https://rbgeomorfologia.org.br/
ISSN 2236-5664

Revista Brasileira de Geomorfologia

v. 24, nº 4 (2023)

http://dx.doi.org/10.20502/rbg.v24i4.2402

Nota Técnica

Caves, Karst Features and Speleological Heritage in Chapada Diamantina, Bahia, Brazil

Cavernas, Carste e Patrimônio Espeleológico na Chapada Diamantina, Bahia, Brasil

Raphael Parra [1], Ricardo Galeno Fraga de Araújo Pereira [2] e Carlos Gleidson Campos da Purificação [3]

[1] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente. Programa de Pós-graduação em Geologia, Instituto de Geociências, Universidade Federal da Bahia, Salvador, Brasil. raphaelparra95@gmail.com.
ORCID: https://orcid.org/0000-0003-3436-3857

[2] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente. Programa de Pós-graduação em Geologia, Instituto de Geociências, Universidade Federal da Bahia, Salvador, Brasil. fraga.pereira@ufba.br.
ORCID: https://orcid.org/0000-0003-3913-3735

[3] Núcleo de Estudos Hidrogeológicos e do Meio Ambiente, Instituto de Geociências, Universidade Federal da Bahia, Salvador, Brasil. carlos_purificacao@hotmail.com.
ORCID: https://orcid.org/0000-0001-5268-3999

Recebido: 03/05/2023; Aceito: 31/10/2023; Publicado: 09/12/2023

Abstract: Chapada Diamantina is among the best known and most visited landscapes in Brazil. Located in the state of Bahia, Northeast region of the country, it is characterized by mountains and plateaus that developed on Proterozoic sedimentary and metasedimentary rocks. Much of its territory is covered by carbonate and siliciclastic rocks, where relevant karst systems develop, marked by the occurrence of sinking streams, sinkholes, and caves with a great diversity of morphologies, speleothems, subterranean fauna, and paleontological and archaeological records. Relevant carbonate systems occur in Iraquara, such as the Lapa Doce, Torrinha, and Pratinha caves, which represent important tourist attractions. Also in these rocks, stand out the Brejões Cave, with a 106-m high entrance, and the Toca da Boa Vista, the largest cave in South America, extending across 114 km. Cultural manifestations are present in the prehistoric cave paintings at Santa Marta Shelter and recent religious pilgrimages at Mangabeiras Cave, in Ituaçu. In turn, siliciclastic karst systems are mainly in *Serra do Sincorá*. The Lapão and Castelo caves have expressive speleogens and speleothems, as well as the Torras Cave, in the Igatu region, ranked as the second largest in Brazil considering siliciclastic rocks.

Keywords: Carbonate Karst, Siliciclastic Karst, Caves, Speleology, Chapada Diamantina

Resumo: A Chapada Diamantina está entre as paisagens mais conhecidas e visitadas do Brasil. Localizada no estado da Bahia, região Nordeste do país, é caracterizada por serras e planaltos, desenvolvidas sobre rochas sedimentares e metassedimentares do Proterozóico. Grande parte do seu território é coberto por rochas carbonáticas e siliciclásticas, onde se desenvolvem sistemas cársticos relevantes, marcados pela ocorrência de sumidouros, dolinas e cavernas com grande diversidade de morfologias, espeleotemas, fauna subterrânea e registros paleontológicos e arqueológicos. Sistemas carbonáticos relevantes ocorrem em Iraquara, como as cavernas Lapa Doce, Torrinha e Pratinha, que representam importantes atrativos turísticos. Também nestas rochas destacam-se a Gruta dos Brejões, cuja entrada alcança 106 m de altura, e a Toca da Boa Vista, a maior caverna da América do Sul, com 114 km de extensão. As manifestações culturais estão presentes nas pinturas rupestres pré-históricas do Abrigo Santa Marta e nas recentes romarias religiosas na Gruta das Mangabeiras, em Ituaçu. Por sua vez, os sistemas cársticos siliciclásticos são encontrados principalmente na Serra do Sincorá. As grutas do Lapão e do Castelo possuem

espeleogens e espeleotemas expressivos, assim como a Gruta das Torras, na região de Igatu, classificada como a segunda maior do Brasil em rochas siliciclásticas.

Palavras-chave: Carste Carbonático, Carste Siliciclástico, Cavernas, Espeleologia, Chapada Diamantina.

1. Introduction

According to the 2020 Brazilian Speleological Heritage Statistical Yearbook (ICMBio, 2021), the state of Bahia ranks third in number of recorded caves. With 1,694 cavities, this represents 7.88% of the total amount of caves in the country, with only the states of Minas Gerais (45.41%) and Pará (12.76%) having greater numbers. Considering the dimensions of the state and the strong presence of thick soluble geological units, in regions which are largely still unexplored, it is assumed that the real number of caves in Bahia is considerably higher.

A significant portion of this speleological heritage is in the Chapada Diamantina territory, where geological, geomorphological, and hydrologic conditions favor the development of karst in different types of rock. The region has been the target of a series of expeditions to explore, map, and carry out academic studies over the last decades, which has contributed to a vast accumulation of knowledge about these systems.

Due to its relevance, part of this heritage is secured through environmental protection areas. These are under either federal jurisdiction, such as the Chapada Diamantina National Park, or state jurisdiction, such as the Environmental Protection Areas of Marimbus/Iraquara and Gruta dos Brejões/Vereda do Romão Gramacho. In addition, several Geopark proposals and projects have been developed in this region, such as Serra do Sincorá, Morro do Chapéu, and Grutas de Iraquara.

Thus, herein will present the main characteristics of these karst terrains, with emphasis on the cave systems that develop in them, seeking to cover aspects of the physical, biological, and cultural/historical environment based on literature review and fieldwork. It must be highlighted that Chapada Diamantina comprises relevant karst relief and caves both in carbonate and siliciclastic rocks.

2. Geographic Location

Chapada Diamantina consists of a group of mountains and plateaus located in the central region of the state of Bahia, in northeastern Brazil (Figure 1). Covering an area of 65,619 km², Chapada Diamantina occupies just over 10% of the state's land area. It represents the northernmost part of a mountain range that extends from the south of the state of Minas Gerais to the north of Bahia, known as '*Serra do Espinhaço*'.

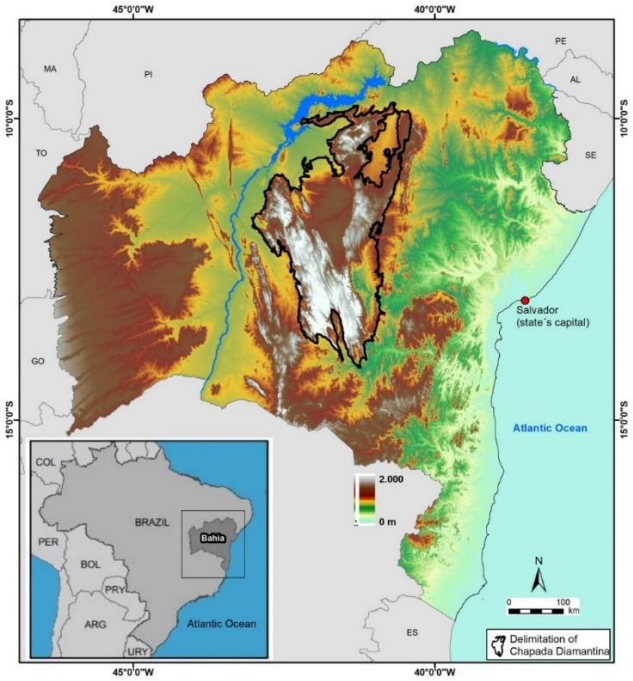

Figure 1. Location map of Chapada Diamantina, Bahia, Brazil.

According to Pereira (2010), the term Chapada Diamantina refers to two different entities. The first one refers to the physical environment, comprising a geographic region, characterized by mountainous relief forms, plateaus, and karst systems, developed essentially on sedimentary and metasedimentary Proterozoic rocks. The second one is related to social, political, and cultural aspects, referring to the territorial identity of local communities from 23 municipalities. In the present paper, we will adopt the first definition, which was used to establish the boundary line of the Chapada Diamantina territory.

The region is home to the springs of the main rivers and watersheds of Bahia, including the Paraguaçu River, which supplies Salvador, the state capital, and a set of important tributaries on the right bank of the São Francisco River. It is important to note that, in the São Francisco River, there are 14 hydroelectric plants, which provide energy to several Brazilian states. These aspects highlight the hydrological importance of this region. Furthermore, Chapada Diamantina currently represents one of the main ecotourism destinations in Brazil (BRITO, 2005), with its geodiversity elements acting as its main tourist appeal.

The climate in Chapada Diamantina is complex and strongly influenced by the relief. In general, it varies between hot caatinga (thorny forest) in the lowlands to a more tropical one on higher altitude, according to the Köppen climate typology (SEI, 1998). Two seasons are well defined, with periods of more significant rainfall, concentrated between November and May, and periods of drought, which occur between June and October, although rainfall rates vary greatly between the eastern and western slopes (BARRETO, 2010).

2. Geology and Geomorphology

Chapada Diamantina is part of the Paramirim Aulacogen, a morphotectonic feature of the northern portion of the São Francisco Craton (ALKMIM, 2004). According to Schobbenhaus (1996), this Aulacogen corresponds to two overlapping and partially inverted intracratonic basins, in which rocks of the Espinhaço Supergroup (Paleo/Mesoproterozoic) and the São Francisco Supergroup (Neoproterozoic) were deposited. These rocks support a set of mountain reliefs and plateaus in the central part of the state of Bahia (Figure 2).

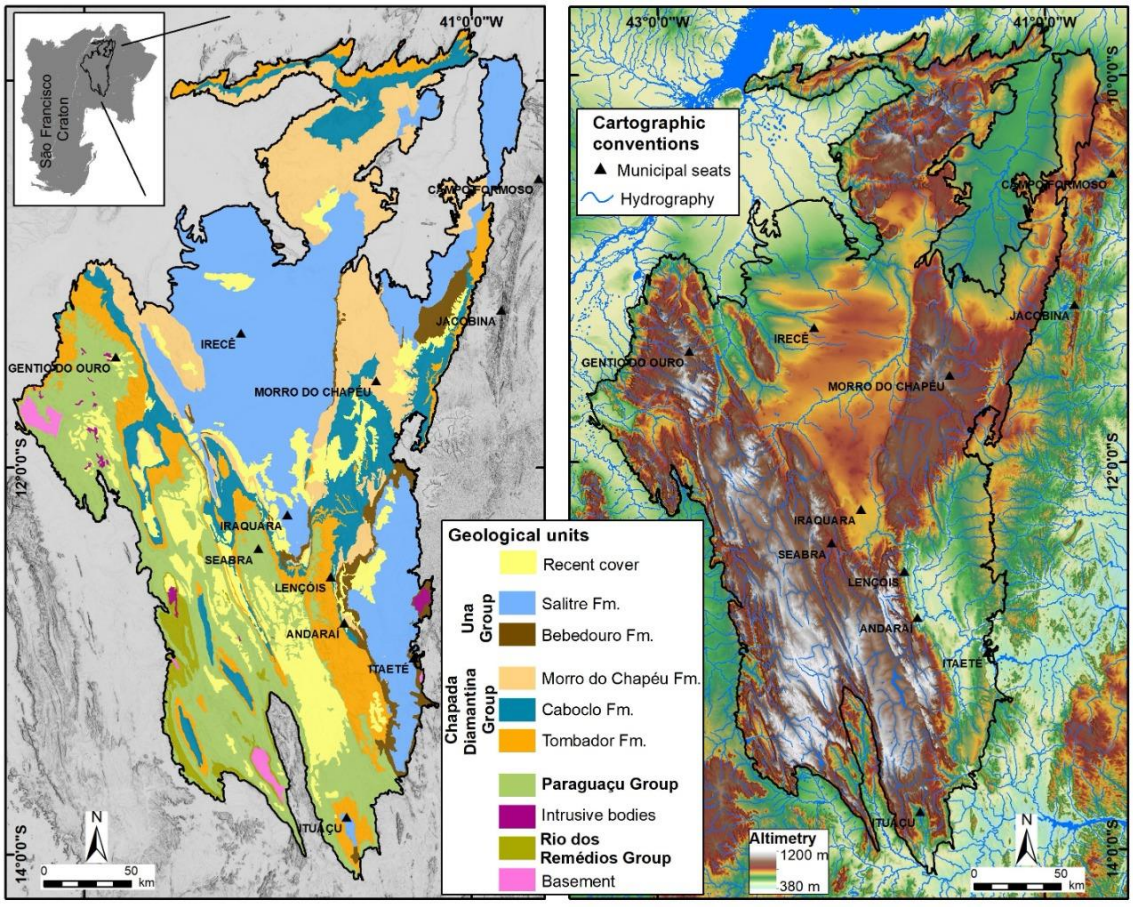

Figure 2. Geological map, modified from Dalton de Souza et al. (2003), scale 1.000.000 (left) and hypsometric map, from SRTM Satellite Imagery (right) of Chapada Diamantina.

In this region, the Espinhaço Supergroup is divided into three groups: Rio dos Remédios, Paraguaçu, and Chapada Diamantina (INDA; BARBOSA, 1978; PEDREIRA, 1994).

The Rio dos Remédios Group is dated to the Statherian period (~1.75 Ga) and is related to the beginning of the intracontinental Espinhaço Rift. It consists of acidic volcanic rocks overlain by sediments deposited in lacustrine and intertwining river systems (GUIMARÃES, 2005). In turn, the Paraguaçu Group shows evidence of a marine ingression. It is composed of eolian and fluvial sediments of a coastal environment overlain by deposits of tidal and deltaic systems (PEDREIRA; DE WAELE, 2008; GUIMARÃES; SANTOS; MELO, 2008; MAGALHÃES et al., 2015).

The Chapada Diamantina Group outcrops throughout the area. From bottom to top, it is composed of the Tombador, Caboclo, and Morro do Chapéu formations (BARBOSA; DOMINGUEZ, 1996). These formations were deposited in the Mesoproterozoic, along with cycles of sea-level transgression and regression, and subsequently subjected to advanced diagenesis and/or anchimetamorphism (GUIMARÃES; ALKMIM; CRUZ, 2012).

The Tombador Formation has great vertical and lateral persistence. It is composed of sandstone and conglomerates deposited in a coastal environment by alluvial, eolian, and tidal-dominated estuarine systems (MAGALHÃES et al., 2014). The Caboclo Formation presents an association of siliciclastic and carbonate lithofacies, such as sandstones, conglomeratic sandstones, and pelites, in addition to calcarenites, laminites, and stromatolites (ROCHA; PEREIRA; SRIVASTAVA, 1992). The Morro do Chapéu Formation consists of basal conglomerates and sandstones interspersed with pelites (GUIMARÃES; PEDREIRA, 1990).

The Una Group represents the rocks of the São Francisco Supergroup in the oriental half of Chapada Diamantina. Deposited during the Neoproterozoic Era, they occur in four carbonate basins and/or sub basins, as follows: Irecê Basin, Campinas Sub Basin, Una-Utinga Basin, and Ituaçu Syncline. According to Teixeira, Misi and Silva (2007), sedimentation occurred in a single large basin, which was later segmented during the Brasiliano tectonic events. This group encompasses the Bebedouro and Salitre formations.

A complex association of glacial diamictite (tillite), mudstone, and sandstone facies, related to the global Neoproterozoic glaciation events, constitutes the Bebedouro Formation (MISI et al., 2007), which occurs on the flanks of the synformal structures related with the carbonate basins of the Una Group. In turn, the Salitre Formation represents a sea-level advance, resulting from deglaciation, and is composed of thick layers of carbonate rocks, such as limestones, calcarenites, dolomites, and individual stromatolites (MISI; VEIZER, 1998).

At the end of the Neoproterozoic, during the Brasiliano orogeny, the distensional regime inverted, leading to the closure of these two basins where the rocks of the Espinhaço and São Francisco Supergroups were deposited (ALKMIM; CHEMALE; ENDO, 1996). This inversion occurred in a compressional regime through the reactivation of normal fault structures of the Statherian rift, with main NNE-SSW orientation (CRUZ; ALKMIM, 2006). It generated anticlines and synclines in a complex tectonic style, evidenced in peculiar relief features (GUIMARÃES; SANTOS; MELO, 2008).

In terms of geomorphology, Chapada Diamantina is strongly characterized by mountains, whose broad plateaus and deep valleys with steep slopes give it a remarkable scenic beauty. As evidence of its relevance, the three largest summits in northeastern Brazil are located here: Barbado, at 2,033 m, Itobira, at 1,970 m, and Almas, at 1,958 m (GIUDICE, 2012); and most of the main rivers of the state of Bahia are born in this region.

Lima and Nolasco (2015) propose two main geomorphological domains for Chapada Diamantina: the karstic domain and the lithostructural domain. This subdivision was determined by geological features, such as lithology and structures that affect these rocks. These aspects created conditions for differential erosion and, consequently, contrasting landforms.

According to these authors, the karstic domain is associated with carbonate rocks of the São Francisco Supergroup and is characterized by flat to gently undulating reliefs, which reach altitudes between 700-800 m in the Irecê Basin and 500-600 m in the Una-Utinga Basin. These terrains are distinguished by typical karst system features, such as sinkholes, fluviokarst valleys, and a large network of caves, which form extensive galleries reaching up to tens of kilometers in length.

The lithostructural domain is supported by sediments of the Espinhaço Supergroup. Their Neoproterozoic folds are reflected in the irregular relief, marked by massive mountains and plateaus limited by scarps and deep valleys, such as the Sincorá and Bastião ridges. Like others, they present crests that are remarkably parallel and elongated in the NNW-SSE direction, reaching altitudes of 1,700 m and 1,200 m, respectively (PEDREIRA, 1994). In the most prominent fractured zones, vertical planes increase the weakness of the rock and accelerate erosive

processes. In these places, larger valleys develop, such as Capão and Pati, whose lateral slopes can reach more than 400 m in height.

3. Caves and Karst Features

Chapada Diamantina houses karst systems developed in both carbonate and siliciclastic rocks, as presented in Figure 3. The figure shows a map with the occurrences of caves registered in the National Registry of Speleological Information (CANIE) for the geological units considered here as karstifiable. Some less-soluble units also have registered caves, such as the Morro do Chapéu Formation, but they need to be further investigated before they can be classified as karst areas.

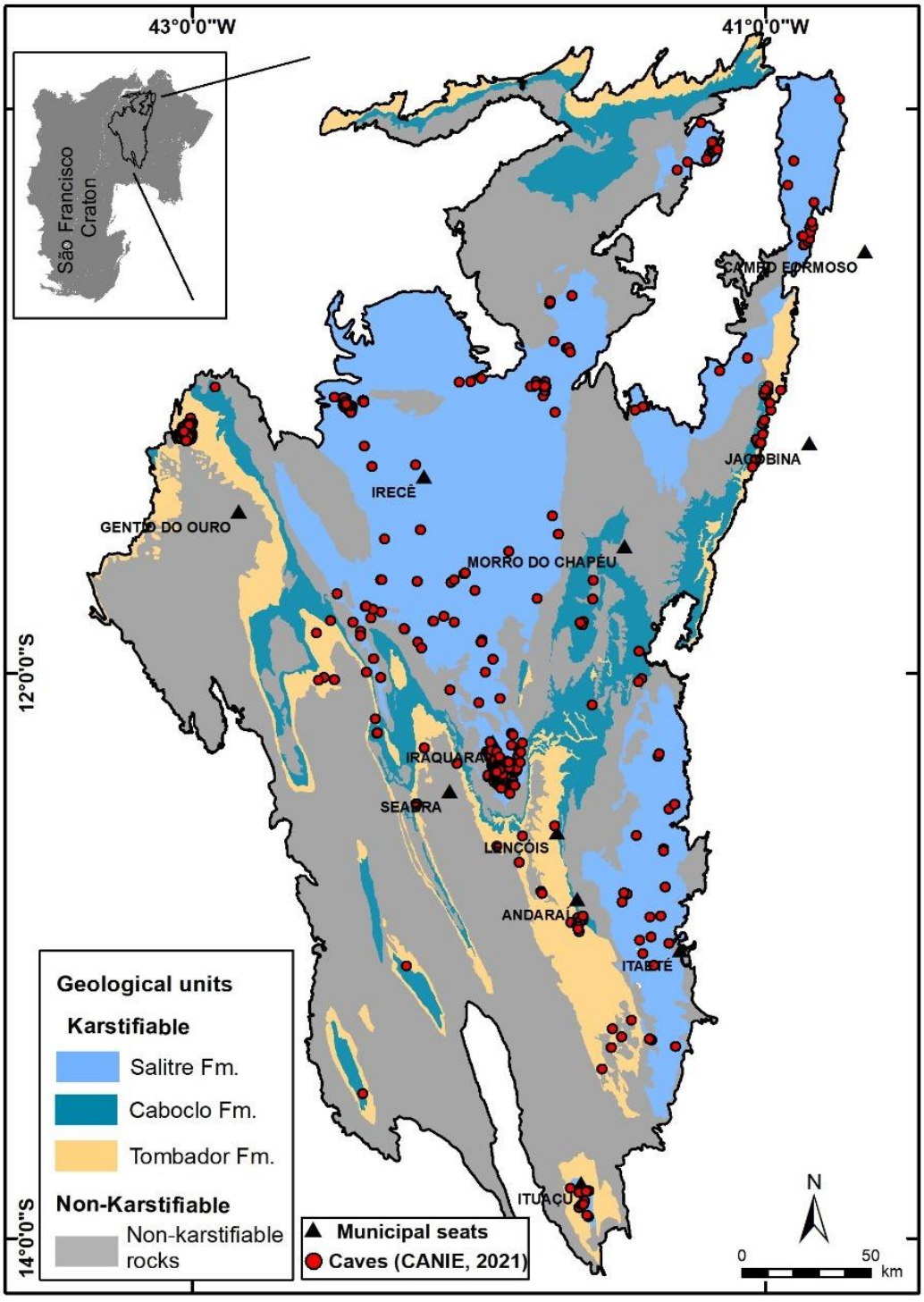

Figure 3. Map of cave occurrences by geological unit, in Chapada Diamantina.

The carbonate karst systems occur mainly in the Neoproterozoic rocks of the Salitre Formation, which belongs to the Una Group. This unit outcrops discontinuously in the Irecê, Una-Utinga, and Ituaçu basins and in the Campinas Sub-Basin. They also occur, on a smaller scale, in the Mesoproterozoic carbonate rocks of the Caboclo Formation, Chapada Diamantina Group.

The siliciclastic karst systems develop mainly in the Mesoproterozoic rocks of the Tombador Formation. In the southern-central portion, relevant caves occur in the area encompassed by the Chapada Diamantina National Park, in Serra do Sincorá, such as the Lapão and Castelo caves, with important tourist potential (FERREIRA, 2009), as well as the underexplored caves in the region of Vila de Igatu.

The presence of caves is also worth mentioning on the slopes of *Serra do Tombador*, in the easternmost part of Chapada Diamantina, and in Gentio do Ouro, in the western portion. Some caves are also present in the Morro do Chapéu Formation. However, due to a lack of information about them, these caves will not be described in this chapter.

3.1. Carbonate Systems

3.1.1. Irecê Basin

The Irecê Basin, in the central-northern region, is the largest carbonate outcrop area of the Salitre Formation and the one with the highest occurrence of caves in the Chapada Diamantina area. This flat land, with altitudes between 600 and 800 m, receives allogenic recharge from waters with high dissolution potential that flow from the surrounding siliciclastic mountains. This has favored the development of a very expressive karst relief, with the occurrence of numerous cave systems, sinkholes and sinkhole clusters, entrenched valleys with steep slopes, blind valleys, and resurgences.

The municipality of Iraquara stands out due to its high number and variety of speleological systems (LAUREANO; CRUZ JR, 2002). This number is so expressive that the area has several zones at risk of collapse and subsidence, as presented by Salles et al. (2019), in the karst hazard index map.

Nicknamed as the "City of Caves", it attracts thousands of visitors every year, representing an important speleotourism center in the country. One of the main attractions is the Lapa Doce System, in which, according to Rubbioli (1995), a large collapse sinkhole measuring 160 m in length and 50 m in depth separates the Lapa Doce I, with 9.3 km of extension, from the Lapa Doce II, with 16.5 km (Figure 4A). However, a recent cave diving expedition was able to connect both caves, but its results have not yet been published.

Another important system is the Torrinha Cave. With 13 km, it stands out for the rich variety of forms and composition of speleothems, with aragonite flowers and gypsum needles that exceed 50 cm in length (Figure 4B). Pontes et al. (2023) proposed a speleogenesis model for the Torrinha Cave System based on the presence of burial stylolites and structural features, which control the cave geometry, at the heterolithic carbonates of Salitre Formation.

In turn, Pratinha Cave surprises visitors with its unique beauty, emerging from crystalline waters of an emerald blue color (Figure 4C), which supplies a large lake and then flows into the Santo Antônio River. According to Valle (2004), there is a convergence of regional groundwater flow towards the spring of Pratinha, thus defining it as the main outlet of the karst system in the southern sector of the Irecê Basin.

In Iraquara, as well as in much of Chapada Diamantina, it is common to identify archaeological sites near the entrance of caves. Caves such as Lapa do Sol and Santa Marta preserve expressive rock paintings, such as geometric, anthropomorphic and zoomorphic figures (Figure 4D).

On the northeastern edge of the basin, along the Jacaré River channel, on the border between the municipalities of Morro do Chapéu and São Gabriel, other relevant karst systems develop, with the presence of caves, dolines, canyons, and karst valley. The course of the river, when on the surface, creates favorable conditions for vegetation to survive, displaying an exuberant green that contrasts with the dry landscape of the caatinga.

The Brejões Cave System is particularly noteworthy, especially for its entrance, which reaches 106 m in height (Figure 4E). A collapse between Brejões I and II, which together reach 7.8 km of development, separates the cave into two segments (BERBERT-BORN; KARMANN, 2002). Furtado et al. (2022a, b) identified, through remote sensing and geophysical methods, a complex fracture system which is essential to cave and canyon development.

Human presence is quite remarkable in this cave, because of both the prehistoric records in rock art and the current religious manifestations that attract, today, thousands of people.

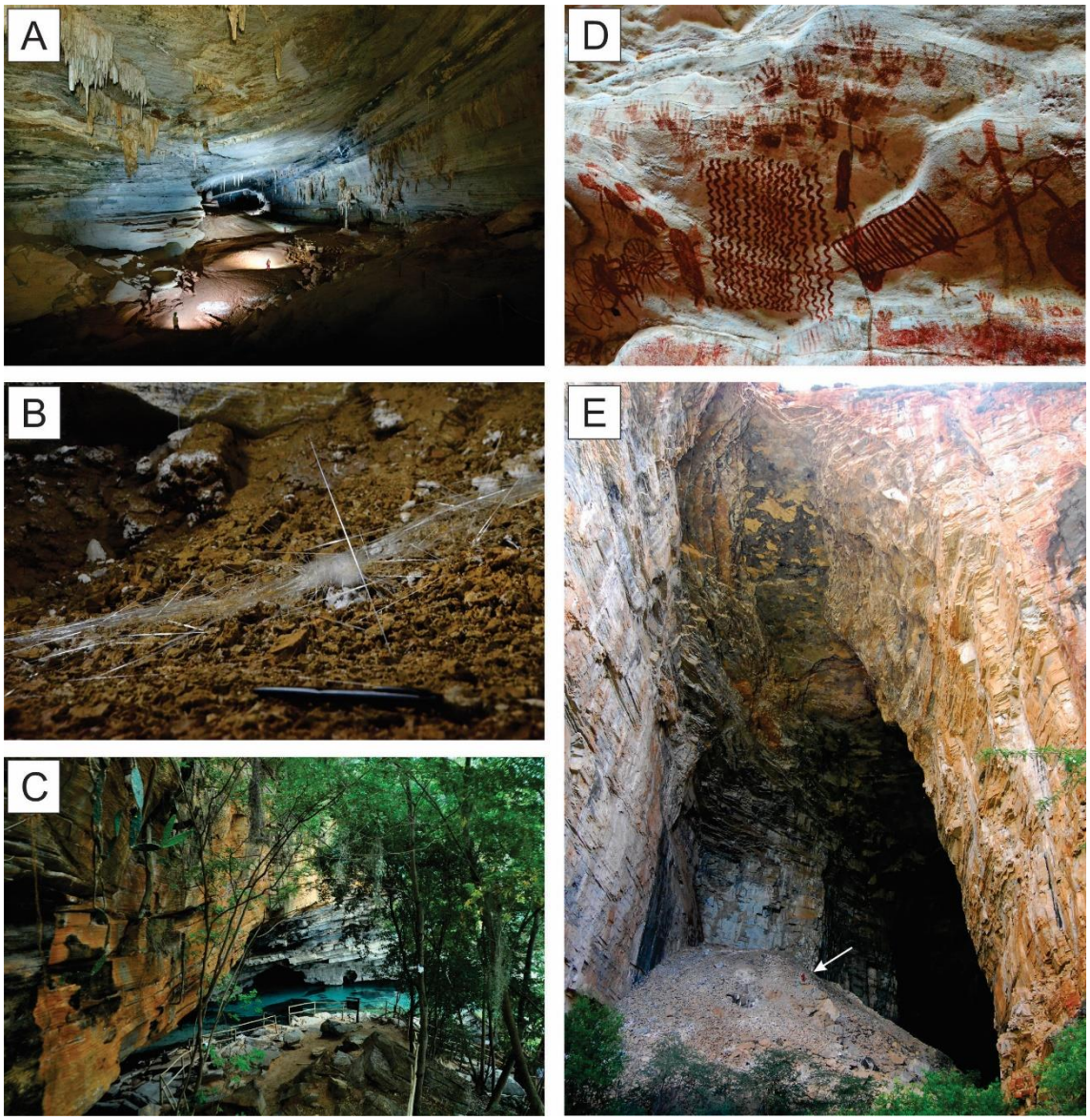

Figure 4. (A) Gallery of Lapa Doce I Cave (Photo: Solon Almeida Neto); (B) Gypsum needle speleothems in Torrinha Cave; (C) Resurgence of translucent emerald-blue waters from Pratinha Cave; (D) Rock paintings in the Santa Marta Shelter; (E) 106-m high entrance of Brejões Cave (person for scale indicated by white arrow).

3.1.2. Una-Utinga Basin

The Una-Utinga Basin, in the southeastern portion of Chapada Diamantina, corresponds to the areas where the rocks of the Una Group occur in the watersheds of the Una River, to the south, and the Utinga River, to the north. In addition, it covers the watersheds of the Santo Antônio and Paraguaçu rivers, in its central portion.

The most expressive karst features are concentrated in the southern region of the basin, where caves with a morphological pattern of large collapse galleries are common and the water level can usually be encountered in voluminous underground lakes (PEREIRA, 1998).

This is the case of Poço Encantado, in the municipality of Itaetê, one of the most popular postcards of Chapada Diamantina (KARMANN; PEREIRA; MENDES, 2002). The site receives its name due to a phenomenon that illuminates the lake, which occurs between the months of April and September, by sunrays that penetrate through the entrance of the cave (Fig. 5A). Poço Encantado has developed in dolomites and has about 506 m of horizontal projection, with an approximate height of 100 m from the entrance shaft to the water level, in addition to about

another 65 m underwater (RUBBIOLI, 1998). There are speleothems in the form of rafts, which occur on the surface of the lake, in addition to rimstone dams and stalactites, in smaller numbers.

Also noteworthy is the Lapa do Bode Cave, the largest cave in the region, with 5.3 km of development. It exhibits a network of horizontal passages, with straight and angular conduits, in which elliptical morphologies predominate, commonly with vadose carving, forming "keyhole" sections. Lapa do Bode is also home to a unique and rich biodiversity (GNASPINI; TRAJANO, 1994), with the presence of several species, including highly specialized troglobites.

It is possible that there is communication through an aquifer between the caves of Poço Encantado and Lapa do Bode, since the same species of troglobitic catfish occurs in them. Other evidence of this connection includes a correlation between water level variations in both caves.

3.1.3. Campinas Sub-Basin

The Campinas Sub-Basin comprises the deposits of the Una Group that outcrop in the northeastern region of Chapada Diamantina, an area drained by the Salitre River Basin. Cenozoic sediments, resulting from the dismantling of these Neoproterozoic ones, cover most of these deposits. In this case, extensive cave systems develop, from which the local communities extracted, in the past, saltpeter to produce gunpowder.

Close to the community of Laje dos Negros, in the municipality of Campo Formoso, is Toca da Boa Vista, the largest cave in Brazil and South America, with 114 km of development, and Toca da Barriguda, the second largest in the country, with 35 km mapped. Developed in the rocks of the Salitre Formation, on the left bank of the Rio Pacuí, one of the tributaries of the Rio Salitre, these two caves has been considered part of the same system, although speleologists have not yet found a connection (AULER; SMART, 2002).

They present a maze morphology, according to Palmer's classification (1991) and developed at a specific stratigraphic level, without any relation to the current surface landforms or fluvial morphologies. These aspects, together with the presence of features such as dissolution domes, suggest a formation by hypogenic processes (KLIMCHOUK et al., 2016; AULER et al., 2017; CAZARIN et al., 2019), closely related to structural aspects (ENNES-SILVA et al., 2015).

Both caves exhibit exuberant secondary deposits. In Toca da Boa Vista, we highlight the Discos Voadores passage (Fig. 5B), with subaqueous speleothems, such as rafts, cones, and shelfstones, in addition to deposits of septaria (contraction cracks filled with calcite) (Fig. 5C). In Toca da Barriguda, gypsum and bassanite speleothems are present, in addition to an abundance of more common speleothem forms, such as stalactites, stalagmites, and flowstones (AULER; SMART, 2002, 2003).

3.1.4. Ituaçu Syncline

In the southernmost part of Chapada Diamantina, Neoproterozoic rocks of the Una Group occur within the Ituaçu Syncline, an open synform structure with about 50 km of wavelength and axial trace oriented along a NNW-SSE direction (CRUZ; ALKMIM, 2007). In this region, where the municipality of Ituaçu is located, there are also important karst systems.

In *Serra das Araras* there is a series of caves, which can be accessed either through openings in the escarpments or through collapse sinkholes. The entrance of the Cortinas Cave presents a vertical shaft measuring 50 m and is largely ornamented by draperies and calcite flowstones. Lapa do Bode also shows impressive ornamentation, with the presence of exuberant stalactites and columns (Fig. 5D), as well as aragonite flowers. In addition, it also stands out for its biological and paleontological potential.

Another expressive cave in Ituaçu is Lapa da Mangabeira. The importance of this area is mainly due to Catholic religious manifestations, which include pilgrimages that attract about 100 thousand people every year to the cave (BARBOSA, 2009). The cave has infrastructure to receive the devotees, with stairs and artificial lighting, providing access to the chapels and the altar where masses are held (Fig. 5E). The pilgrims usually light candles, leave offerings, and drink the "sacred" waters of the cave.

3.1.5. Caboclo Formation and the Cristal Cave

At Fazenda Cristal, located in the municipality of Morro do Chapéu, eastern portion of Chapada Diamantina, carbonate facies at the base of the Caboclo Formation emerge, marked by the presence of internationally relevant

stromatolites. These structures are formed through microbial activities in aquatic environments (SRIVASTAVA; ROCHA, 2002). Expressive karst features, such as caves and sinkholes, develop in these rocks.

Cristal Cave, which is located also in this area, has 6.7 km of development, with a labyrinthine maze pattern in three preferred directions. According to La Bruna et al. (2021), sets of vertical fractures that coincide with the axial planes of open anticlinal folds control conduits and galleries (Fig. 5F). A particularity of this cave is the silicification of limestones at the stratigraphic level where it develops, possibly associated with hydrothermal processes (SOUZA et al., 2021). This factor may explain the scarcity of speleothems in the cave.

Large collapse sinkholes also occur in the area, such as the entrance to Velha Duda Cave and the Buracão Sinkhole, marked by steep walls, reaching 120 m in diameter and 50 m in depth (BERBERT-BORN; HORTA, 1995).

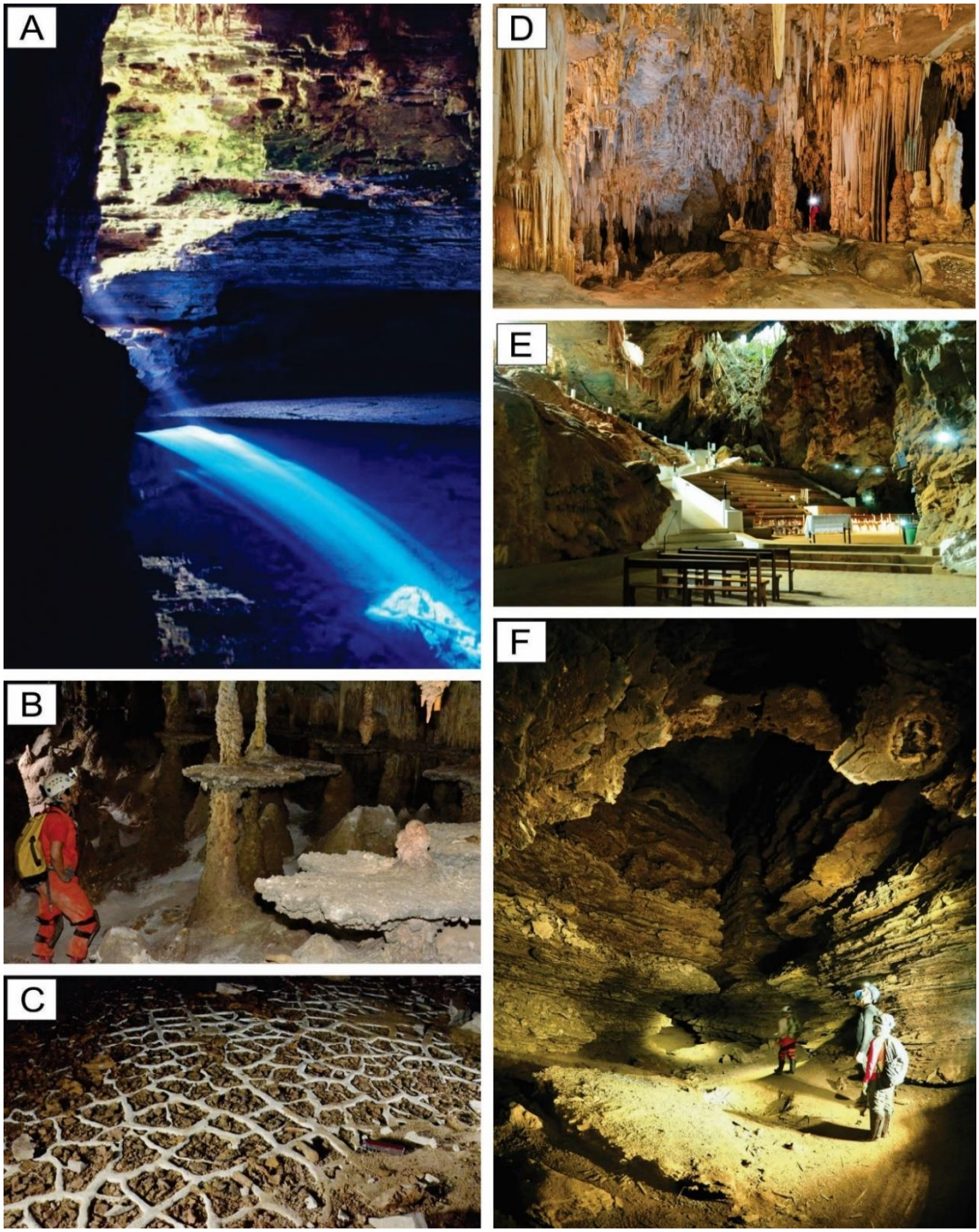

Figure 5. (A) Light phenomenon in the translucent lake of the Poço Encantado Cave; (B) Discos Voadores Hall and (C) Septarian speleothems of Toca da Boa Vista; (D) Speleothems of Lapa do Bode Cave, in Ituaçu (Photo: Solon Almeida Neto); (E) Church structure in the Mangabeira Cave; F) Conduit of Cristal Cave (Photo: CristalDOM Project – Prof. Francisco Hilário Bezerra, UFRN).

3.2. Siliciclastic Systems

3.2.1. Lapão Cave

Lapão Cave is located in the municipality of Lençóis and, despite having been an important tourist attraction at the end of the last century, it currently receives a modest number of visitors. With 1.6 km of development and a series of karst features such as sinking streams, sinkholes, and speleothems, it is among the most relevant caves in siliciclastic rocks in South America and worldwide (AULER, 2004; WRAY; SAURO, 2017).

Inserted in the eastern face of *Serra do Sincorá*, the cave develops at the contact between a conglomerate facies, which outcrops in the cavity ceiling, and a sandstone facies, which forms its walls and floor. In plan view, it presents a pattern of rectilinear morphology, with strong structural control of predominant NW-SE direction. The cave also has some narrow passages with low ceilings and large halls.

Within the Lapão Cave flows the Lapão River, whose sinkhole is located at an elevation of 634 m, while its resurgence is positioned at 495 m, about 80 m below the level of the main entrance to the cave (Figure 6A). The alluvial sediments deposited inside the cave serve as evidence of intense floods associated with this river. In addition, reports from local guides confirm episodes of fast water level rise in the underground river level during heavy rains. This phenomenon, together with the analysis of the geomorphology and hydrological dynamics of the region, suggests that river captures are developing upstream from the cave, increasing the catchment area of this river basin.

The diversity of secondary chemical deposits recognized in this cave includes stalagmites of large dimensions, small stalactites, coralloids, microgours, and helictites (Figure 6B). Many of these rare speleothems were damaged by visitors, with a significant portion having been broken and removed from the cave, on some occasions even used in the construction of house walls.

The Lapão Cave also stands out for its historical and cultural aspects and importance, mainly related to the exploration of diamonds. In the late 19th century and beginning of the 20th century, the cavity, as well as a good part of Chapada Diamantina, was the target of intense mining activity, which left marks in the form of caves and tunnels. Miners in search of diamond-containing river terraces built these structures to reach the diamonds (Figure 6C).

3.2.2. Castelo Cave

Castelo Cave is located in the municipality of Mucugê and receives an intense flow of visitors, estimated in about 9,000 people annually, based on verbal information from regional guides. This rate of visitation leaves evident marks along the cavity, such as the trampling of clastic and chemical deposits, as well as broken speleothems.

This cave is understood as a relict feature of the karst processes related to relief evolution in the Vale do Pati region. The Lapinha Hill, where the cavity develops, testifies that it has remained from the process of differentiated erosion of the antiform structure present there. Ruiniform reliefs are present in this hill, marked by intense weathering action concentrated along vertical fracture planes, generating erosive surfaces with clear structural control, which are characteristic of karst reliefs in sandstone rocks, according to Wray (2013).

The entrance to the cave is at an elevation of 1,320 m, more than 350 m above the Funis River, the current base level of the slope. The Castelo Cave has about 380 m of horizontal development and 35 m of altitudinal difference. Each of its three entrances provides access to a conduit of predominantly linear geometry, in some points meandering. These conduits, which are preferentially oriented in the E-W direction, relate to water bodies that are sometimes visible and sometimes confined by the debris of blocks and clastic deposits.

It is common to observe lithological variation between the sandstone facies that make up the ceiling and walls of the cavity, which involves, according to microscopic analyses by Souza (2019), a difference in the mineralogical composition of the rock and in the percentages of matrix and pores that can control the genesis of the cave. There are also frequent features of initiation and evolution of karst porosity, such as *tafoni* (Figure 6D), evidence of the dissolution of cement and/or rock matrix, especially taking advantage of discontinuities associated with primary structures, such as bedding planes and cross-bedding.

Castelo Cave has a wide variety of speleothems that, despite being mostly small, have a rich diversity of shapes and colors. Essentially, coralloids, cauliflower-shaped speleothems, crusts, and microgours are present. The

presence of a geoform known as "stone arch", in the external part of the cavity, close to its entrance, suggests that the Castelo Cave must have been larger, but has suffered collapses (Figure 6E).

3.2.3. Vila de Igatu, Andaraí

Vila de Igatu, also known as Xique-Xique de Igatu, is a district of the municipality of Andaraí, on the eastern edge of Chapada Diamantina. Its history closely relates to diamond exploration (NOLASCO; MEDEIROS; OLIVEIRA, 2001). At the peak of mining activity, it was home to tens of thousands of people. Today, with the decline of mining in the region, the village counts less than 400 inhabitants. This mining activity left important historical, cultural and architectural records, which led to the listing of the area as a geoheritage site (NOLASCO et al., 2017).

Part of these records is associated with the karst relief, especially the caves, which developed in the sandstones and conglomerates of the Tombador Formation. Many of these caves were accessed and modified by miners who, in search of diamonds in the alluvial deposits, unblocked conduits obstructed by sediment, excavated new galleries, and altered the course of underground rivers. Today, it is a challenge to distinguish between natural and anthropic processes in the evolution of each cave.

Although well-known by local residents, few technical and scientific studies have been carried out in these caves. There are eleven caves registered in the National Registry of Speleological Information (CANIE) for this locality, but oral reports suggest that the number of occurrences is much higher. Only a minority of this cave set is mapped and documented. However, there is a significant amount of research on local biodiversity, with the region being considered a hotspot for neotropical subterranean fauna, highlighting the occurrence of troglobitic species, such as mollusks, scorpions, spiders, and fish (GALLÃO; BICHUETTE, 2015).

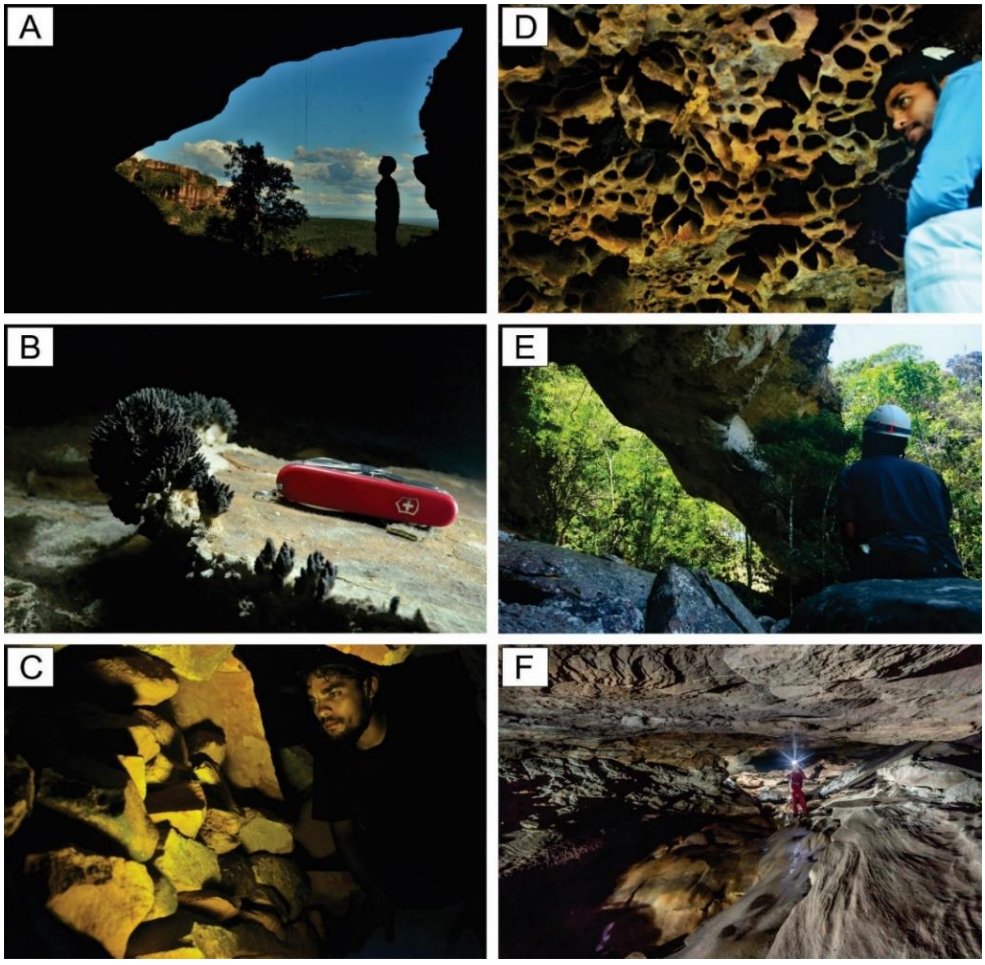

Figure 6. (A) Internal view of the entrance of Lapão Cave; (B) Helictites and (C) containment structures made of stones, from the diamond-mining period in Lapão Cave; (D) *Tafoni* dissolution features and (E) "Stone Arch" structure of Castelo Cave; (F) Gallery of Torras Cave (Photo: Daniel Menin).

The most relevant cave in the Igatu region is Torras Cave (Fig. 6F). With 3.6 km of horizontal development, Auler and Sauro (2019) classify it as the 2nd largest in Brazil and 8th largest in South America, among caves that developed in sandstone and quartzite rocks. Rock dissolution features are present in its interior, along sub-vertical fracture planes, as well as collapse marks, along the sub-horizontal bedding planes. This evidence suggests an initial formation through the dissolution of sandstones, with subsequent enlargement due to collapsing.

4. Conclusions

Chapada Diamantina occupies an area of 65,619 km² in the central region of the state of Bahia. It is characterized by reliefs with mountains, plateaus, and karst systems, developed in Proterozoic sedimentary and metasedimentary rocks. Karst systems are found in this territory in carbonate rocks of the Salitre and Caboclo formations, as well as in siliciclastic rocks of the Tombador Formation. Important features are present in these terrains, such as caves, sinkholes and resurgences, speleothems, among others.

As presented in this paper, the Chapada Diamantina caves are of exceptional importance in several aspects. Their scientific value is particularly noteworthy, with different disciplines finding, in these environments, relevant records of geological history and of the species (including human ones) that have already inhabited, or still inhabit, the region. Also noteworthy are the historical and cultural values, which are present, for example, in archaeological and current religious manifestations in several caves.

The Karst Systems in Chapada Diamantina house the longest cave of the southern hemisphere - the Toca da Boa Vista, with about 120 km mapped and located at the municipality of Campo Formoso. Furthermore, at the district of Igatu, located at the municipallity of Andaraí, in the mesoproterozoic siliciclastic rocks of the Tombador Formation, the Torras cave with 3.6 km mapped is one of the longest caves in the world in this kind of lithology.

Many of these karst landscapes are important tourist attractions, nationally and internationally, receiving thousands of visitors a year. At the center of Chapada Diamantina, the municipality of Iraquara houses one of the highest concentrations of caves in Brazil, and represents one of the most important speleotourism centers in the country. The successfully experience obtained at this municipality could be adopted in other karst districts.

It should be noted, however, that karst reliefs, especially caves, have their specificities and are usually quite sensitive environments to anthropic impact. Therefore, it is necessary that the structure and planning of tourist activities are based on scientific recommendations and proposals aligned with local knowledge. Only then can we avoid risks both to visitors and to the speleological heritage.

The municipalities where the diversified karst systems are located, in general, are characterized by low socioeconomic indexes. The use of this heritage for speleotourism activities could be an alternative to foster sustainable use, of part of these karst regions, and provide alternatives for employment and incomes.

Despite its diversity, with karst systems installed in rocks of distinct ages and lithologies, the researches related to speleogenesis and other geodiversity aspects are concentrated only in a few karst terrains of Chapada Diamantina. Even though these researches have a localized character, they were able to recover relevant and detailed information from the geological and geomorphological record, such as of climate changes in the northeast of South America.

Finally, it is worth highlighting the enormous potential that this territory still holds, for a better characterization of the systems that have not yet been adequately studied, especially those in siliciclastic rocks, as well as for the exploration and discovery of new ones.

Author's contributions: PARRA, R.; PEREIRA, R. G. F. de A.: Conception, Research, Writing; PURIFICACAO, C. G. C. da: Cartography; PEREIRA, R. G. F. de A.: Supervision, Revision.

Funding: Masters Scholarship from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

Acknowledgments: We acknowledge the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), for funding through scholarship and the photographers for kindly providing their images. *In memoriam* of Caroline Lessio Cazarin.

Conflict of interest: The authors declare no conflict of interest**.**

References

1. ALKMIM, F. O que faz de um cráton um cráton? O Cráton do São Francisco e as revelações Almeidianas ao delimita-lo. In: MANTESSO-NETO, V., BARTORELLI, A., CARNEIRO, C.D.R., BRITO-NEVES, B.B. (Eds.). **Geologia do Continente Sul-Americano: Evolução da obra de Fernando Flávio Marques de Almeida**. Becca, 2004. p. 17-35.
2. ALKMIM, F.F, CHEMALE, J.R.F., ENDO, I. A deformação das coberturas proterozóicas do Cráton do São Francisco. **Revista Escola de Minas**, v. 1, p. 22–38, 1996.
3. AULER, A. Quartzite Caves of South America. In: GUNN, J. (Ed.). **Encyclopedia of Cave and Karst Science**. New York: Fitzroy Dearborn, 2004. p. 1306-1311.
4. AULER, A.S., SMART, P.L. Toca da Boa Vista (Campo Formoso), Ba – A Maior Caverna do Hemisfério Sul. In: SCHOBBENHAUS, C., CAMPOS, D.A., QUEIROZ, E.T., WINGE, M., BERBERT-BORN, M. (Eds.). **Sítios Geológicos e Paleontológicos do Brasil**. 1ª Ed. Brasília: DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP), 2002. v. 1, p. 443-452.
5. AULER, A.S., SMART, P.L. The influence of bedrock-derived acidity in the development of surface and underground karst: evidence from the Precambrian carbonates of semi-arid northeastern Brazil. **Earth Surface Processes and Landforms**, v. 28, n. 2, p. 157-168, 2003.
6. AULER, A.S., KLIMCHOUK, A., BEZERRA, F.H.R.B., CAZARIN, C.L., ENES-SILVA, R., BALSAMO, F. Origin and evolution of Toca da Boa Vista and Toca da Barriguda cave system in northeastern Brasil. In: KLIMCHOUK, A., PALMER, A., WAELE, J.D., AULER, A.S., AUDRA, P. (Eds.) **Hypogene karst regions and caves of the world**. [s.l.] Springer, 2017. p. 827-840. doi.org/10.1007/978-3-319-53348-3_56
7. AULER, A.S., SAURO, F. Quartzite and quartz sandstone caves of South America. In: WHITE, W.B., CULVER, D.C., PIPAN, T. (Eds.) **Encyclopedia of Caves**. London: Academic Press, 2019. p. 850-860.
8. BARBOSA, E.P. Cavernas e Religião: Considerações Sobre Algumas Romarias em Cavernas no Sertão da Bahia. In: XXX Congresso Brasileiro de Espeleologia (CBE), 2009, Montes Claros (MG). **Anais...** Sociedade Brasileira de Espeleologia. p. 1-6.
9. BARBOSA, J.S.F., DOMINGUEZ, J.M.L. Mapa geológico do Estado da Bahia ao milionésimo. Scale 1:1.000.000. Salvador: SICM, SGM, 1996.
10. BARRETO, E.A.S. **Reconstituição da pluviosidade da Chapada Diamantina (BA) durante o Quaternário Tardio através de registros isotópicos (O e C) em estalagmites**. Dissertação (Mestrado em Geoquímica e Geotectônica) – Instituto de Geociências, Universidade de São Paulo, São Paulo, 2010.
11. BERBERT-BORN, M., HORTA, L.S. Espeleologia. In: ROCHA, A.J.D., COSTA, I.V.G. (Eds.) **Informações básicas para o planejamento e administração do meio físico**. Salvador: CPRM, 1995. p. 158-202.
12. BERBERT-BORN, M., KARMANN, I. Lapa dos Brejões - Vereda Romão Gramacho, Chapada Diamantina, Bahia - Gigantesca caverna e vale cárstico com rico depósito de fósseis do Quaternário. In: SCHOBBENHAUS, C., CAMPOS, D.A., QUEIROZ, E.T., WINGE, M., BERBERT-BORN, M. (Eds.) **Sítios Geológicos e Paleontológicos do Brasil**. 1ª Ed. Brasília: DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP), 2002. v. 1, p. 469-479.
13. BRITO, F.E.M. **Os ecos contraditórios do turismo na Chapada Diamantina**. Salvador: Ed. EDUFBa, 2005. 418p.
14. CAZARIN, C.L., BEZERRA, F.H., BORGHI, L., SANTOS, R.V., FAVORETO, J., BROD, J.Á., AULER, A., SRIVASTAVA, N.K. The conduit-seal system of hypogene karst in Neoproterozoic carbonates in northeastern Brazil. **Marine and Petroleum Geology**, v. 101, p. 90-107, 2019. doi.org/10.1016/j.marpetgeo.2018.11.046
15. CRUZ, S.C.P., ALKMIM, F.F. The Tectonic interaction between the Paramirim Aulacogen and the Araçuaí Belt, São Francisco craton region, Eastern Brazil. **Anais da Academia Brasileira de Ciências**, v. 78, n. 1, p. 151-173, 2006. doi.org/10.1590/S0001-37652006000100014.
16. CRUZ, S.C.P., ALKMIM, F.F. A história de inversão do aulacógeno do Paramirim contada pela sinclinal de Ituaçu, extremo Sul da Chapada Diamantina (BA). **Revista Brasileira de Geociências**, v. 37, n. 4, p. 92-110, 2007.
17. DALTON DE SOUZA, J.; KOSIN, M.; MELO, R. C.; SANTOS, R. A.; TEIXEIRA, L. R.; SAMPAIO, A. R.; GUIMARÃES, J. T.; VIEIRA BENTO, R.; BORGES, V. P.; MARTINS, A. A. M.; ARCANJO, J. B.; LOUREIRO, H. S. C.; ANGELIM, L. A. A. **Mapa Geológico do Estado da Bahia – Escala 1:1.000.000**. Salvador: CPRM, 2003. Versão 1.1. Programas Carta Geológica do Brasil ao Milionésimo e Levantamentos Geológicos Básicos do Brasil (PLGB). Convênio de Cooperação e Apoio Técnico-Científico CBPM-CPRM.
18. ENNES-SILVA, R. A., BEZERRA, F. H., NOGUEIRA, F. C., BALSAMO, F., KLIMCHOUK, A., CAZARIN, C. L., & AULER, A. S. Superposed folding and associated fracturing influence hypogene karst development in Neoproterozoic carbonates, São Francisco Craton, Brazil. **Tectonophysics**, v. 666, p. 244-259, 2016.

19. FERREIRA, C.F. Levantamento Espeleológico e Considerações Relativas ao Manejo do Patrimônio Espeleológico em Unidades de Conservação Federais. In: XXX Congresso Brasileiro de Espeleologia (CBE), 2009, Montes Claros (MG). **Anais...** Sociedade Brasileira de Espeleologia. p. 69-75.
20. FURTADO, C.P., BORGES, S.V., BEZERRA, F.H., DE CASTRO, D.L., MAIA, R.P., TEIXEIRA, W.L., SOUZA, A.M., AULER, A.S., LIMA-FILHO, F.P. The fracture-controlled carbonate Brejões Karst System mapped with UAV, LiDAR, and electroresistivity in the Irecê Basin-Brazil. **Journal of South American Earth Sciences**, v. 119, 103986, 2022a.
21. FURTADO, C.P., MEDEIROS, W.E., BORGES, S.V., LOPES, J.A., BEZERRA, F.H., LIMA-FILHO, F.P., MAIA, R.P, BERTOTTI, G., AULER, A.S., TEIXEIRA, W. L. The influence of subseismic-scale fracture interconnectivity on fluid flow in fracture corridors of the Brejões carbonate karst system, Brazil. **Marine and Petroleum Geology**, v. 141, 105689, 2022b.
22. GALLÃO, J.E., BICHUETTE, M.E. Taxonomic distinctness and conservation of a new high biodiversity subterranean area in Brazil. **Anais da Academia Brasileira Ciências**, v. 87, p. 209-217, 2015. doi.org/10.1590/0001-3765201520140312
23. GIUDICE, D.S. **Geodiversidade e Lógicas Territoriais na Chapada Diamantina – Bahia**. Série Publicações Especiais, v. 12. Salvador: CBPM, 2012. 126p.
24. GNASPINI, P., TRAJANO, E. Brazilian Cave Invertebrates, with a Checklist of Troglomorphic Taxa. **Revista Brasileira de Entomologia**, v. 38, n. 3, p. 549-584, 1994.
25. GUIMARÃES, J.T. **Projeto Ibitiara-Rio de Contas: Estado da Bahia**. Programa Recursos Minerais do Brasil. Salvador: CPRM, 2005. 157p. 3 mapas.
26. GUIMARÃES, J.T., PEDREIRA, A.J. Geologia da Chapada Diamantina Oriental, Bahia (Folha Utinga). In: GUIMARÃES, J.T., PEDREIRA, A.J. (Org.) **Programa de Levantamentos Geológicos Básicos do Brasil - Utinga (Folha SD.24-V-A-II)**. Estado da Bahia, Texto Explicativo. Brasília: DNPM/CPRM, 1990. p. 19–92.
27. GUIMARÃES, J.T., SANTOS, R.A.S., MELO, R.C. **Geologia da Chapada Diamantina Ocidental (Projeto Ibitiara – Rio de Contas)**. Série Arquivos Abertos, v. 31. Salvador: CBPM, CPRM, 2008.
28. GUIMARÃES, J.T., ALKMIM, F.F., CRUZ, S.C.P. Supergrupos Espinhaço e São Francisco. In: BARBOSA, J.S.F. (Ed.) **Geologia da Bahia: Pesquisa e Atualização**. Série Publicações Especiais, v. 2. Salvador: CBPM, 2012. p. 32-85.
29. INDA, H.A.V., BARBOSA, J.S.F. **Texto Explicativo para o Mapa Geológico do Estado da Bahia**. Escala 1:1.000.000. Salvador: SME/CPM, 1978. 237p.
30. ICMBIO - Instituto Chico Mendes de Conservação da Biodiversidade. **Anuário Estatístico do Patrimônio Espeleológico Brasileiro 2020**. Brasília: Centro Nacional de Pesquisa e Conservação de Cavernas (CECAV), 2021. https://www.gov.br/icmbio/pt-br/assuntos/centros-de-pesquisa/cecav/publicacoes/Publicacaoes[accessed: April 15, 2022].
31. KARMANN, I., PEREIRA, R.G.F.A., MENDES, L.F. Caverna do Poço Encantado, Chapada Diamantina, Bahia: patrimônio geológico e biológico. In: SCHOBBENHAUS, C., CAMPOS, D.A., QUEIROZ, E.T., WINGE, M., BERBERT-BORN, M. (Eds.) **Sítios Geológicos e Paleontológicos do Brasil**. 1ª Ed. Brasília: DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP), 2002. v. 1, p. 491-498.
32. KLIMCHOUK, A., AULER, A. S., BEZERRA, F. H., CAZARIN, C. L., BALSAMO, F., & DUBLYANSKY, Y. Hypogenic origin, geologic controls and functional organization of a giant cave system in Precambrian carbonates, Brazil. **Geomorphology**, v. 253, p. 385-405, 2016.
33. LA BRUNA, V., BEZERRA, F.H.R., SOUZA, V.H.P., MAIA, R.P., AULER, A.S., ARAUJO, R.E.B., CAZARIN, C.L., RODRIGUES, M.A.F., VIEIRA, L.C., SOUSA, M.O.L. High-permeability zones in folded and faulted silicified carbonate rocks – implications for karstified carbonate reservoirs. **Marine and Petroleum Geology**, v. 128, 105046, 2021. doi.org/10.1016/j.marpetgeo.2021.105046
34. LAUREANO, F.V., CRUZ JR, F.W. Grutas de Iraquara – (Iraquara, Seabra e Palmeiras), BA – Um dos principais sítios espeleológicos do Brasil. In: SCHOBBENHAUS, C., CAMPOS, D.A., QUEIROZ, E.T., WINGE, M., BERBERT-BORN, M.L.C. (Eds.) **Sítios Geológicos e Paleontológicos do Brasil**. 1ª Ed. Brasília: DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP), 2002. v. 1, p. 461-468.
35. LIMA, C.C.U., NOLASCO, M.C. Chapada Diamantina: a remarkable landscape dominated by mountains and plateaus. In: VIEIRA, B.C., SALGADO, A.A.R., DOS SANTOS, L.J.C. (Eds.) **Landscapes and landforms of Brazil**. New York: Springer, 2015. p. 211–220.
36. MAGALHÃES, A.J.C., SCHERER, C.M.S., RAJA GABAGLIA, G.P., BÁLLLICO, M.B. Unincised fluvial and tide-dominated estuarine systems from the Mesoproterozoic Lower Tombador Formation, Chapada Diamantina basin, Brazil. **Journal of South American Earth Sciences**, v. 56, p. 68-90, 2014. doi.org/10.1016/j.jsames.2014.07.010
37. MAGALHÃES, A.J.C., SCHERER, C.M.S., RAJA GABABLIA, G.P., CATUNEANU, O. Mesoproterozoic delta systems of the Açuruá Formation, Chapada Diamantina, Brazil. **Precambrian Research**, v. 257, p. 1-21, 2015. doi.org/10.1016/j.precamres.2014.11.016

38. MISI, A., VEIZER, J. Neoproterozoic carbonate sequences of the Una Group, Irece Basin, Brazil: chemostratigraphy, age and correlations. **Precambrian Research**, v. 89, p. 87-100, 1998. doi.org/10.1016/S0301-9268(97)00073-9
39. MISI, A., KAUFMAN, A.J., VEIZER, J., POWIS, K., AZMY, K., BOGGIANI, P.C., GAUCHER, C., TEIXEIRA, J.B.G., SANCHES, A.L., IYER, S.S. Chemostratigraphic correlation of Neoproterozoic successions in South America. **Chemical Geology**, v. 237, p. 143-167, 2007. doi.org/10.1016/j.chemgeo.2006.06.019
40. NOLASCO, M.C., MEDEIROS, R.A., OLIVEIRA, A.M. Depósitos diamantíferos garimpáveis das lavras diamantinas, BA: a geologia do olhar garimpeiro. **Revista Brasileira de Geociências**, v. 31, n. 4, p. 457-470, 2001.
41. NOLASCO, M.C., SILVESTRE, P., TORLAY, R., ROCHAS, A.J.D. Patrimônio Garimpeiro: Memória do Diamante. In: PEREIRA, R.G.F.A., ROCHA, A.J.D., PEDREIRA, A.J. **Geoparque Serra do Sincorá (BA) – Proposta**. SGB/CPRM. Anexo II, 30 p, 2017.
42. PALMER, A.N. Origin and Morphology of Limestone Caves. **Geological Society of America Bulletin**, v. 103, p. 1-21, 1991.
43. PEDREIRA, A.J. **O Supergrupo Espinhaço na Chapada Diamantina Centro-Oriental, Bahia: Sedimentologia, Estratigrafia e Tectônica**. Tese (Doutorado em Geoquímica e Geotectônica) – Instituto de Geociências, Universidade de São Paulo, São Paulo, 1994.
44. PEDREIRA, A.J., DE WAELE, B. Contemporaneous evolution of the Paleoproterozoic-Mesoproterozoic sedimentary basins of the São Francisco-Congo craton In: PANKHURST, J.R., TROUW, R.A.J., BRITO NEVES, B.B., DE WIT, M.J. (Eds.) **West Gondwana: Pre-Cenozoic Correlations across the South Atlantic Region**. Spec. Publ. London: Geological Society of London. v. 294, 2008. p. 33-48.
45. PEREIRA, R.G.F.A. **Caracterização Geomorfológica e Geoespeleológica do Carste da Bacia do Rio Una, Borda Leste da Chapada Diamantina (Município de Itaetê, Estado da Bahia)**. Dissertação (Mestrado em Geoquímica e Geotectônica) – Instituto de Geociências, Universidade de São Paulo, São Paulo, 1998.
46. PEREIRA, R.G.F.A. **Geoconservação e desenvolvimento sustentável na Chapada Diamantina (Bahia-Brasil)**. Tese (Doutoramento em Ciências – Especialidade em Geologia). Escola de Ciências, Universidade do Minho, 2010.
47. PONTES, C. C., BALSAMO, F., PIZZATI, M., BEZERRA, F. H., LA BRUNA, V., & LIMA, R. S. Burial stylolites enhance karst dissolution and control cave geometry in heterolithic carbonates, Salitre Formation, Brazil. **Marine and Petroleum Geology**, v. 148, 106029, 2023.
48. ROCHA, A.J.D., PEREIRA, C.P., SRIVASTAVA, N.K.. Carbonatos da Formação Caboclo (Proterozoico médio) na região de Morro do Chapéu – Estado da Bahia. **Revista Brasileira de Geociências**, v. 22, n. 4, p. 389-398, 1992.
49. RUBBIOLI, E.L. Iraquara - Um Novo Paraíso Espeleológico. **O Carste**, v. 7, n. 3, p. 34-40, 1995.
50. RUBBIOLI, E.L. Mergulho no Sertão Baiano - Projeto Hidrocarste. **O carste**, v. 10, n. 1, p. 20-25, 1998.
51. SALLES, L.D.Q., LEAL, L.R.B., PEREIRA, R.G.F.D.A., NASCIMENTO, S.A.D.M., BARBOSA, N.D.S., LAUREANO, F.V., & ZUCCHI, M.D.R. Hydrogeochemical and isotopic tools (δ 18 O and δ 2 H) applied to understanding the processes of groundwater salinization in Proterozoic carbonate aquifers: evidence from the semi-arid region of Northeastern Brazilian. **Anuario do Instituto de Geociencias** (Online), v. 42, n. 2, p. 117-125, 2019.
52. SCHOBBENHAUS, C. As tafrogêneses superpostas Espinhaço e Santo Onofre, Estado da Bahia: Revisão e novas propostas. **Revista Brasileira de Geociências**, v. 26, p. 265-276, 1996.
53. SOUZA, C.E.F. **Caracterização Geológica e Topografia Espeleológica da Gruta do Castelo, Vale do Pati, Chapada Diamantina (BA)**. Monografia (Graduação em Geologia) – Instituto de Geociências, Universidade Federal da Bahia, Salvador, 2019.
54. SOUZA, V.H.P., BEZERRA, F.H.R., VIEIRA, L.C., CAZARIN, C.L., BROD, J.A. Hydrothermal silicification confined to stratigraphic layers: implications for carbonate reservoirs. **Marine and Petroleum Geology**, v. 124, 104818, 2021. doi.org/10.1016/j.marpetgeo.2020.104818
55. SRIVASTAVA, N.K., ROCHA, A.J.D. Fazenda Cristal, BA – Estromatólitos mesoproterozoicos. In: SCHOBBENHAUS, C., CAMPOS, D.A., QUEIROZ, E.T., WINGE, M., BERBERT-BORN, M. (Eds.) **Sítios Geológicos e Paleontológicos do Brasil**. 1ª Ed. Brasília: DNPM/CPRM – Comissão Brasileira de Sítios Geológicos e Paleobiológicos (SIGEP), 2002. v. 1, p. 87-93.
56. SEI - Superintendência de Estudos Econômicos e Sociais da Bahia. **Mapa de Tipologia Climática Koppen: Estado da Bahia**. Bahia: Secretaria do Planejamento, Ciência e Tecnologia, 1998. Escala 1:2.000.000.
57. TEIXEIRA, J.B.G., MISI, A., SILVA, M.G. Supercontinent evolution and the Proterozoic metallogeny of South America. **Gondwana Research**, v. 11, n. 3, p. 346- 361, 2007. doi.org/10.1016/j.gr.2006.05.009
58. VALLE, M.A. **Hidrogeoquímica do Grupo Una (Bacias de Irecê e Salitre): um Exemplo da Ação de Ácido Sulfúrico no Sistema Cárstico**. Tese (Doutorado em Geoquímica e Geotectônica) – Instituto de Geociências, Universidade de São Paulo, São Paulo, 2004.

59. WRAY, R.A.L. Solutional weathering and karstic landscapes on quartz sandstones and quartzite. In: FRUMKIN, A. (Ed.) **Treatise on Geomorphology**. San Diego: Academic Press, 2013. v. 6, p. 463–483.
60. WRAY, R.A.L., Sauro, F. An updated global review of solutional weathering processes and forms in quartz sandstones and quartzites. **Earth-Science Reviews**, v. 171, p. 520-557, 2017. doi.org/10.1016/j.earscirev.2017.06.008