed both in outcrops and in the first vertical derivative geophysical image.

Fig. 18a and b presents a comparison between the limits of the blocks mentioned above showing the current position of the suture zone and the suggestion made by the researchers involved in the present study in order to re-delimit these boundaries between JB and ISCB.

Such as Sampaio et al. (2017) achieved in the Valença Region, this paper aimed to contribute to the understanding of the evolution of the São Francisco Craton during the Paleoproterozoic and shows that airborne geophysical data may have large applications in Regional geology of the referred Craton, since it has yet a lot to develop until it is completely understood and its transition zones accurately delimited.

One important aspect of this result is its applicability for mineral exploitation, since the new setting may allow a more precise definition of target areas of possible minerals and mineralizing geologic processes.

Acknowledgements

The authors thank CPRM – Geological Survey of Brazil for the support towards this study by supplying geophysical data and images, and the Federal University of Bahia (UFBA) for having financed field activities. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

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CAPÍTULO 3

ARTIGO – GRANITOGÊNESE DA ZONA DE SUTURA ENTRE OS BLOCOS ITABUNA-SALVADOR-CURAÇÁ E JEQUIÉ, NA REGIÃO DE MILAGRES E IATIM, CRÁTON DO SÃO FRANCISCO, BAHIA, BRASIL: CORRELAÇÕES ENTRE OS DADOS PETROLÓGICOS.

Granitogênese da Zona de Sutura Entre os Blocos Itabuna-Salvador-Curaçá e Jequié, na Região de Milagres e Iatim, Cráton do São Francisco, Bahia, Brasil: Correlações Entre os Dados Petrológicos.

Granitegenesis of the Suture Zone Between Itabuna-Salvador-Curaçá and Jequié Blocks, in Milagres and Itatim Region, Within the São Francisco Craton, Bahia, Brazil: Correlations Between Petrological Data.

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Resumo. A área de estudo encontra-se localizada no limite entre dois blocos crustais que compõem o Cráton do São Francisco (CSF), os blocos Jequié (BJ) e Itabuna-Salvador-Curaçá (BISC). Este trabalho tem como objetivo principal identificar as características petrográficas e geoquímicas das rochas intrusivas que afloram nesta região, resultantes da colisão entre esses grandes blocos e desta forma contribuir com o conhecimento da evolução geotectônica que moldou essa região. Através da descrição petrográfica verificou-se que a mineralogia dos litotipos é composta principalmente por quartzo, feldspatos e micas, apresentando um baixo grau de deformação e feições de alterações deutéricas *tardi* magmaticas, principalmente envolvendo a biotita. Os estudos litogeoquímicos mostraram um contexto de rochas calcioalcalinas peraluminosas a metaluminosas com alto K, essencialmente graníticas e com visível fracionamento dos ETR_L em relação aos ETR_P. Utilizando dados de geocronologia U-Pb de estudos anteriores foi sugerida uma idade de intrusão em torno de 2,07-2,06 Ga (U-Pb em zircão), para essa Suíte.

Palavras-chave. Petrografia, Geoquímica, Cráton do São Francisco, Geologia.

Abstract. The study area is located between two crustal blocks that make up the São Francisco Craton (SFC), the Jequié (JB) and Itabuna-Salvador-Curaçá (ISCB) blocks. This work has as main objective to identify the petrographic and geochemical characteristics of the intrusive rocks that emerge in this region, resulting from the collision between these blocks and thus contribute to the knowledge of the geotectonic evolution that shaped this region. Through the petrographic description, it was verified that the lithology mineralogy is composed mainly of quartz, feldspars and micas, with low degree of deformation and with tardi magmatic messomatic alterations, mostly within the biotites. The lithogeochemical studies showed a context of high-K, peraluminous to metaluminous calc-alkaline rocks, commonly composed of granites and with evident fractionalization of light REE and heavy REE. The U-Pb geochronology bibliographic data suggests that the intrusive rocks were formed around 2.07-2.06 Ga

Keywords. Petrography, Geochemistry, São Francisco Craton, Geology.

1 Introdução

Estudos nos terrenos granulíticos do centro-leste da Bahia, região na qual se insere a área de pesquisa, têm possibilitado estabelecer a caracterização composicional dos produtos metamórficos, bem como a identificação dos protólitos, a determinação de idades, as condições termobarométricas de formação e como consequência, os ambientes do principal evento tectono-metamórfico que atingiu essas rochas. Estas pesquisas também sugerem modelos metalogenéticos ligados à evolução geológica do CSF.

A área de estudo desta pesquisa encontra-se no limite de dois segmentos crustais arqueanos a paleoproterozoicos constituintes do CSF: o Bloco Jequié (BJ) e o Bloco Itabuna-Salvador-Curaçá (BISC) (Figura 1) (Barbosa e Sabaté (2002, 2004)). Esses autores sugerem, para esta área, uma zona de subdução na parte mais oriental do Cinturão Itabuna-Salvador-Curaçá (CISC) e um arco de ilha insular precoce.

O presente trabalho objetiva principalmente a caracterização petrográfica e geoquímica da granitogênese da zona de sutura entre o BISC e o BJ, na região de Itatim e Milagres, e correlação com outros dados petrológicos existentes na literatura.

2 Localização da área de estudo

O Cráton do São Francisco (CSF) (Figura 1A) representa uma das unidades geotectônicas mais importantes do continente Sul-americano, posicionado na porção leste da plataforma homônima e no centro-leste do território brasileiro (Almeida, 1977). O CSF é moldado e limitado por faixas de dobramentos e cavalgamentos neoproterozoicas denominadas: Riacho do Pontal, ao norte, Brasília a oeste, Rio Preto, a noroeste, Araçuaí a sul e a Sergipana a nordeste e cuja maior extensão aflorante de seu embasamento está localizada no estado da Bahia (Figura 1B).

A presente pesquisa foi realizada especificamente no centro leste do estado da Bahia, nos arredores dos municípios de Milagres e Itatim, inseridos na folha Milagres (SD-24-V-B-V) (Figura 2B). O acesso principal é realizado a partir de Salvador, capital do estado, através da BR-324 até o município de Feira de Santana, seguido da BR-116 até a cidade de Milagres (Figura 2B), principal município da folha estudada, totalizando cerca de 240 km de deslocamento.

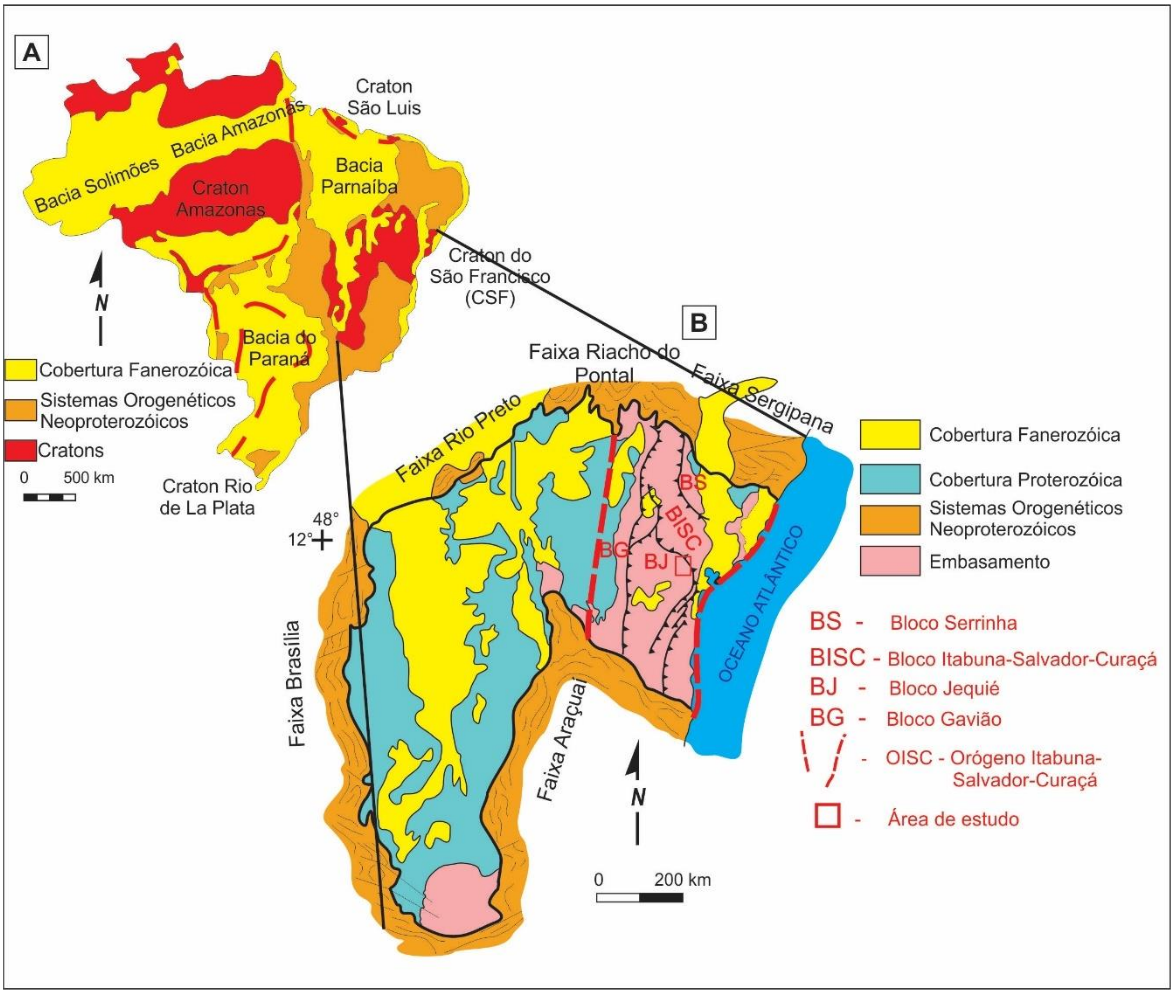

Figura 1 – (A) Principais crátons e sistemas orogenéticos neoproterozoicos do território brasileiro; e (B) Mapa geológico simplificado do CSF. Fonte: Modificado de Barbosa et al (2012).

3 Materiais e Métodos

Esta pesquisa baseou-se no estudo petrográfico e litogeoquímico das rochas aflorantes na zona de sutura entre Bloco Jequié (BJ) e o Bloco Itabuna-Salvador-Curaçá (BISC) (Teixeira de Souza et al., 2019), onde, a partir das amostras coletadas nos trabalhos de campo, foram confeccionadas 8 lâminas petrográficas e realizadas 8 análises litogeoquímicas de rocha total.

A confecção das lâminas petrográficas foi realizada no Laboratório de Laminação (LABAM) do Instituto de Geociências da Universidade de Brasília (UnB), enquanto que as análises litogeoquímicas foram realizadas pela ALS GLOBAL. A preparação das amostras baseia-se na britagem, quarteamento e posterior pulverização. A análise de 13 elementos maiores foi realizada após preparação por fusão com borato de lítio e determinação por espectrometria de emissão atômica (ICP-AES), os 38 elementos traço analisados foram preparados da mesma forma, mas analisados por espectrometria de massa (ICP-MS).

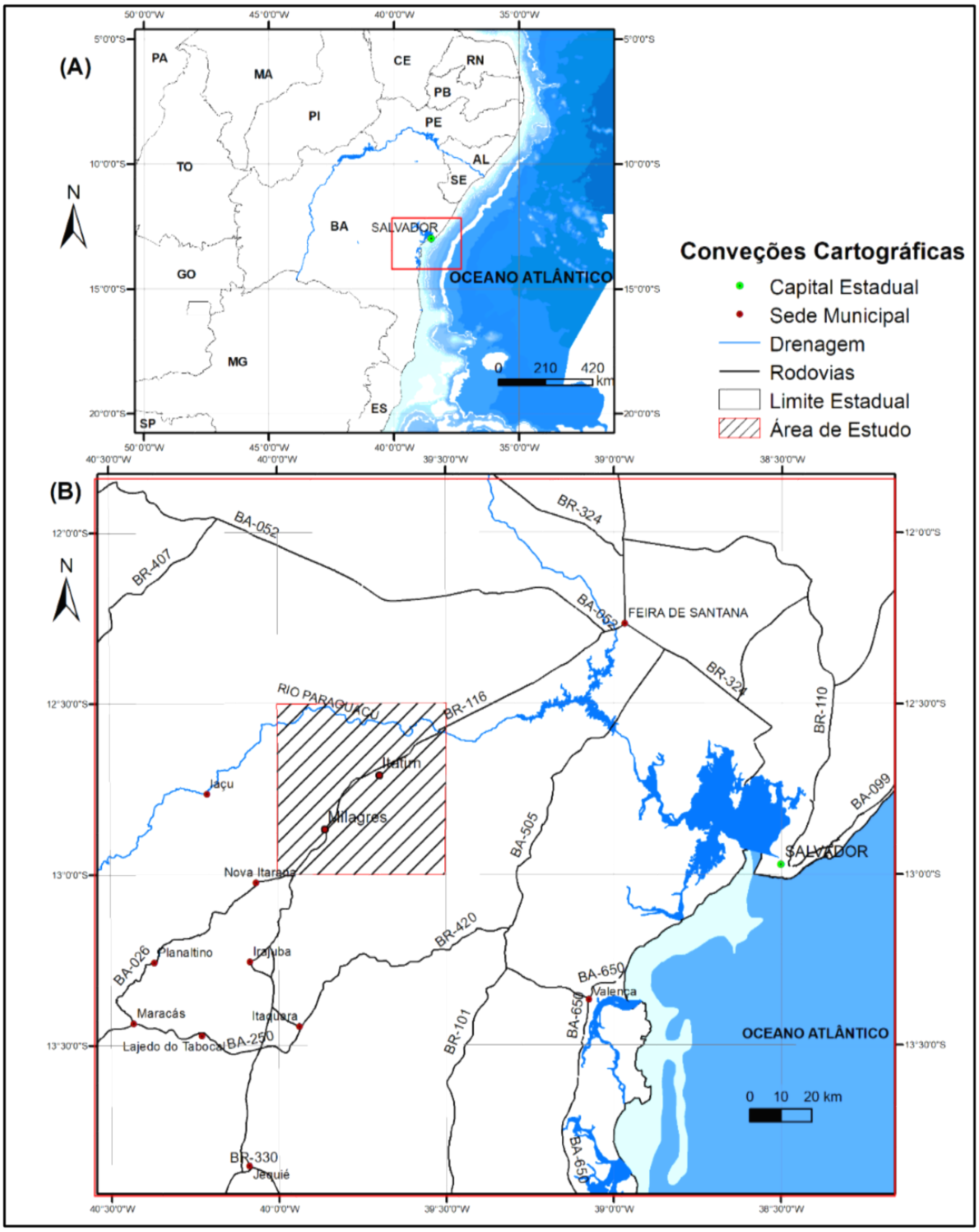

Figura 2 – Mapa de localização da área de estudo. A) Mapa de localização da área de estudo na região Nordeste do Brasil; e B) Localização no estado da Bahia, onde o polígono que marca a área de estudo representa a Folha Milagres (SD-24-V-B-V). Fonte: Teixeira de Souza et al. (2019).

Em uma etapa de escritório as lâminas petrográficas foram descritas no Laboratório de Petrografia da Universidade Federal do Oeste da Bahia (UFOB) utilizando miscroscópio de luz transmitida do tipo OLYMPUS BX41, onde foram observadas as paragêneses minerais, texturas e estruturas microscópicas das rochas. Os dados litogeoquímicos foram tratados utilizando os *softwares Microsoft Excel* e *GCDKit in R*.

4 Geologia Regional

A presente pesquisa foi realizada na zona de sutura entre dois dos principais segmentos crustais que compõem o Cráton do São Francisco (CSF), o Bloco Jequié (BJ) e o Bloco Itabuna-Salvador-Curaçá (BISC) (Figura 1), onde Teixeira de Souza et al. (2019) iniciaram o mapeamento geológico baseado em dados de campo, descrições macroscópicas e estruturais das rochas e complementando com estudos geofísicos. Nessa pesquisa, os citados autores conseguiram delimitar a zona de transição entre o BJ e o BISC (Figura 3).

Nunes e Melo (2007) classificam as rochas intrusivas da região de Itatim e Milagres como granitoides pós-tectônicos e indeformados. No entanto, Teixeira de Souza et al. (2019) identificou variados graus de deformação dessas rochas intrusivas e consequentemente, fizeram a sugestão de que fossem associadas com a Suíte Intrusiva Itaberaba. Teixeira de Souza et al. (2019) também classificam a área em tela como pertencente a um ambiente transpressivo com deformação evoluindo de estágios dúcteis a rúpteis, desde o início da colisão até o colapso do Orógeno.

De acordo com Teixeira (1997), Macedo (2006), Nunes e Melo (2007), Santiago (2010), Barbosa et al. (2012) e Teixeira de Souza et al. (2019), as rochas dos BISC e BJ se tratam de complexos granulíticos, principalmente ortoderivados, de composição charnockítica, charnoenderbítica e enderbítica. São rochas meso a leucocráticas de granulação média a grossa, bandamento gnáissico bem marcado e por vezes migmatizadas. Sua composição modal é representada principalmente por plagioclásio, feldspato mesopertítico, quartzo, biotita e ortopiroxênio, por vezes apresentando hornblenda e k-feldspato de forma subordinada. Alguns afloramentos podem apresentar feldspato mesopertítico como porfiroblastos, sendo comum a ocorrência de veios de quartzo tanto concordantes como discordantes da foliação principal destas rochas.

Esses blocos são de idade neoarqueana/paleoproterozoica, com datação U/Pb em zircão em torno de 2,7 Ga e idades modelo TDM Sm/Nd de 3,2Ga (Barbosa & Sabaté 2002, 2004; Macedo, 2006), para as rochas do BJ e idades próximas a 2,6 e 2,1 Ga para as rochas do BISC (Barbosa & Peucat, 2006). As rochas da Suíte Intrusiva Itaberaba (SII) são identificadas como sieno a monzogranitos levemente deformados de idade 2,1 Ga (método Rb-Sr) (Fernandes, 1991).

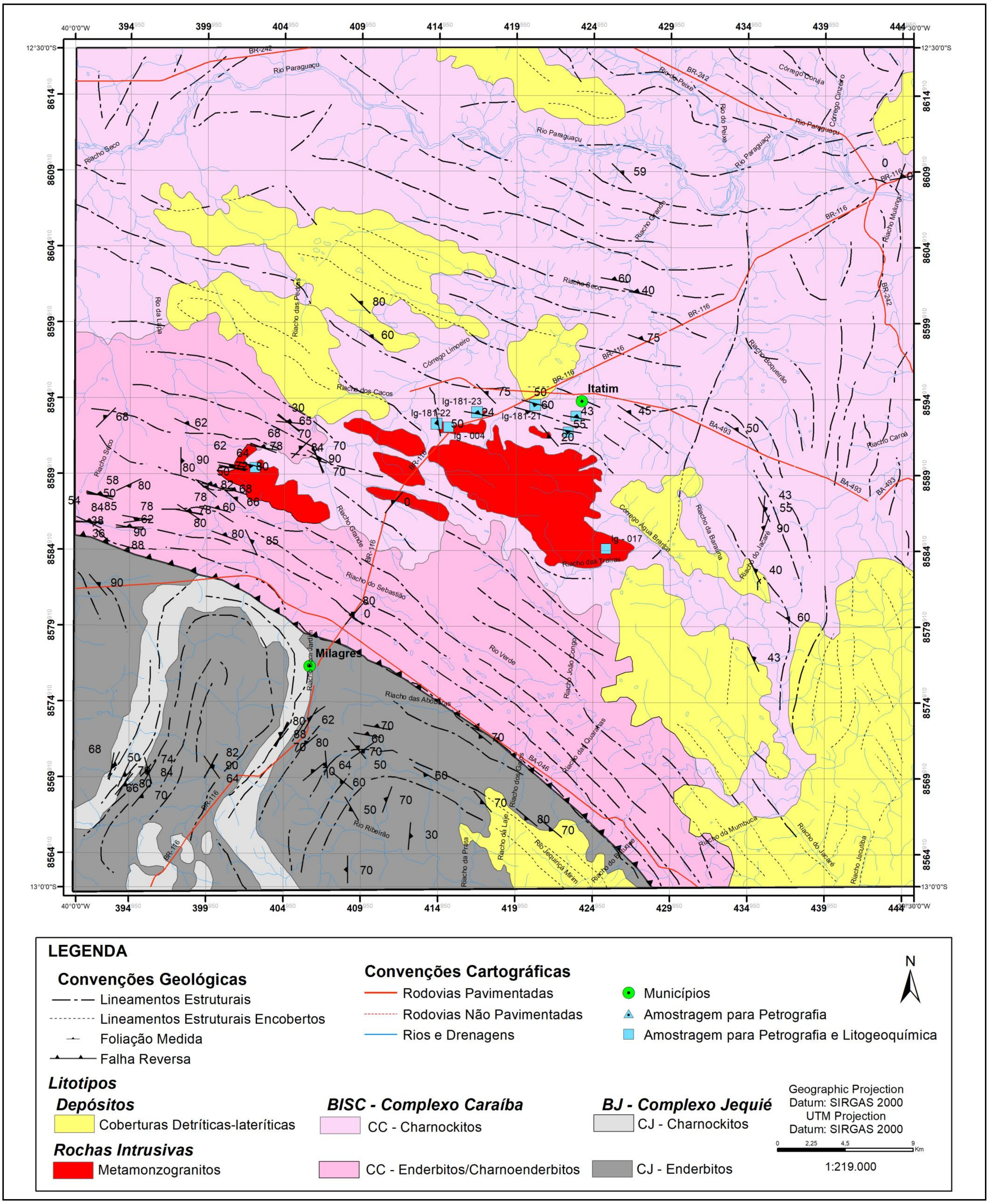

Figura 3 – Mapa geológico da porção central do CSF, na região de Itatim/Milagres, representativas à zona de sutura entre o BJ e o BISC. Fonte: Teixeira de Souza et al. (2019).

Trabalhos anteriores na região de Itatim e Milagres (Santiago, 2010) e em áreas adjacentes (Macedo, 2006; Santos, 2009; Queiroz, 2011; Souza, 2012; dentre outros) descrevem as rochas aflorantes como (i) granulitos heterogêneos migmatíticos, formado por rochas charnockíticas a charnoenderbíticas. A composição mineral principal desses granulitos envolve plagioclásio, mesopertita, quartzo, ortopiroxênio, biotita e anfibólio, podendo ou não conter granada, além de zircão, apatita e minerais opacos como acessórios.

Interpretações litogeoquímicas de Macedo (2006) e Queiroz (2011) sugerem que os granulitos charnockíticos-enderbíticos foram originados da cristalização fracionada de magma granítico/granodiorítico, cálcio-alcalino de intermediário K e que os domos charnockíticos, mapeados na região, foram resultado da fusão parcial de parte desses granulitos enderbíticos-charnockíticos mais antigos, recristalizados na fácies granulito em condições cumuláticas de alguns dos minerais constituintes do protólito, como plagioclásio e piroxênios.

Corrêa-Gomes et al., (2012) realizaram datações U-Pb (*Laser Ablation*-ICP-MS) na região de Itatim e a partir das diferenças de idades entre borda e centro dos zircões definiram que as rochas dessa área são representadas por protólitos arqueanos com idades entre 2,7 e 2,6 Ga (Figura 4a, b e c), referentes a análise das rochas do BISC (Complexo Caraíba), e são afetadas por marcantes eventos metamórficos Paleoproterozoicos entre 2,07 e 2,06 Ga (Figura 4c e d).

Esses dados se apresentam compatíveis com os encontrados por Barbosa & Sabaté (2002, 2004) e Peucat et al., (2011) tanto para as idades de cristalização (2,7-2,6 Ga) e de metamorfismo (2,07-2,06 Ga) e permitiram que esses autores realizassem a interpretação que o intervalo de tempo entre o pico do metamorfismo e colapso orogênico foi em torno de 30-40 Ma, indicando que os eventos de colisão dos blocos crustais na borda leste do CSF ocorreram de modo diacrônico. Outros estudos de estimativas geocronológicas relacionadas ao período de duração entre o pico do metamorfismo e o colapso orogenético que costuma marcar a estabilização do novo continente foram realizados por Fritz et al. (2013) e Rosas et al. (2008), no leste africano e na região de Portugal no sudoeste europeu, respectivamente. O Orógeno do Leste Africano, segundo Fritz et al. (2013) apresenta idade do pico do metamorfismo em torno de 650-620 Ma a 600-500 Ma e colapso orogenético por volta de 600-550 Ma e 550-480 Ma. No terreno de Portugal as idades registradas por Rosas et al. (2008) são de 380-370 Ma para o pico metamórfico e 365-310 Ma para o colapso. Esses trabalhos colocam um intervalo de aproximadamente 40 a 70 Ma entre o pico metamórfico e o colapso do orógeno.

Desta forma, o período entre colisão e colapso do Orógeno Itabuna-Salvador-Curaçá se apresenta compatível com outros exemplos mundiais.

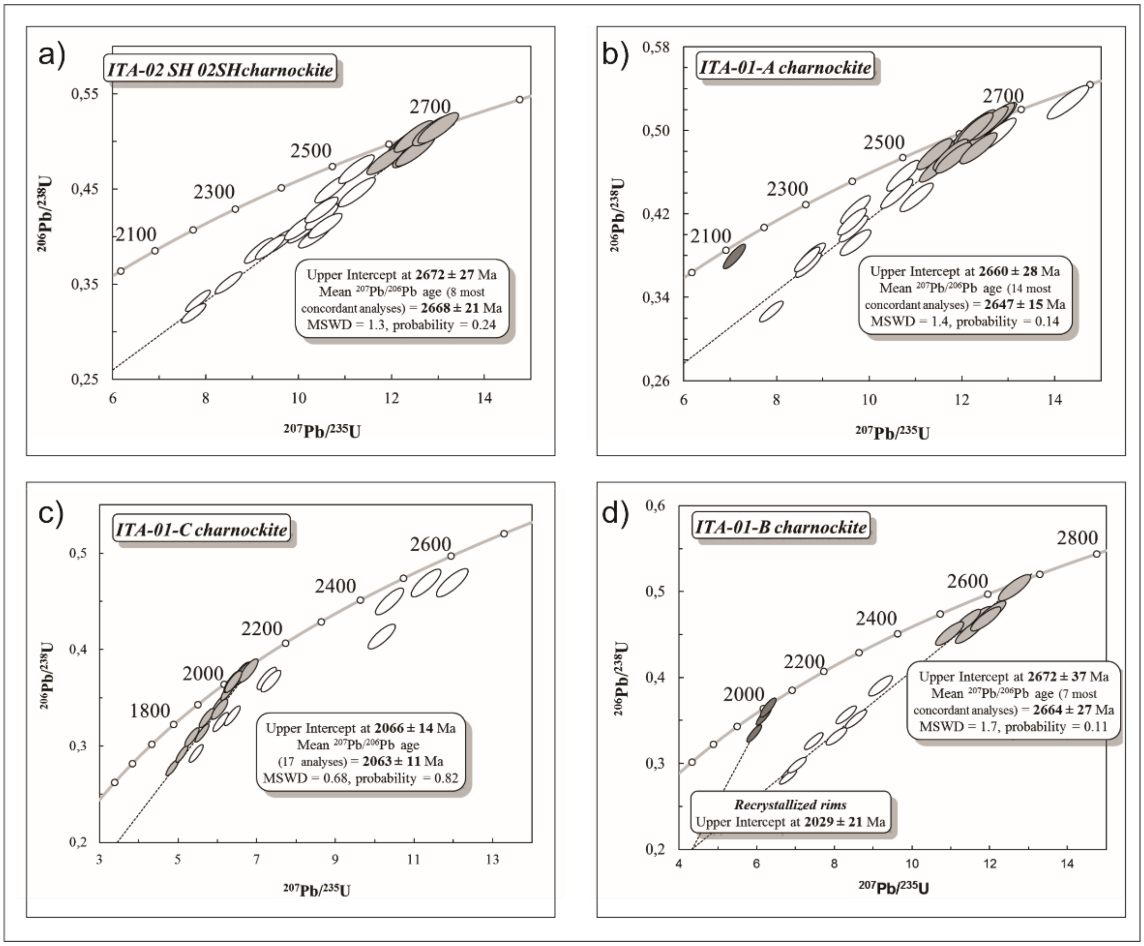

Figura 4 – Idades U-Pb para zircões de quatro amostras da região de Itatim/Milagres. (A), (B) e (C) idades de intercepto superior de análise dos núcleos; e (D) idade de intercepto superior de análise do núcleo e intercepto superior de análise da borda recristalizada. Fonte: Correa-Gomes et. al. (2012).

5 Resultados dos dados petrográficos e geoquímicos

As rochas desta suíte ocorrem distribuídas na porção central do Complexo Caraíba, representante do BISC na área de estudo (Figura 3) e são classificadas macroscopicamente como monzogranitos, leucocráticos, com texturas fanerítica, inequigranular, granulação média a grossa e composta por plagioclásio, quartzo, microclínio e biotita, raramente com granada. Apresentam foliação incipiente, marcada principalmente pela orientação da biotita, e são classificadas como *sin a tardi* tectônicas devido a essa deformação incipiente (Teixeira de Souza et al., 2019).

Microscopicamente essas rochas apresentam pouca mesopertita e ausência de minerais máficos como hornblenda e piroxênios, com maiores porcentagens de quartzo e k feldspato (Tabela 1). Sua análise modal confirma a classificação macroscópica realizada por Teixeira de Souza et al. (2019), identificando essas rochas como monzogranitos, com apenas uma amostra com maior porcentagem de feldspato alcalino e classificação como sienogranito (Figura 5). A deformação pode ser observada nas lâminas principalmente pela orientação das biotitas (Figura 8a), porém também pelas extinções ondulantes dos quartzos e feldspatos. Localmente também podem ser observados quartzos estirados formando planos (Figura 8a). Essas rochas se apresentam inequigranulares, com minerais variando de 0,1 a 7mm, com microestruturas granoblástica decussada, lepidoblástica, pertítica e poiquiloblástica (Figura 8b), com apatita, biotita, quartzo e minerais opacos como inclusões.

Alterações do tipo saussuritização e sericitização são comuns nos feldspatos, assim como a cloritização (Figura 8c) e moscovitização das biotitas (Figura 8d).

Amostra	Litotipo	Qz	Pl	Mp	Mc	Bt	Hbl	Opx	Cpx	Opq	Ms	Chl	Ep	Ap
Ig_004	SII	28	10	15	43	1				1	0,5	0,5		1
Ig_017	SII	34	19,5	30	15	0,2				0,2		0,3	0,3	0,5
Ig-181-16	SII	53		40		5				1		0,5	0,5	
Ig-181-17	SII	36	20	10	30	2,5				0,5	0,3	0,3	0,2	0,2
Ig-181-18	SII	47	25		17	9				1	0,3	0,3	0,2	0,2
Ig-181-21	SII	33	15	25	20	3				2		2		
Ig-181-22	SII	33,5	25		35	5				0,5	0,4		0,3	0,3
Ig-181-23	SII	35	25		32	5				0,5	0,5	1	0,5	0,5

Tabela 1 – Variação mineralógica modal (% volume) das rochas da Suíte Intrusiva Itaberaba (SII) da região de Milagres. Qz – Quartzo; Pl – Plagioclásio; Mp – Mesopertita; Mc – Microclínio; Bt – Biotita; Hbl – Hornblenda; Opx – Ortopiroxênio; Cpx – Clinopiroxênio; Opq – Minerais opacos; Ms – Moscovita; Chl – Clorita; Ep – Epidoto; Ap – Apatita. Abreviações segundo Whitney & Evans (2010).

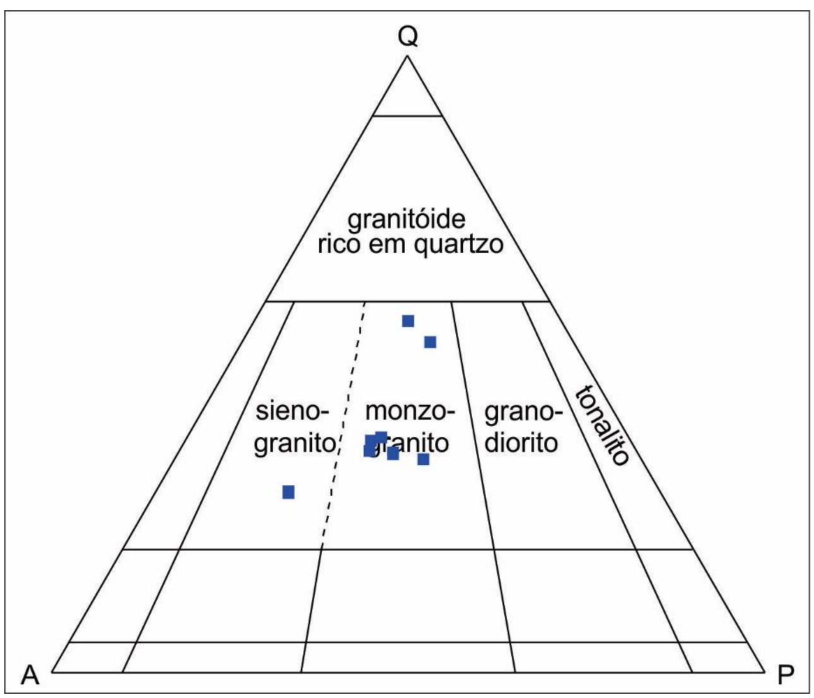

Figura 5 – Diagrama modal QAP (Streckeisen, 1976) para nomenclatura e classificação das rochas da Suíte Intrusiva Itaberaba.

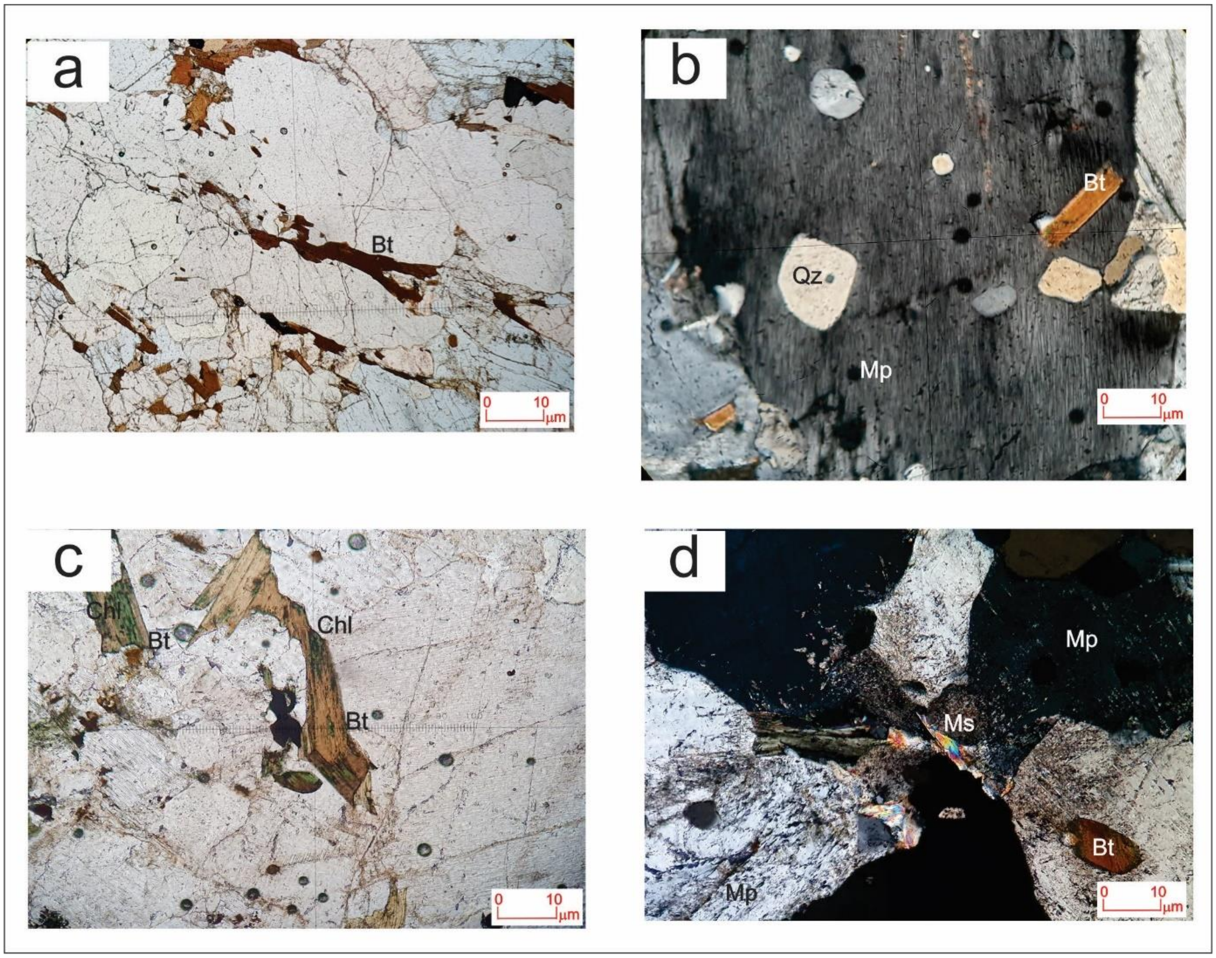

Figura 6 – Microestruturas nas rochas da SII. (a) Deformação incipiente marcada principalmente pela orientação dos cristais de biotita, marcando a textura lepidoblástica (Lp); (b) Textura poiquiloblástica marcada pela inclusão de cristais de quartzo e biotita em grande cristal de mesopertita (Nx); (c) Processo de cloritização da biotita (Lp); e, (d) Processo alteração da biotita para moscovita (Nx). Mp – Mesopertita, Bt – Biotita, Qz – Quartzo, Mc – Microclinio, Chl – Clorita, Ms – Moscovita.

5.2 Litogeoquímica

Como determinado na seção 3, as rochas intrusivas tiveram um total de oito análises litogeoquímicas, objetivando a classificação deste magmatismo ocorrente na zona de sutura entre os BJ e BISC no Cráton do São Francisco.

As análises deste litotipo se apresentam com valores de SiO_2 entre 69,6 e 74,6%, teores de Al_2O_3 variando entre 14,15 e 15,45%, o Fe_2O_3 varia de 1,57 a 3,18, o CaO possui porcentagens entre 1,7 e 2,28%, com o MgO entre 0,34 e 0,85%, Na_2O entre 3,49 e 3,99%, K_2O na faixa de 3,5 a 4,69%, P_2O_5 variando de 0,03 a 0,15% e os teores de TiO_2 entre 0,23 e 0,41% (Tabela 4). Os valores dos principais elementos traços mostram o Ba com proporções entre 875 e 4570ppm, o Rb apresenta variações entre 61,4 e 90,7ppm, o Sr varia de 228 a 601ppm, o Zr possui valores entre 179 a 365ppm, Nb entre 1,7 e 3,0ppm e Y variando de 3 e 7,1ppm (Tabela 2).

Suíte Intrusiva Itaberaba								
	Ig-181-22	Ig-181-19	Ig-181-18	Ig_004	Ig-181-17	Ig-181-23	Ig-181-21	Ig_017
SiO_2	69,6	70,3	71,6	72,3	72,5	73,3	74,4	74,6
Al_2O_3	15,15	14,7	15,45	14,4	14,9	14,5	14,35	14,15
Fe_2O_3	3,18	1,8	2,44	1,83	1,7	1,86	1,86	1,57
CaO	2,22	2,28	1,83	1,86	1,82	1,71	1,7	1,92
MgO	0,85	0,45	0,7	0,4	0,49	0,43	0,43	0,34
Na_2O	3,81	3,98	3,61	3,62	3,83	3,49	3,79	3,99
K_2O	4,1	3,5	4,52	4,4	4,34	4,69	4,24	3,95
Cr_2O_3	0,004	0,005	0,003	0,003	0,002	0,003	0,003	0,004
TiO_2	0,4	0,29	0,41	0,25	0,28	0,28	0,26	0,23
MnO	0,02	0,02	0,01	0,02	0,01	0,01	0,01	0,01
P_2O_5	0,15	0,06	0,1	0,06	0,04	0,04	0,04	0,03
LOI	0,69	0,99	0,72	0,53	0,63	0,84	0,7	0,73
Total	100,44	98,57	101,99	99,86	100,69	101,37	101,9	101,65
La	98,9	61,9	261	67,9	64	108	63,8	43,5
Ce	175,5	102	421	121,5	112	185,5	111	72,4
Pr	17,15	9,87	39,9	12,35	10,9	17,7	10,85	6,91
Nd	54,1	31,9	117,5	38,2	33,1	53,2	33,3	21,8
Sm	7,69	4,9	12,25	5,08	5,43	6,87	5,36	3,56
Eu	1,53	1,1	1,97	1,3	0,96	1,22	0,89	0,87
Gd	4,14	2,55	4,5	2,1	2,65	3,07	2,97	2,23
Tb	0,42	0,24	0,39	0,25	0,28	0,3	0,33	0,22
Ho	0,27	0,14	0,21	0,13	0,12	0,15	0,16	0,13
Er	0,61	0,33	0,46	0,41	0,3	0,27	0,34	0,28
Tm	0,07	0,04	0,04	0,03	0,04	0,05	0,05	0,05
Yb	0,32	0,3	0,26	0,15	0,23	0,24	0,25	0,37
Lu	0,04	0,05	0,04	0,03	0,03	0,02	0,04	0,04
Ba	1650	1235	4570	1215	1005	1635	887	875
Cr	30	40	30	30	20	20	20	30
Cs	0,06	0,18	0,1	0,08	0,18	0,12	0,11	0,13
Dy	2,23	0,93	1,6	0,97	0,94	1,07	1,36	0,84
Ga	21,3	21,8	23,6	19,2	22,7	21,2	22,2	20,3
Hf	6,2	5,2	7,9	4,8	5,5	5,7	5,4	4,6
Nb	2,5	3	1,9	1,9	2,5	1,7	4,2	3
Rb	69,6	61,4	87,3	71,5	90,7	90,3	83,7	66,5
Sn	2	<1	1	2	3	1	1	<1
Sr	601	443	552	460	287	308	228	295
Ta	0,2	0,1	0,1	0,1	0,2	0,1	0,2	0,1
Th	26,5	28,8	86,4	35,1	32,5	46,8	29,3	20,6
U	0,69	1,16	0,56	0,76	1,35	1,18	1,71	1,47
V	41	27	38	21	17	18	20	10
W	1	<1	1	1	1	1	1	1
Y	7,1	3,7	4,8	3,5	3,6	3,6	4,4	3
Zr	257	217	365	182	214	225	198	179

Tabela 2 – Dados de análises geoquímicas deste trabalho para as rochas da SII. Elementos maiores em porcentagem em peso e elementos traço em ppm.

As amostras apresentam caráter sub-alcalino de acordo com o diagrama de classificação TAS (COX et al., 1979) (Figura 7a), sendo classificadas principalmente como granitos, com uma amostra classificada como granodiorito (Figura 7a). Utilizando o diagrama AFM de Irvine & Baragar (1971) elas situam-se próximas ao vértice de alto álcalis, possivelmente devido ao alto grau de diferenciação, sendo classificadas como do tipo calcioalcalina (Figura 7b). O diagrama A/CNK-A/NK de Shand (1943) permite visualizar que essas possuem caráter peraluminoso a metaluminoso, posicionando na transição entre os dois campos (Figura 7c). A sua classificação quanto à saturação em potássio permite classifica-las como calcioalcalinas de alto K, de acordo com o diagrama K_2O-SiO_2 de Peccerillo & Taylor (1976) (Figura 7d). Para o diagrama normativo de classificação dos feldspatos, essas rochas apresentam baixos valores de An e uma proporção quase que 50% de Ab e Or, seu posicionamento no diagrama confirmam sua classificação como granitos (Figura 7e).

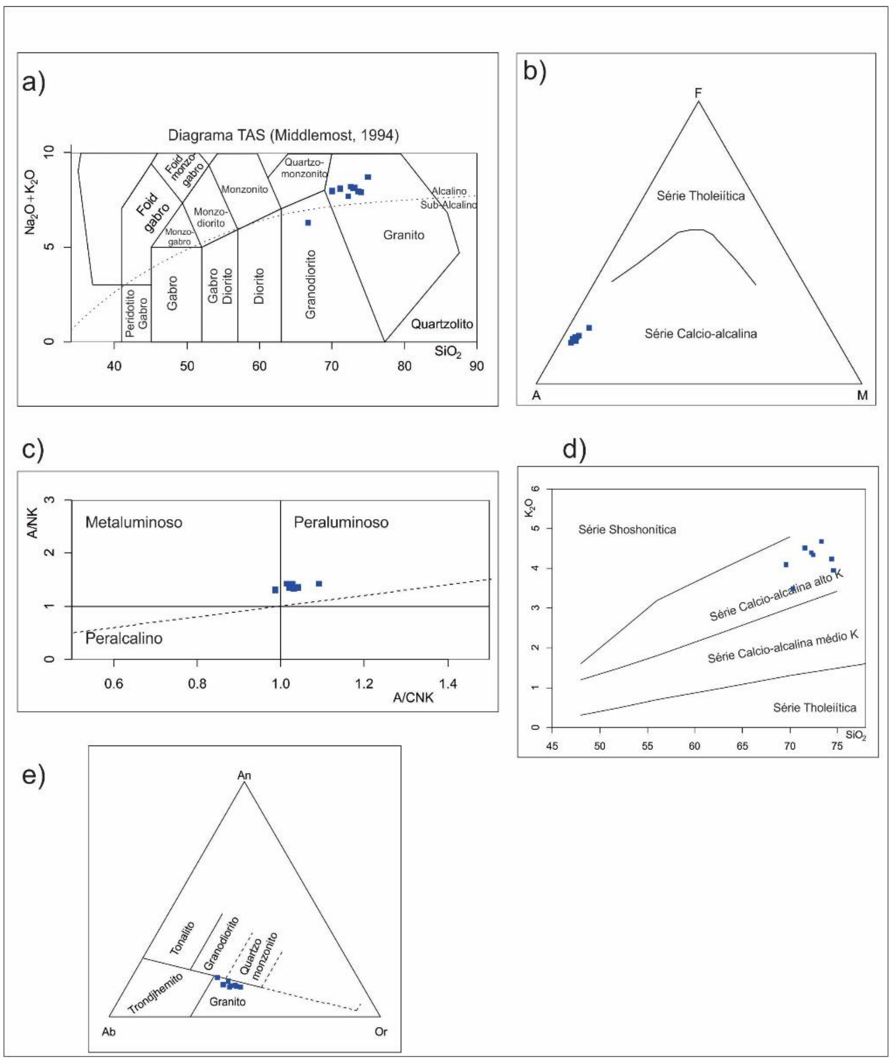

Figura 7 - Diagramas de classificação utilizando elementos maiores das análises litogeoquímicas da SII. a) Diagrama total de álcalis vs sílica – TAS (Cox et al., 1979); b) Diagrama triangular AFM (Irvine & Baragar, 1971); c) Diagrama do índice de saturação em alumina – A/CNK-A/NK (Shand, 1943); d) Diagrama do índice de saturação em potássio (Peccerillo & Taylor, 1976); e, e) Diagrama triangular de classificação dos feldspatos (O’Connor, 1965).

O comportamento dos elementos maiores quando observados em função do aumento de SiO_2 (Diagramas tipo Harker) apresentam *trends* onde se observa depleção em Al_2O_3, CaO, MgO, TiO_2, P_2O_5 e FeO_t, porém também com intervalos retilíneos para o CaO, P_2O_5 e FeO_t. Enquanto que há um aumento apenas nos teores de K_2O, com o Na_2O se apresentando levemente disperso (Figura 8). Para avaliação da real dispersão desses elementos, foram produzidos diagramas MPR da razão entre elementos que não tiveram comportamento móvel e estes que possivelmente estiveram móveis durante a cristalização (Figura 9). Esses diagramas são realizados na base logarítmica segundo as definições de Beswick (1982) e esses diagramas apresentam *trends* lineares dos valores plotados, mostrando que a dispersão foi promovida pela cristalização fracionada e não por processos pós-magmáticos. Os diagramas do tipo Harker para elementos menores e traço apresenta pouco ou nenhum fracionamento em Ba, Ce, Cr, La, Y e Zr, os quais aparentam ter uma correlação lateral de teores desses elementos em função do aumento de SiO_2 (Figura 10). O Sr e o Ba são os únicos elementos que aparentemente apresentam um *trend* mais bem definido, com uma leve depleção com o aumento de acidez das rochas para o Sr e enriquecimento para o Rb (Figura 10). Anomalias pontuais ocorrem em cada um desses elementos, com exceção do Sr, porém não restritas a apenas uma amostra.

O estudo do diagrama multielementar normalizado pelo Manto Primitivo (MCDONOUGH & SUN, 1995) permite a observação de fortes anomalias negativas de P, Ta, Nb e Cs, e fraca anomalia negativa de Ti e Yb (Figura 11a). Os valores mais elevados observados nesse diagrama são do Th, Rb, Ba e La, caracterizando esse magmatismo como enriquecido em elementos incompatíveis (Figura 11a).

O comportamento das amostras desses granitoides de acordo com a classificação de ETR normalizados pelo Manto Primitivo (MCDONOUGH & SUN, 1995), mostra que essas rochas apresentam um forte fracionamento entre ETR_L e ETR_P (Figura 11b), corroborando o alto grau de diferenciação. Estes espectros apresentam razões de La_N entre 67.13 e 402,78, razões de Lu_N entre 0,29 e 0,74 e razões Eu/Eu* 0,68 a 1,21, Eu_N/Yb_N entre 6,73 e 24,82 e La_N/Yb_N 80,01 e 683,17. Evidenciando o forte fracionamento de ETR_P em relação aos ETR_L.

A classificação geotectônica para esses granitoides se deu utilizando o diagrama de Pearce et al. (1984), onde as amostras se posicionaram nos campo do tipo VAG – Granitóides de Arco, tanto no diagrama Rb/Y+Nb (Figura 12a), como nos diagramas Nb/Y e Ta/Yb (Figura 12b e c).

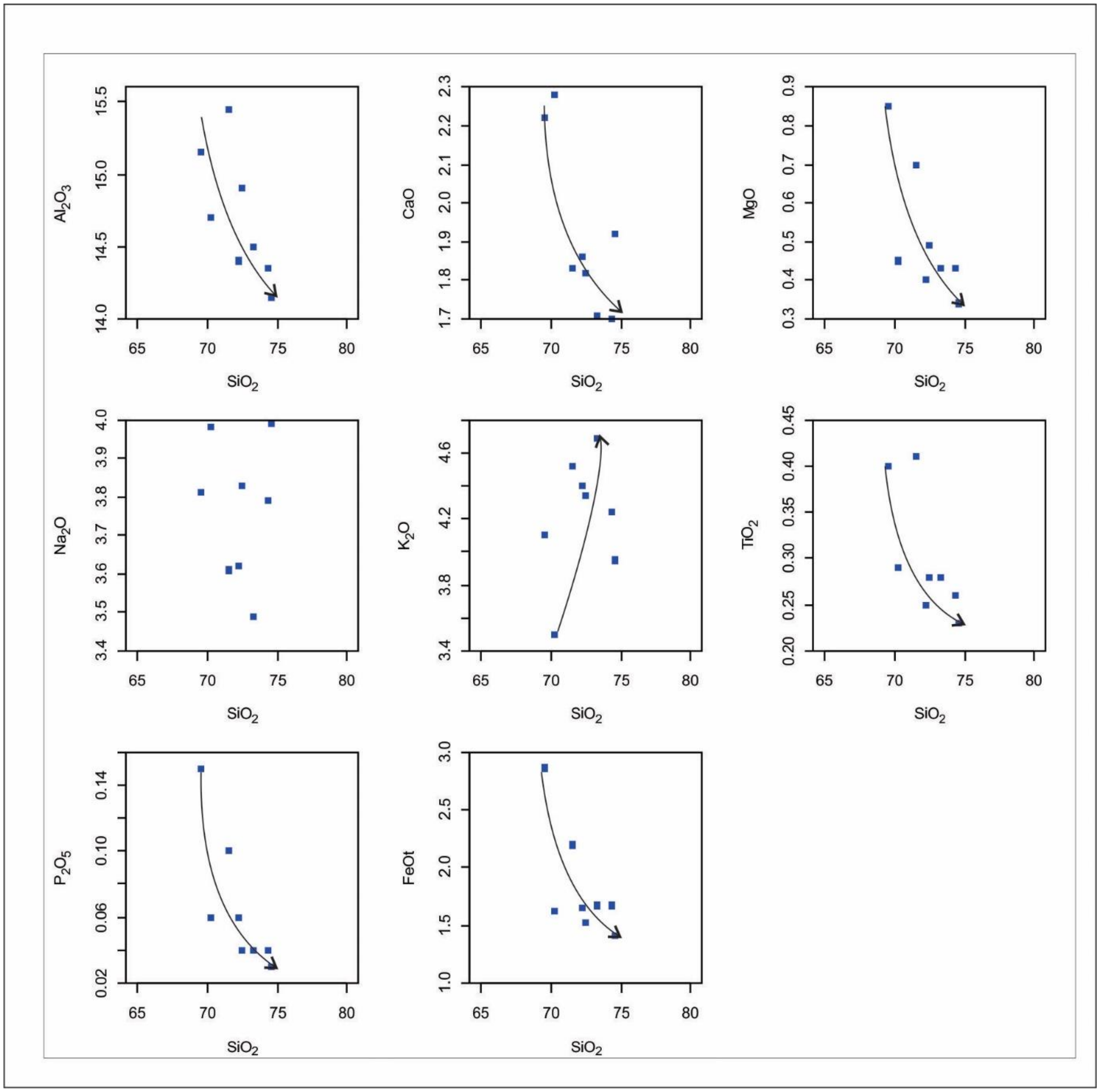

Figura 8 – Elementos maiores das rochas intrusivas em relação à sílica plotados nos diagramas de Harker (1909).

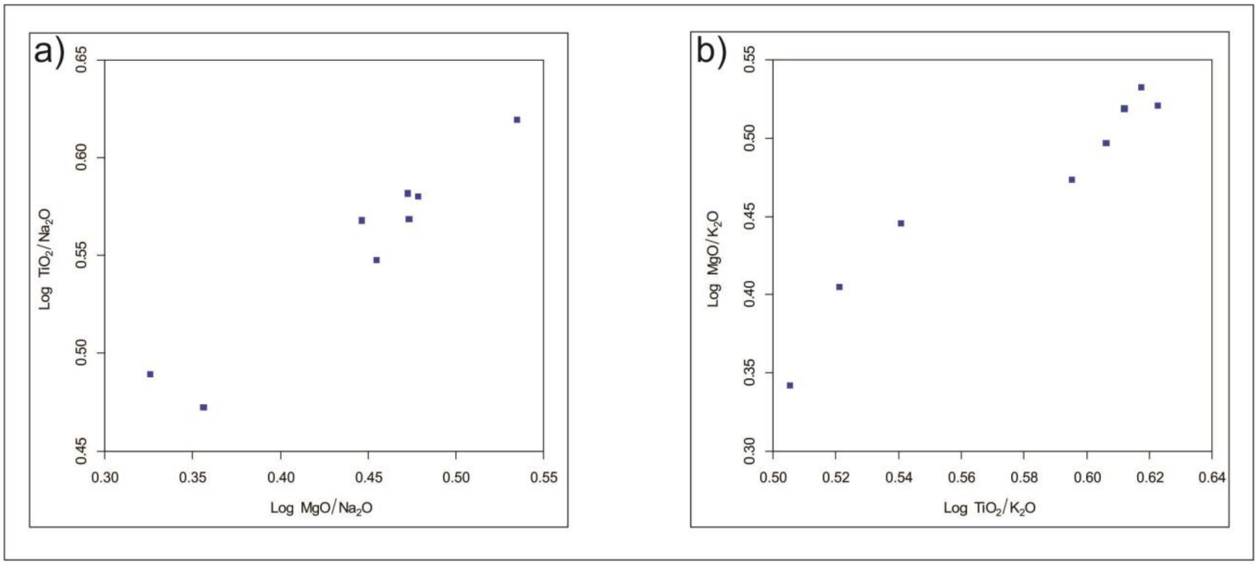

Figura 9 – Diagramas MPR de Beswick (1982) para os elementos Na2O e K2O para avaliação de dispersão desses elementos.

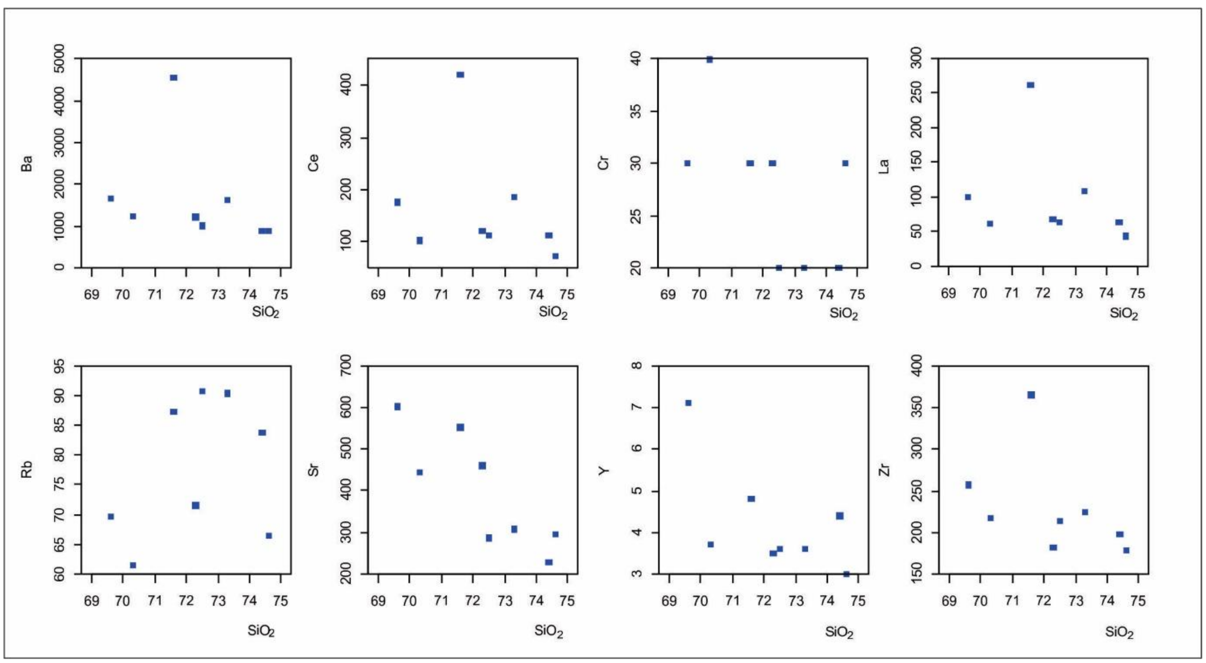

Figura 10 – Alguns elementos menores e traços das rochas intrusivas em relação à sílica plotados nos diagramas de Harker (1909).

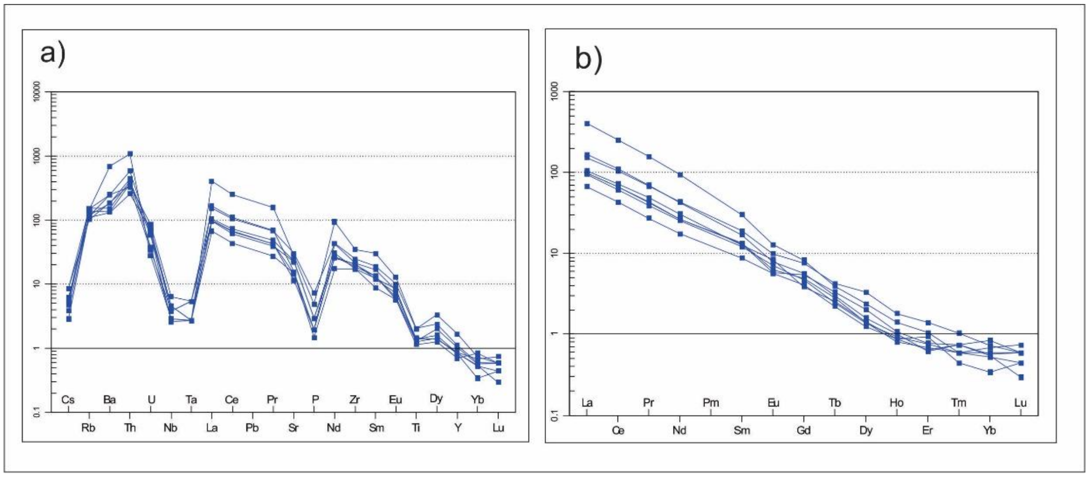

Figura 11 – Diagramas de elementos traço para as rochas intrusivas: a) Diagrama de Elementos Terras Raras; e, b) Diagrama multielementar. Ambos normalizados pelo manto primitivo segundo (McDonough & Sun, 1995).

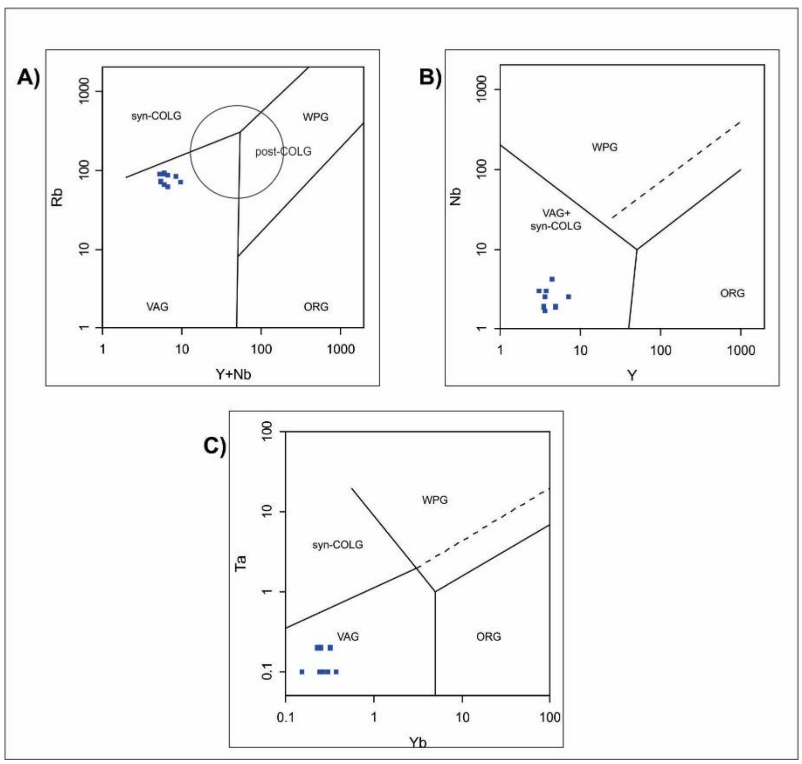

Figura 12 – Diagramas de classificação geotectônica de Pearce et al. (1984): A) diagrama Rb/Y+Nb; B) diagrama Nb/Y; e, C) diagrama Ta/Yb. (VAG: volcanic arc granites, COLG: collisional granites, ORG: orogenic granites, WPG: within plate granites).

6 Discussões

Petrograficamente, as rochas intrusivas da SII apresentam deformação de baixo grau, representada pela orientação das biotitas e extinção ondulante dos quartzos e feldspatos, ocasionalmente com estiramento de feldspatos e quartzo, indicando sua característica *sin a tardi-*

colisional. Santiago (2010) identificou também que em algumas porções dos granitoides intrusivos ocorrem ações metassomáticas, principalmente quando próximas da zona de contato com a encaixante. Ocorrem ainda reações que indicam condições de alterações deutéricas *tardi* magmáticas, como observado pela transformação biotitas em moscovita e clorita (Figura 6c e d). As texturas de exsolução como as pertitas e mesopertitas (Figura 6b) sugerem um ambiente de alta pressão de fluidos, corroborando que houve atividade metassomática durante o processo magmático.

Sua classificação modal (Tabela 1 e Figura 5) classificaram essas rochas essencialmente como metamonzogranitos.

Além disso, os dados geocronológicos se mostram compatíveis com as idades de cristalização e metamorfismo de (Barbosa e Sabaté, 2002, 2004; Peucat et al., 2011), apresentando idades de cristalização em torno de 2,7 e 2,6 Ga e pico do metamorfismo em 2,07-2,06 Ga (Figura 4) para as rochas do Complexo Caraíba. As diferenças de idades entre borda e centro dos zircões analisados sugerem que o intervalo de tempo entre o pico do metamorfismo e o colapso orogênico foi em torno de 40-30 Ma, indicando que os eventos de colisão dos blocos crustais na borda leste do CSF ocorreram de modo diacrônico. Esses dados sugerem que a intrusão das rochas graníticas se deu por volta 2,06Ga, no final do pico metamórfico da colisão entre o Bloco Jequié e Itabuna-Salvador-Curaçá, como já sugerido por Teixeira de Souza et al. (2019) na fase Dn’’ (Figura 13c).

As rochas graníticas intrusivas da região de Itatim e Milagres foram classificadas nesse trabalho como subalcalinas, calcioalcalinas, de alto potássio com caráter peraluminoso a fracamente metaluminoso (Figura 7a, b, c e d) e essencialmente como granitos (Figura 7e).

Os diagramas do tipo Harker sugerem para as rochas da SII um comportamento fracamente incompatível de K_2O e Na_2O com o fracionamento, com leve dispersão deste último (Figura 8), no entanto, os diagramas MPR mostram que ao avaliar esses elementos em função de outros não móveis, não houve dispersão, de modo que essa leve dispersão não está ligada a processos metamórficos ou de deformação regional. Já os demais elementos maiores apresentaram comportamento compatível durante o fracionamento (Figura 8), além de pouco fracionamento dos elementos menores, apresentando variação negativa apenas para o Sr e levemente positiva para o Ba (Figura 10).

Os diagramas multielementares e de ETR (Figura 11) permitem observar que essas rochas são enriquecidas em elementos incompatíveis, principalmente os ETR_L, indicando que houve fracinamento desse magma durante sua ascensão. As anomalias encontradas no diagrama multielementar (Figura 11a), principalmente as negativas de P, Ta, Nb, Ce, Ti e Yb confirmam essa característica de fracionamento do magma e também são indicativas de que essas rochas foram geradas por um mecanismo de subducção. No entanto, o grau de fracionamento desse magmatismo não é considerado muito elevado, devido a inexistência de anomalia negativa de Eu (Figura 11b), a qual é característica em magmas graníticos muito fracionados.

Em relação à discriminação tectônica, esses granitos da SII foram classificados como granitoides de arco magmático (Figura 12), confirmando as observações de deformação das suas rochas em relação ao final da atividade tectônica de colisão entre o BJ e BISC.

As anomalias em nos elementos incompatíveis supracitados, caracterizando o ambiente de subducção para a formação desse magma, a idade de colocação dos granitos em 2,07-2,06 Ga encontradas por Correa-Gomes et al., (2012), a caracterização tectônica de granitos tipo VAG provenientes dos dados litogeoquímicos e a colocação da intrusão durante o período do pico metamórfico, na fase D’’ propostas por Teixeira de Souza et al. (2019) confirmam que esses granitos intrusivos da região de Itatim e Milagres se tratam de granitos *sin* a *tardi* tectônicos e não pós-tectônicos, como eram considerados anteriormente.

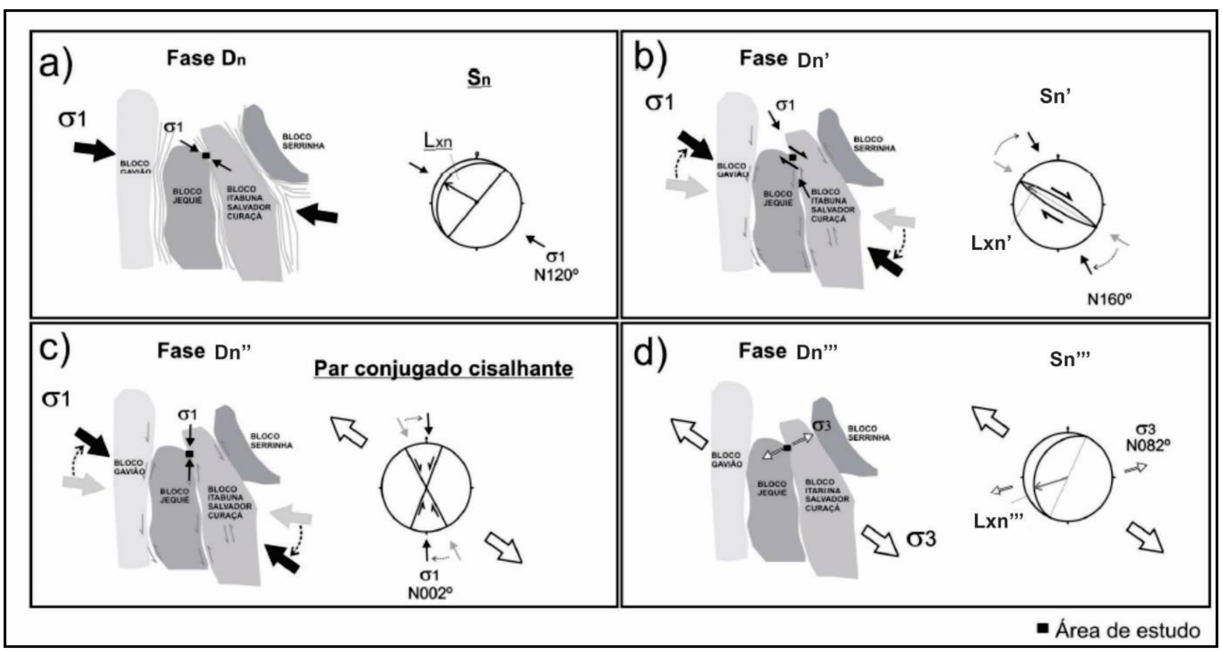

Figura 13 – Modelo esquemático dos tensores atuantes nas fases de deformação regionais e sua associação com as estruturas descritas neste trabalho: (a) Dn; (b) Dn’; (c) Dn’’; e (d) Dn’’’. A rotação dos paleotensores principais de σ1 ocorre progressivamente de (a) a (c). As setas pretas menores representam os tensores compressivos locais e as cinzas os tensores extensivos locais, enquanto que as setas de mesma cor maiores representam os tensores regionais obtidos por Sabaté, (1996) e Corrêa-Gomes et al. (2005). Fonte: Teixeira de Souza et al. (2019).

7 Conclusões

As rochas da SII foram identificadas nesse trabalho como resultantes de um magmatismo calcioalcalino o qual possivelmente foi gerado pela fusão crustal do BISC, representado pelo Complexo Caraíba, uma vez que Teixeira de Souza et al (2019) haviam sugerido uma subducção Bloco Jequié sob esse, resultando na estabilização do CSF na sua porção central. Essa intrusão se deu em torno de 2,06 Ga no final deste evento compressivo e em decorrência disso, as rochas dessa suíte apresentam baixo grau de deformação a incipiente, com fraco metamorfismo, principalmente em relação aos minerais micáceos. Essa interpretação é confirmada pelos dados obtidos nos diagramas de ambiência tectônica (Figura 12), onde as amostras ficaram posicionadas no campo de magmatismo de Arco.

A ausência de fracionamento de Eu nas rochas da SII, sugere que esta suíte tenha sofrido baixo fracionamento durante sua ascensão, porém não inexistente, uma vez que há um claro fracionamento entre ETR_L e ETR_P (Figura 11b), além das anomalias negativas de P, Ta, Nb, Ce, Ti e Yb (Figura 11a). Os autores acreditam ainda que dados isotópicos poderiam enriquecer e confirmar algumas interpretações realizadas nesse trabalho.

Agradecimentos

Agradecemos à Universidade de Brasília (UnB) pelo apoio na confecção das lâminas petrográficas e ao Programa de Pós-Graduação da Universidade Federal da Bahia (UFBA). O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Código de Financiamento 001.

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CAPÍTULO 4
CONCLUSÕES

A área de estudo apresenta alta complexidade geológica onde a utilização de um conjunto de dados geológicos, como a geologia estrutural, geoquímica e geocronologia, aliadas a estudos geofísicos são ferramentas extremamente importantes para o entendimento da evolução da região. Porém ainda insuficientes para a melhor caracterização dos terrenos granulíticos do CSF, necessitando de dados isotópicos para auxiliar nas interpretações sugeridas por esses métodos citados.

A região estudada se trata claramente um ambiente geológico caracterizado por uma zona transpressional, representada principalmente por falhas reversas resultantes da colisão entre os Blocos Itabuna-Salvador-Curaçá e Jequié, causando a superposição do BISC sobre BJ. Essa colisão também é caracterizada pelo magmatismo calcioalcalino representado pelas intrusões graníticas tardias, uma vez que as rochas intrusivas descritas neste estudo apresentaram deformação incipiente, caracterizada principalmente pelo estiramento de minerais micáceos e plagioclásios, com *srtike* compatíveis com a deformação regional.

Os padrões estruturais sugerem uma deformação progressiva, característica em zonas de colisão, apresentando evidências de quatro estágios de deformação, interpretados principalmente pela análise da relação entre superfícies de foliação e lineações de entiramento mineral. Alguns dos estágios de deformação resultaram da rotação dos tensores de tensão até as estruturas finais do colapso do orógeno. Os dados geocronológicos utilizados nesse trabalho também determinam uma linha do tempo para o evento extensivo deste colapso do orogênico, propondo um intervalo de tempo em torno de 30-40 Ma entre o final da colisão continental e o supracitado evento extensivo.

A utilização petrográficos, estruturais e geoquímicos, apesar de ter auxiliado bastante na individualização dos litotipos desses terrenos metamórficos do CSF, ainda apresenta grandes desafios. Sendo necessária a utilização também de dados isotópicos para melhor caracterizar cada grupo de rocha. No entanto, foi possível determinar características importantes em relação à granitogênese decorrente dessa subducção que estabilizou o CSF.

As rochas da Suíte Intrusiva Itaberaba foram interpretadas como provável produto da fusão parcial do Complexo Caraíba e apresentam características de um magmatismo calcioalcalino de alto K e peraluminoso a levemente metaluminoso, durante o final da colisão entre o BJ e o BISC. Essa subducção deu origem a rochas metamonzograníticas pouco fracionadas, evidenciadas pelas anomalias negativas de P, Ta, Nb, Ce, Ti e Yb e pela diferença de valores entre ETR_L e ETR_P. A presença de texturas de exsolução indicam ainda que houve alta pressão de fluidos durante essa intrusão e, consequentemente, alta atividade metassomática envolvida, principalmente nas proximidades com as rochas encaixantes.

A combinação destes dados juntamente com a utilização dos mapas aerogeofísicos gamaespectrometricos e magnetométricos foram de suma importância na delimitação dos blocos e na identificação da zona de sutura, sendo sugerida neste trabalho para uma posição mais a sul da proposta por antigos autores. Este agrupamento de dados ainda permitiu as interpretações acerca da geotectônica da região, identificando a evolução da deformação e sugerindo um período temporal entre o pico metamórfico e colapso do orógeno, bem como a caracterização geoquímica e petrográfica das rochas intrusivas formadas por este evento colisional.

Um aspecto importante deste trabalho é sua aplicabilidade à exploração mineral, uma vez que o novo cenário pode permitir uma definição mais precisa das áreas-alvo de possíveis minerais e processos geológicos de mineralização.

ANEXO A – REGRAS DE FORMATAÇÃO DA REVISTA

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