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National in Scope:
1 - Geoethics and geoconservation: integrated approaches;
2 - Classification of geo-mining heritage based on anthropogenic geomorphology;
3 - The performance of the Geoparks Commission of the Brazilian Geology Society, from 2018 to 2020.

Assessment of geodiversity and geological heritage
4 - MT - Three hundred years of geodiversity in the Historic Center of the Gold City, Cuiabá, Brazil;
5 - PR - A survey of the paleontological heritage of Paraná State, Brazil ;
6 - SP - The geological heritage of the state of São Paulo: potential geosites as a contribution to the Brazilian national inventory.

Geotourism and geoparks
7 - BA - Characterization of the potential demand of geotourists in Lençóis, state of Bahia, Brazil: Serra do Sincorá Geopark Project;
8 - RJ - Geologic Highway Map of Rio de Janeiro State: a product to stimulate geotourism and broadcast Rio de Janeiro's geodiversity;

Geodiversity and society
9 - PE - The opinion of divers on the interpretation of marine geology in the archipelago of Fernando de Noronha (Brazil);
10 - SP - Strategic diagnosis of geocommunication using SWOT analysis in the Varvite Geological Park, São Paulo, Brazil.

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Journal of the Geological Survey of Brazil

Special Issue on Geoconservation

Invited Editors

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Editorial from the Editor-in-Chief

Initiatives to protect the Earth system in several countries are known since the seventeenth century, mostly dealing with the preservation of fossils, caves, and other geomorphological features. The word **"Geoconservation"**, which best describes this activity, appeared and became popular in the 1990's, together with subjects such as Geoknowledge, Geoheritage, Geotourism, Geoparks, Geodiversity, and led to the gradual development of this emerging branch of Geosciences also in Brazil. As a whole, Geoconservation includes the inventory, assessment, protection, valuation and sustainable use of geological heritage along with legal initiatives, aimed at preserving or conserving geological-geomorphological sites of interest.

Therefore, I am proud to open this first special issue of the Journal of the *Geological Survey of Brazil* – JGSB – to the Geoconservation theme. I am grateful to the Invited Editors, **Marcos Antônio Leite do Nascimento** (Federal University of Rio Grande do Norte), **Maria da Glória Motta Garcia** (University of São Paulo), and **Kátia Leite Mansur** (Federal University of Rio de Janeiro), recognized researchers who accepted the task of compiling this edition, and the reviewers, who brought their expertise to make the published version of the articles to be the best possible. Most of all, thanks to the authors who accepted JGSB as the venue for publishing your research, without which this special volume would not be possible, you are most acknowledged.

I hope the readers enjoy this special issue, and that it can contribute to the dissemination of Geoconservation to the geoscientific community.

Evandro L. Klein
Editor-in-Chief
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Introduction to the special issue on "Geoconservation" of the Journal of the Geological Survey of Brazil

Invited Editors

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1. Introduction

Since 1997, when the Brazilian Commission of Geological and Paleobiological Sites (SIGEP) was created, the subjects of Geodiversity, Geological Heritage, Geoconservation, Geotourism, and Geoparks - the so-called 5 Gs - have been gradually included in the national events and publications.

An increasingly expressive number of researchers and institutions have been working to study and promote this area, an effort that has led to the creation of a specific event, the Brazilian Symposium on Geological Heritage (BSGH), which the first edition took place in 2011, in the city of Rio de Janeiro.

Over the years, an intense exchange of knowledge, the development of methods, and the achievement of technical and scientific support through partnerships with researchers and international institutions, have gradually promoted the scientific maturity necessary for the advancement of this research area in Brazil. From almost exclusively descriptive works, aimed mainly at the dissemination of sites of geological interest, research at the national level has progressively included discussions and ideas that bring important scientific contributions to the development of methods and concepts focused on geodiversity, geological heritage, and geoconservation. Moreover, these advances have been accompanied by a growing concern with the insertion of these themes in the scope of society, which reinforces the multidisciplinary character of geoconservation and the crucial role of geosciences in understanding the great current socio-environmental themes.

It is with pleasure that we present the Special Issue on Geoconservation of the Journal of the Geological Survey of Brazil, which brings relevant contributions from Brazilian researchers on topics ranging from data collection to geoscientific outreach. These papers were initially presented as abstracts at the V Brazilian Symposium on Geological Heritage, held in Crato, Ceará, from October 14 to 18, 2019.

2. Content of the Special Issue

The ten articles in this special volume cover numerous aspects of the topic of Geoconservation. Three of the papers are national in scope and deal with geoethics, mining heritage, and geoparks, while the other seven articles have a more local scope, being related to the assessment of geodiversity and geological heritage (three papers); geotourism and geoparks (two papers); and geodiversity and society (two papers). Those of more local importance are highlighted in Figure 1, being two in the state of São Paulo and one in the states of Mato Grosso, Paraná, Rio de Janeiro, Bahia, and Pernambuco. In the following paragraphs, these papers are briefly described.

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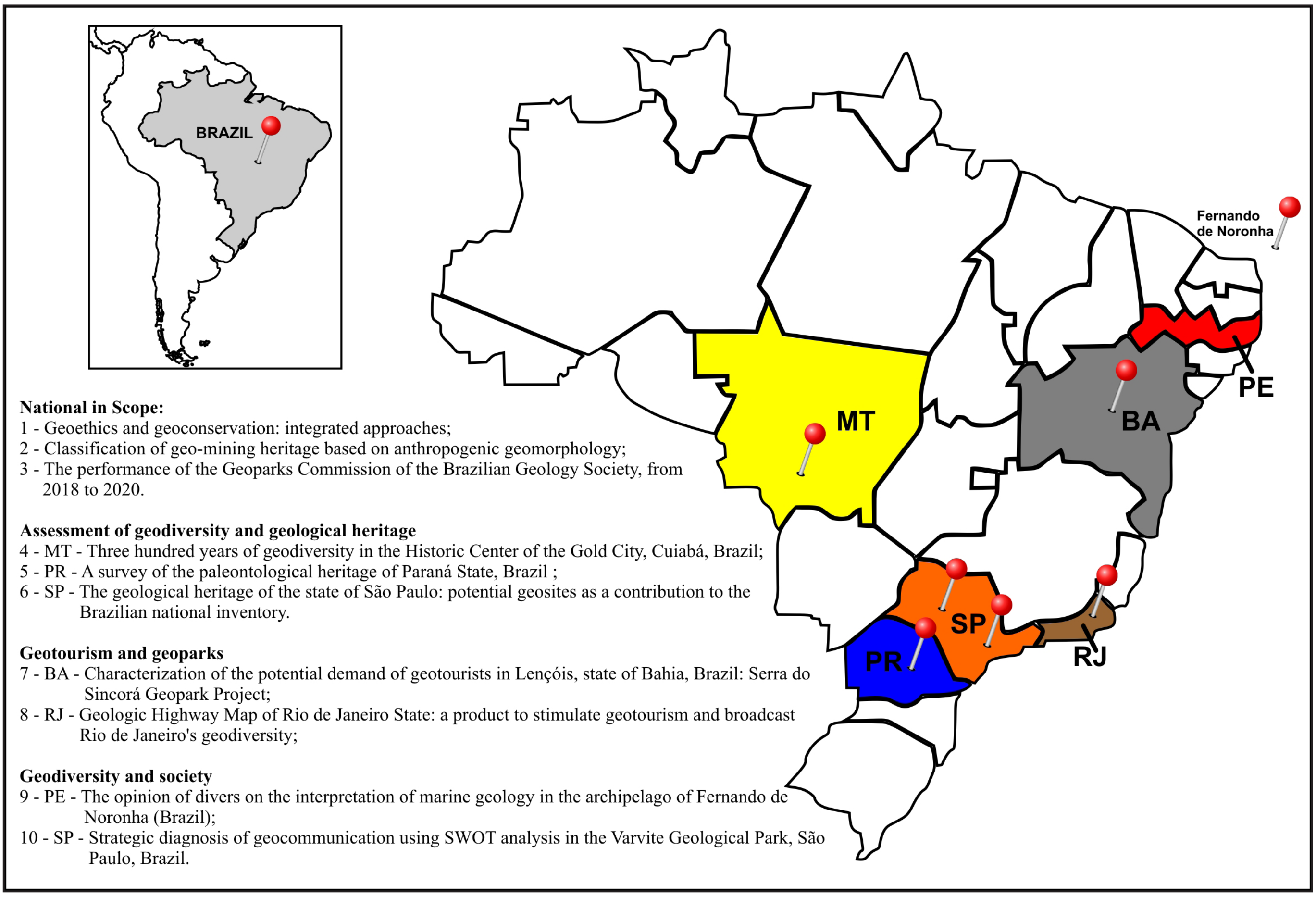

FIGURE 1. Location of the studied areas addressed by the articles included in this special issue

2.1. National in scope (geoethics, mining heritage and geoparks)

The paper “Geoethics and geoconservation: integrated approaches” by **Paulo de Tarso Amorim Castro, Kátia Leite Mansur, Úrsula Azevedo Ruchkys, and Rosely Aparecida Liguori Imbernon** (Castro et al. 2021a) presents a discussion on integrative approaches regarding two emerging fields of geosciences: geoconservation and geoethics. While the first is related to the conservation relevant elements of geodiversity and associated processes, the latter deals with the connection between humankind and the Earth system as a whole, aiming at both education and professional fields. Issues such as intensive rock sampling and the integrity of iconic rock exposures are discussed in the light of geoconservation and the role of geoscientists. The authors also argue on the importance of disseminating geoscientific information for society when dealing with both natural and human-induced disasters.

The paper “Classification of geo-mining heritage based on anthropogenic geomorphology” by **Paulo de Tarso Amorim Castro, Stênio Toledo Nascimento, and Suzana Fernandes de Paula** (Castro et al. 2021b) analyzes the geo-mining heritage based on concepts of anthropogenic geomorphology. A theoretical discussion is made about the relationship between the geological heritage and the mining heritage, including their differences and similarities, enabling the conception of mixed heritage, namely, geomining. Based on the discussion and analysis of case studies in several countries, including Brazil, a geomining classification is proposed considering the intensity and extent of anthropic alterations on the geoforms: (a) Re-qualifiable local landscape; (b) Regional landscape intensely transformed through mining activities; and (c) Regional landscape exhumed by regional mining activities. This is an innovative approach based in the landscape concept, which incorporates elements of the natural and the anthropic.

The paper “The performance of the Geoparks Commission of the Brazilian Geology Society, from 2018 to 2020” by **Marilda Santos-Pinto, Marcos Antonio Leite do Nascimento, Caiubi Emanuel Souza Kuhn, Gilson Guimarães, and Antonio Dourado Rocha** (Santos-Pinto et al. 2021) discusses the processes involved in the conception and the creation of this commission within the most traditional Brazilian geological organization. Following careful documentary research on existing data, the text describes the role of the commission as a channel for information on geoparks in Brazil and the several actions that have been implemented regarding its regional branches, the aspiring and geopark projects, events, dissemination of information through a website, and its positioning on the creation of a National Geoparks Committee, which reinforce its contribution to the promotion of the theme.

2.2. Assessment of geodiversity and geological heritage

The paper “Three hundred years of geodiversity in the Historic Center of the Gold City, Cuiabá, Brazil” by **Ana**

Cláudia Dantas da Costa, Marcos Antonio Leite do Nascimento, Carlos Humberto da Silva, and Renato Blat Migliorini (Costa et al. 2021) presents descriptions about stone heritage and sites of geodiversity of the city of Cuiabá, which has its origin in gold mining. An inventory of the sites was made, as well as the characteristics and materials used in the monuments were described. The associated historical aspects were also highlighted. From this research, a geological heritage was identified by the association between an outcrop of the geological fault, that stands out in the landscape, and the place where the city's historic buildings are located. The authors point out that this site can be considered the first geosite described in the city.

The paper “A survey of the paleontological heritage of Paraná State, Brazil” by **Christopher Santos and Antonio Liccardo** (Santos and Liccardo 2021) emphasizes the paleofauna and paleoflora of the state of Paraná in the context of sedimentary outcrops from the sedimentary basins of Paraná, Bauru, and Curitiba, as well basement rocks. The survey was carried out with the aim of subsiding the creation of a geoscience museum, using methods that involved bibliographic research, consultations with experts, visits to institutions, and final selection of samples. The results reflect the state-of-art of knowledge within the several State institutions, organized as an exhibition at the UEPG’s Museum of Natural Sciences. Twenty-five geosites and ten museums in twenty municipalities were identified.

The paper "The geological heritage of the state of São Paulo: potential geosites as a contribution to the Brazilian national inventory" by **Lígia Maria de Almeida Leite Ribeiro, Maria da Glória Motta Garcia, and Karina Kawai Higa** (Ribeiro et al. 2021) emphasizes the inventory of the geological heritage of the state of São Paulo, with 137 geosites, being the first systematic inventory in Brazil. The study analyzed this inventory and propose criteria to indicate geosites to the national list of the geological heritage inventory, which is being carried out by the Geological Survey of Brazil. In this paper, 57 geosites were chosen and further analyzed according to the main thematic classification and general geological context. The geosites were also evaluated according to typology and statutory framework.

2.3. Geotourism and geoparks

The paper " Characterization of the potential demand of geotourists in Lençóis, state of Bahia, Brazil: Serra do Sincorá Geopark Project" by **Natália Augusta Rothmann Eschiletti** (Eschiletti 2021) seeks to understand consumer demands regarding geotourism and shows how essential it is to direct strategies in the elaboration of tourism products and planning of tourism supply. The definition of the tourist profile serves to segment the tourism market, contributing to promoting ecotourism as an economic segment in Brazil and in the world. The aim of the research was to analyze the demand for geotourists and contribute to the management and planning of geotourism in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

The paper “Geologic Highway Map of Rio de Janeiro State: a product to stimulate geotourism and broadcast Rio de Janeiro's geodiversity” by **Raphael e Silva Girão, Thaís Lima Verde Monteiro, Natália Cota de Freitas, Roney Almeida dos Santos Chagas, Marcus Felipe Emerick Soares Cambra, Miguel Tupinambá, Rodrigo Costa Santos, Henrique Bruno, and Julio Cesar Horta de Almeida** (Girão et al. 2021) brings a tool that has been commonly used abroad to promote geosciences to drivers along main highways. The authors use the rich and complex geodiversity of the state of Rio de Janeiro state to explore the potential of the several geotouristic resources that may be found along the highways. The product is presented as a pioneering initiative in Brazil and a way to disseminate geodiversity and promote geotourism.

2.4. Geodiversity and society

The paper " The opinion of divers on the interpretation of marine geology in the archipelago of Fernando de Noronha (Brazil)" by **Tatiane Ferrari do Vale, Rafael Altoe Albani, and Jasmine Cardozo Moreira** (Vale et al. 2021) shows that environmental interpretation seeks to reveal meanings to provoke personal connections between the public and the protected heritage. In the specific case of geological heritage, it determines and communicates the meaning of a geological and geomorphological phenomenon, event, or site. Fernando de Noronha is one of the best diving sites in Brazil and actions focused on marine geology aspects add even more value to the activity. Thus, this study sought to investigate divers' opinions concerning environmental interpretation and aspects of marine geology in the archipelago by means of a questionnaire.

The paper "Strategic diagnosis of geocommunication using SWOT analysis in the Varvite Geological Park, São Paulo, Brazil" by **Andrea Duarte Cañizares and Christine Laure Marie Bourotte** (Cañizares and Bourotte 2021) deals with the Varvito Geological Park as a geosite of the state of São Paulo and that is often used in formal education activities, highlighting its importance for the dissemination of knowledge in geosciences. This municipal park brings important geodiversity elements that represent the late Paleozoic glaciation in southeastern Brazil, such as sedimentary structures, dropstones, and ichnofossils. A SWOT analysis of the park itself was carried out involving various stakeholders. The results of the SWOT (strengths, weaknesses, opportunities, and threats) analysis pointed out a discontinuity in the existing communication actions and the lack of an integrated and strategic approach.

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We are particularly grateful to the authors of the articles included in this special volume on Geoconservation of the Journal of the Geological Survey of Brazil, as well as the several reviewers who contributed to improve the quality of the articles, facilitating our editing work. Furthermore, we would like to thank the Editor-in-Chief, Dr. Evandro Luiz Klein for the excellent idea of creating this special issue, which will greatly contribute to the dissemination of Geoconservation to the whole Brazilian geoscientific community.

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Journal of the Geological Survey of Brazil

Geoethics and geoconservation: integrated approaches

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Abstract

The last thirty years have seen major changes in the relationship between humanity and the Earth system. The United Nations Conference on Environment and Development, RIO 92, brought both the society and the scientific community, in general, the perception of the need for an integrated view of the Earth and the meaning of the irresponsible intensity of the exploitation of natural resources, by definition restricted to the planet. From this convention emerged integrative initiatives in the natural, human, and social sciences. Two fields of geoscientific knowledge have emerged: geoconservation and geoethics. Geoconservation, more widespread today, deals with the conservation of outcrops, rocks, minerals, and fossils of geoscientific relevance and their forming processes, spreading its values both at the scientific, educational, and tourist levels. Geoethics, for its part, is concerned with the relationship between humanity and the Earth system, seeking to act in education as well as in the professional practice of geoscientists. Between both fields, there is an overlap of action zones. In these overlapping zones, intensive rock sampling in important outcrops from the point of view of geoconservation is discussed. What is in focus is the responsibility of geoscientists to preserve the integrity of emblematic outcrops in the construction of knowledge about geohistory. Equally important are the way and quality of the dissemination of information on the elements of geodiversity and the implications for society, in terms of natural disasters and those resulting from the anthropic activity. This article presents an analysis of the interaction between these fields in the educational agenda of universities and professional associations of geoscientists.

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1. Introduction

“Land, like Odysseus' slave-girls, is still property. The land relation is still strictly economic, entailing privileges but no obligations.” Such were the words of Aldo Leopold (1949) at the dawn of conservationist thinking. Although he was writing in respect to the use of land, and not the Earth system, the basis of the human relationship with the Earth can no longer ignore the necessary obligations and remain centered only on the enjoyment of its components, understood as resources for humanity.

According to data from the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (United Nations 2020), in July 2020, planet Earth reached around 7.8 billion humans, double the human population in 1973. According to Roser (2019), if the exponential growth of the world population continues within the current parameters, it is forecast that we will reach 11 billion inhabitants on the planet by 2100. Anthropic action on the Earth System has promoted profound modifications since the beginning of the industrial period. It is widely known that the emission of gases that increase the greenhouse effect and growth in the production of genetically modified foods generate ever more evident risks of water scarcity, increased food insecurity and impacts on ecosystems. In the same way, the constant demand for more energy, rawer materials and other inputs has promoted a process of global environmental degradation, which requires a collective scientific effort in search of an acceptable and controlled level of consumption.

However, this relationship has been profoundly transformed over the last two centuries. Castro and Ruchkys (2017) recognize five different phases in the relationships of human society with the Earth system; these phases coexist until today. The first phase is marked using geomaterials as resources to satisfy its survival needs. There are countless types of lithic artifacts in prehistoric archeological sites scattered throughout the world, indicating the utilitarian relationship of geomaterials as resources by human groups.

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Subsequently, there appeared phases of understanding of the Earth's nature, concerns regarding the use of finite natural resources, and that of environmental degradation. The last of the five phases appeared at the beginning of the 1990s, its historical milestone being the United Nations Conference on Environment and Development (UNCED), RIO-92. The seeds of Geoconservation and Geoethics are in this phase, which, despite being contemporaneous and along the same lines, differ on certain points.

Thus, based on conceptual analysis and selected case studies, the present article has the main aim of presenting the possible interactions between Geoconservation and Geoethics in order to contribute to their theoretical formulation, which remains incipient.

2. Methodological standards

According to Mogk et al. (2018), solutions for the confrontation of great future challenges involve integration between different academic fields, representing four basic procedures:

1. Knowledge of the Earth system and its functioning;
2. Understanding of social and cultural values, and their dynamic;
3. Understanding of economic realities; and
4. Awareness of the philosophical approaches that address human actions that generate catastrophic and negatively irreversible impacts on human existence and on ecosystems.

This future scenario places us before various problems and dilemmas, in different areas of knowledge, for which we must question whether geoscientists are prepared to intervene. Based on this reflection, it is essential to discuss the ethical aspects involved in human action within the scope of the Earth system.

In recent years, the importance of conserving abiotic nature gained recognition, which has led to the theoretical and practical development of this area. Considering this context, a geoethical approach associated with geoconservation may assist in society's understanding of the value of abiotic nature, and in the formulation of more informed strategies for the conservation of geodiversity and geoheritage (Allan 2015).

Thus, terms that are applied to geosciences and characterized by the geo prefix, such as geodiversity, geoheritage, geoconservation, geotourism, geopark, and geoethics have appeared and been widely divulged over the last 30 years. According to Ruchkys et al. (2018), the *geo* prefix brings the perspective of a systemic view of the Earth, with its use being associated with the Gaia hypothesis postulated by Lovelock (1995), which considers that the planet and all its biotic and abiotic elements constitute a unique system of interactions, which present an integrated dynamic of functioning. The inspiration for the name of the theory comes from Greek mythology where Gaia, Geia or Ge (Γαία in Greek) is the Mother-Earth.

Geoconservation can be defined as a set of techniques and measures that aim to guarantee conservation (including rehabilitation) of geological heritage and geodiversity, based on analysis of their intrinsic values, vulnerability and degradation risk (Carcavilla et al. 2007). Brilha (2016) inserts the protection of *ex situ* geodiversity into the concept when it holds scientific, educative, and/or touristic value.

Peppoloni and Di Capua (2015) present the etymology of the word *geoethics*, asserting that the prefix "geo" refers to "Gaia". In ancient Sumerian, the meaning is "house, place of habitation". Thus, "geo" refers to the place where humans live. The word "ethics" has a double meaning: firstly, it contains a sense of belonging to a social dimension of life; secondly, it is related to the individual sphere of each person. Both in the social and individual field, the etymological root of the word "ethics" demands that human beings face their responsibilities.

According to the definition on the IAPG – International Association for Promoting Geoethics Website (Di Capua and Peppoloni 2019), "Geoethics consists of research and reflection on the values which underpin appropriate behaviors and practices, wherever human activities interact with the Earth system. Geoethics deals with the ethical, social, and cultural implications of geoscience knowledge, education, research, practice, and communication, providing a point of intersection for Geosciences, Sociology, Philosophy and Economy". The authors add that "Geoethics represents an opportunity for geoscientists to become more conscious of their social role and responsibilities in conducting their activity, being a tool to influence the awareness of society regarding problems related to geo-resources and geo-environment".

Many important points unite Geoethics and Geoconservation. One such point refers to the need to divulge geoethical postures in relation to sample collection for laboratory analyses with the aim of geosite conservation (Mansur et al. 2017), the popularization of science, definition of load capacity at geosites, and even occasional bans on visitation when such sites are considered fragile.

Thus, according to Bobrowsky et al. (2017), from the perspective of geoscientists, there are four levels of responsibility to be considered in Geoethics: (1) in the individual conducting of the work of each geoscientist; (2) in multidisciplinary cooperation with other colleagues; (3) with society, aiming to minimize environmental impacts and respecting the natural dynamic; and (4) with the Earth system, which should be conserved for future generations.

For Drąsutė et al. (2019), the integration between Geoconservation and the principles of Geoethics can be defined by the social responsibility and ethical attitude of geoscientists. Thus, the application or relationship of geoethics with geoconservation occurs mainly at level (3) and level (4), considering the Earth system and its abiotic elements (geodiversity) as assets to be conserved (especially geoheritage) for the next generations.

Considering geoconservation from a geoethical perspective, we should bear in mind two central questions: (1) how this approach has been carried out at a level of scientific production and in education in Geosciences; and (2) the role that geoconservation may have in the promotion of geoethics. As Peppoloni and Di Capua (2015) emphasize, Geoethics may represent a new way of thinking and interaction with the Earth system, and a new way of addressing global problems. In this case, Geoconservation may benefit from these principles while also helping to promote them.

"Natural capital", according to the definition given by the World Forum on Natural Capital (2017), involves "the world's stocks of natural assets which include geology, soil, air, water and all living things". This definition, although not the only one, is one of the most important and includes geodiversity, recognizing its place as the basis of the planet (Gray 2019).

Within this context, when we refer to natural systems, we identify a high degree of complexity and natural or anthropic processes, which often promote irreversible environmental changes.

The human concern with environmental impacts has a long history (Mooney and Ehrlich 1997), which has intensified since the 1960s. In May of 2019, an international agreement in the scope of the Subcommission on Quaternary Stratigraphy (2019) indicated that we are experiencing a new geological period - the Anthropocene. This finding ratifies that human beings have become an important threat to natural capital, which has driven the search for development and consumption models defined based on sustainable management of natural capital.

Mansur (2018) highlights that the definition of natural, in the popular sense, points to “everything that was not produced by man”, distancing human beings from their essence as part of nature, whereby “One is not part of the space of the other. With reciprocal externalities, nature and man exclude each other and oppose each other. Born is the basis of the man-environment dichotomy characteristic of modern thought” (Soares 2008, pages 4 and 5). However, a movement appeared at the end of the 20th Century, which, driven by the weight of thousands of years of thought distancing man from nature, saw human beings start to understand that they will need to unify the “world of man” with the “world of nature” (Carvalho 1991) to live a healthier life and glimpse a more optimistic future.

Thus, as we come to complete two decades of the 21st Century, the growing use of natural resources has awakened in society questions that involve planetary sustainability. This is not only in issues related to the exhaustion of Earth's resources and impacts resulting from intense anthropic action on a local and global scale but also protection before processes of the Earth's dynamic - natural disasters (Peppoloni and Di Capua 2015).

Within this scenario, the methodological approach consists of the theoretical analysis of two fields of knowledge, above all, their connection with society and convergences with sustainable development initiatives. The methods were developed in four stages: 1) analysis of the principles of Geoconservation; 2) analysis of the principles of Geoethics; 3) points of convergence between the two; and 4) practical applications with examples.

To that end, the proposition involving Geoethics and Geoconservation is associated with X-disciplinarity, as scientific knowledge should transpose epistemological limits and dialogue with other understandings, in different forms of knowledge production, to go beyond the academic environment, as presented in definitions of “transdisciplinarity” (Castro 2019).

Also, according to the same author, X-disciplinarity makes us “think with greater precision on our academic practice, on research, on teaching and on related activities”, which Geoethics and Geoconservation propose in the field of Geosciences.

“Even more importantly, we do this to force ourselves to leave the comfort zone of our disciplinary spaces, which frequently operate as sterile, airtight compartments, and stimulate us to contribute to development in the form of producing knowledge guided by the principles of complexity, relational and dialogic thought, in the search to overcome fragmentation and promote greater reintegration of the sciences”. Castro (2019).

Thus, by adopting X-disciplinarity to stimulate individual and collective critical reflection on the knowledge processes in which we are involved, we establish, in principle, a question on the meaning of the numerous prefixes we seek to introduce into disciplinary interactions, such as cross, inter, multi, trans, and post-disciplinarity, among many others.

3. Results

3.1. Philosophical bases of Geoconservation and Geoethics (their common origin) and the events that have culminated in the present moment.

Geoscientists, as professionals and scientists with specific competencies in the understanding and study of the dynamic of the planet, have a fundamental role in society. According to Peppoloni and Di Capua (2012), when “discussing the ethics in relation to Geosciences, Geoethics, establishes considering the social implications of geological research and practice, as an indispensable requirement for geoscientists”.

Geoconservation or conservation of geodiversity can be defined as actions taken with the aim of conserving and improving characteristics, processes, places, or elements, particularly geological or geomorphological, related to geodiversity. This generally involves working with natural changes to maintain a characteristic of interest, for example, maintaining the clear exposition of a stratigraphic sequence on a cliff undergoing an erosive process, despite the erosion. It does not mean stopping the erosion and freezing the exposition in time. Successful geoconservation often depends on understanding and valuing resources that need to be conserved, which is why geoconservation actions include promotional and awareness-raising activities on the desired object of conservation (Burek and Hope 2006).

Some geoconservation principles can be found in the International Declaration of the Rights of the Memory of the Earth (Digne - FR 1991): “Just as an ancient tree retains the record of its life and growth, the Earth retains memories of the past inscribed both in its depths and on its surface, in the rocks and in the landscape, a record which can be read and translated; We have always been aware of the need to preserve our memories - i.e. our cultural heritage. Now the time has come to protect our natural heritage, the environment. The past of the Earth is no less important than that of human beings. Now it is time for us to learn to protect, and by doing so, to learn about the past of the Earth, to read this book written before our advent: that is our geological heritage”.

Thus, geoconservation principles include recognition of the historical records of the evolution of the Earth as geoheritage, to be protected and safeguarded for future generations. Stephens (2020) emphasizes that geoconservation is associated with a new social responsibility related to the sustainable development and valuing of geodiversity resources from the heritage point of view, as originally argued by Henriques et al. (2011).

The relationships between Geoconservation and Geoethics occur in the historical, philosophical and, to a certain extent, temporal spheres (Figures 1 and 2). In temporal terms, the 1990s represent an important milestone. The term *geoethics* was introduced in 1991 by Nemec and the International Declaration of the Rights of the Memory of the Earth was elaborated in the same year. The concern with the conservation of geodiversity resources, their finitude and guarantee of use for future generations are common points. It is important to highlight the UN proclamation of the International Year of Planet Earth in2008 (Mulder et al. 2006) and the International Year of Global Understanding, in 2016 (Werlen et al. 2016).

From the historical perspective, the importance of the advance in geological knowledge in the 19th century is clearly noted, whereby the scientific bases for observation of the planet were introduced, bringing relevance to those elements that stood out for representing patterns and/or characterizing rarities. While the philosophical basis for Geoethics was introduced in the first half of the 20th century, Geoconservation demonstrated this advance in discussions on environmental sustainability in the 1970s. For both, the 1990s, represented by the temporal milestone of Rio 92, are crucial. The concept of geoethics, and the International Declaration of the Rights of the Memory of the Earth were introduced in 1991. In Brazil, discussions on geoconservation came before those on geoethics.

3.2. The values and objectives of Geoconservation and Geoethics and the overlap zone between them

Figure 3 presents a scheme of common paths to Geoconservation and Geoethics and the overlap zone between the two themes. In the overlap, the theme of sampling demarcates the field of the direct action of the geoscientist in the individual conducting of their work, while uses, the availability of resources for future generations and communication with society refer to their social responsibility and responsibility for the environment (Bobrowsky et al. 2017). This shows that the geoethical posture is also essential for Geoconservation.

In the field of Geoconservation, the importance of the intrinsic value of geodiversity is clear, whereby the simple existence of geological heritage defines its relevance. For Geoethics, on the other hand, its importance to society is evident, and it clearly shows the direct relationship between Geoethics and natural and anthropic disasters.

3.3. National and international examples of good and bad relationships between the scientific community and society from the perspectives of Geoconservation and Geoethics

It is a fact that, in general, geoconservation has been focused primarily on rural and/or natural environments, which involve natural heritage: "education for the Earth System, incorporated into practices in Education for Sustainability, is a critical tool in the construction of knowledge and values by rural communities. It contributes to transforming current practices impacting the environment, to raising the awareness of producers as agents responsible for the recovery and maintenance of environmental systems, and valuing the environmental services provided by the systems" (Penkaitis et al. 2020).

However, in the urban scenario, beyond discussing questions that involve sustainability and quality of life, we should also evaluate the role of geodiversity and geoconservation within the scenario of environmental degradation: "upon recognizing the fundamental and vital value to humanity arising from geodiversity, possible impacts and threats to the same are distinguished, which occur both at local scales and in wider contexts. Normally underestimated or not even recognized, activities that result in the loss or degradation of geodiversity, due to both natural processes and those induced by humans, are abundant" (Fontana et al. 2015).

Given the great environmental debates occurring in the first two decades of the 21st century, it is evident that there is a need for conservation and protection of ecosystems, as well as of the geoheritage and forest remnants in urban areas. Various examples of geoconservation in urbanized areas have been the object of studies, both in small-scale urban centers and in

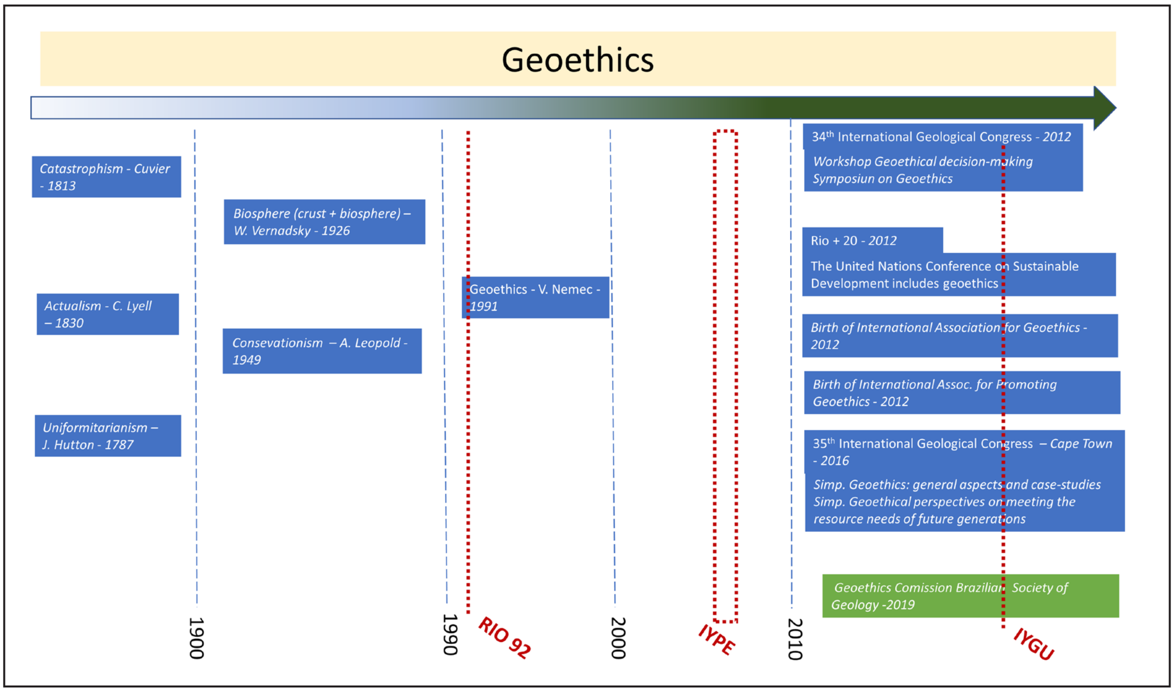

FIGURE 1. Evolution of the concept, applications and milestone events in Geoethics in the world and in Brazil. Rio – 92 United Nations Conference on Environment and Development; IYPE - International Year of Planet Earth; IYGU International Year of Global Understanding.

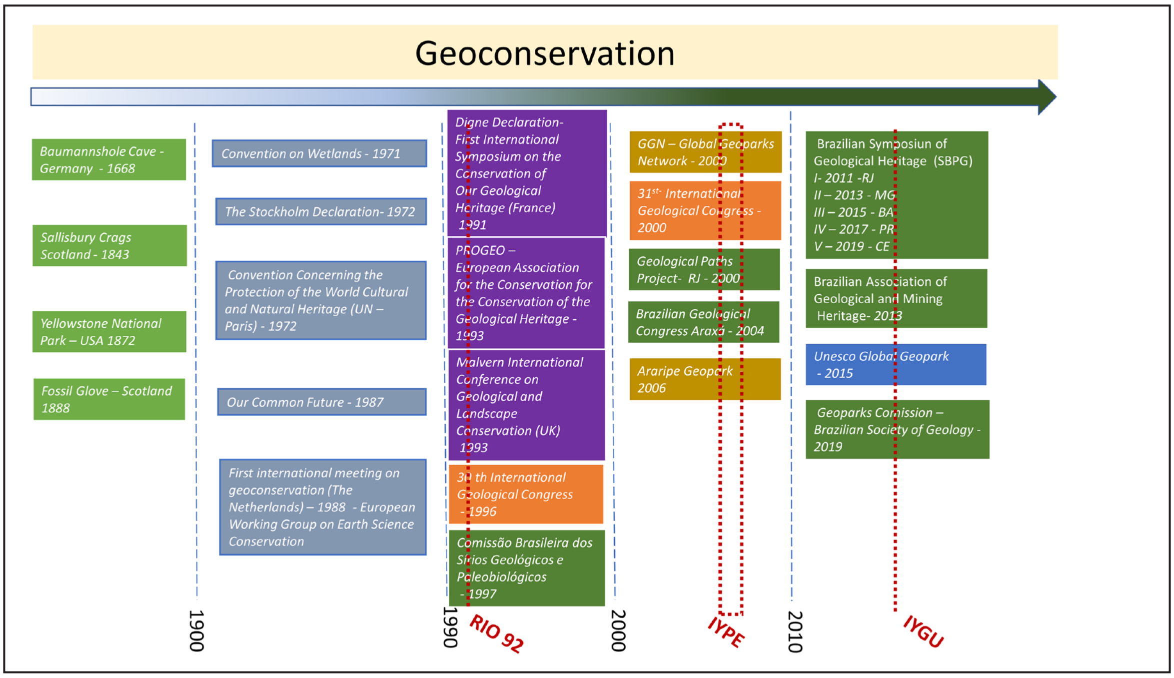

FIGURE 2. Evolution of the concept, applications and milestone events in Geoconservation in the world and in Brazil. Rio – 92 United Nations Conference on Environment and Development; IYPE - International Year of Planet Earth; IYGU International Year of Global Understanding.

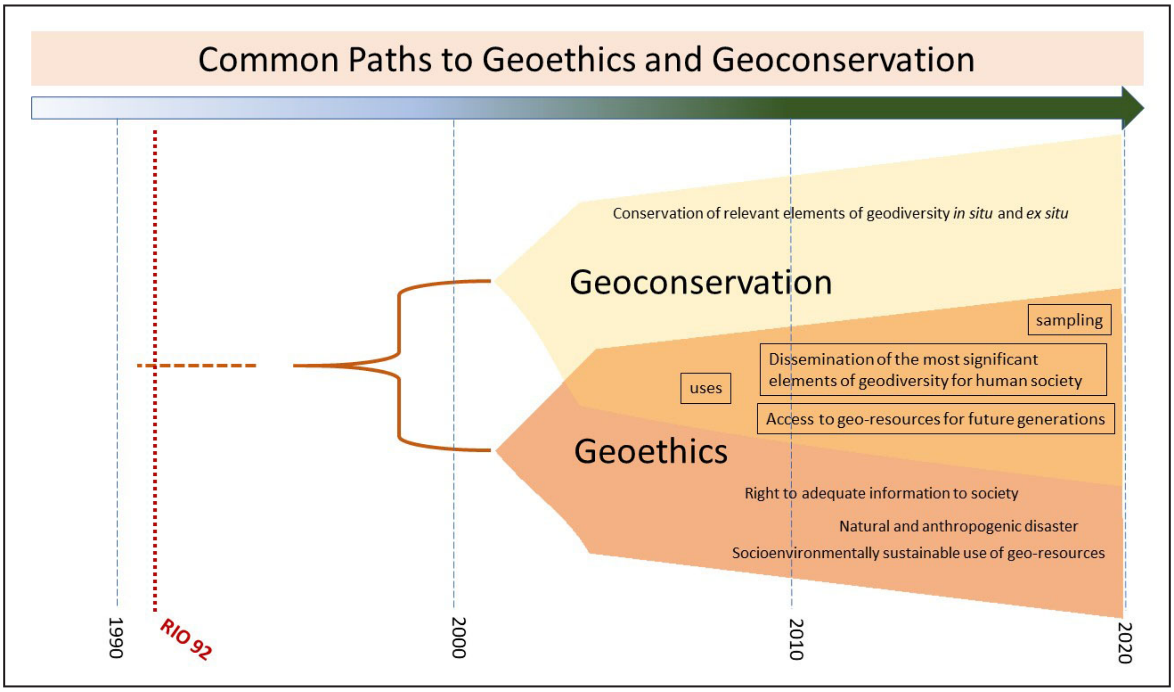

FIGURE 3. Overlap zone between Geoconservation and Geoethics

big cities, whether natural heritage or constructed (Fernández-Martínez et al. 2011; Minvielle and Hermelin 2011; Del Lama et al. 2014). It is worth mentioning that the world urban population overtook the rural in 2014 (United Nations 2014) and should reach around 70% by 2050 (United Nations 2020).

In general, beyond geoconservation, the conducted studies involve geoscientific education and geotourism, associated with urban geoconservation actions (Wrede and Mügge-Bartolović 2012; Del Lama et al. 2014). Catana (2009) proposed formal education programs involving the Arouca Geopark, Portugal, which besides divulging geosciences in formal and informal educational activities, would also involve the community in the management process for the conservation of local geoheritage. “UNESCO Global Geoparks are areas that use the concept of sustainability, value the heritage of Mother Earth and recognize the need to protect it” (UNESCO, 2020).

In Brazil, when referring to areas protected by law, involving the National System of Conservation Units (Sistema Nacional de Unidades de Conservação - SNUC), various categories can be identified within and/or with limits close to urban centers.

However, little inclusion is identified, on the part of managing bodies, involving the community in programs or actions that translate into shared management, when compared to geoparks (Imbernon et al. 2014).

An example to be cited is observed in the administrative area of Greater London, in which geoconservation is proposed as a possibility for raising awareness on the themes that involve preservation and conservation in large urban centers (Carlsen and Heath 2012).

Examples of this ethical posture for the Earth system can be seen in Bonito (state of Mato Grosso do Sul), in the visitation of the Cavernas do Lago Azul (Blue Lagoon Caves) and in diving in the Formoso River (Boggiani et al. 2007); regulated visitation at The Wave geosite, in Arizona (Antelope Canyon 2017); and the Naica cave of the crystals, in México (Daily JSTOR 2017).

However, beyond the environmental and social discussion lies the necessity for scientists to discuss Geoconservation and Geoethics. This finding passes through data collection to research and attitudes during the fieldwork teaching process (Mansur et al. 2017). It also reaches the construction of an attitude of respect for the planet and other researchers/teachers that use the same site for their research or teaching in the field. This leads to the need for codes of conduct based on geoethical behavior for companies, universities and professionals.

Butler (2015) heavily criticizes sampling through boreholes carried out on protected sites with heritage value, which he calls “Destructive sampling ethics”. He attributes the responsibility for damage to outcrops not only to the researcher but also to the institution to which they belong and the publisher of the journal where the related article and data collection were published.

4. Final considerations

With the evolution of thought on nature and human interference, at the end of the 20th century and the beginning of the 21st century, there appeared various concepts that had been maturing and gaining strength with the Rio 92 Conference. Among these concepts are Geoethics and Geoconservation. The argument of the present article is developed based on the relationship between these two areas of knowledge that arose amid the need for new perspectives in the approach of geosciences, triggered, in part, by environmentalist movements.

Based on the analysis of the timelines elaborated from the first steps to the consolidation of concepts, as well as the interpretation of how they are intercepted today, we can see that they have a common origin and an interconnected and interdependent future.

Nowadays, there is no possibility of professional action, whether in industry or academia, in a report or a class in the field, in which these concepts do not need to be placed as part of a responsible posture towards people and the environment. Geoconservation and Geoethics should be immediately added to the training agenda of Geoscience professionals at Brazilian universities, evolving towards dissemination in science popularization projects and natural risk prevention aimed at the public in general.

Geoscientists are responsible for the use and management of the Earth’s non-renewable abiotic resources. The guarantee of these resources for future generations makes it necessary to include concepts of Geoethics and Geoconservation in concrete actions, so that the Anthropocene is experienced within a perspective of respect and ethics between people and the immediate and global environment.

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Classification of geo-mining heritage based on anthropogenic geomorphology

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Abstract

Studies on mining heritage and geoheritage walk different paths. While the former is based on a more cultural bias, the latter has its bases and conceptions geared towards the natural. However, the concept of landscape, which merges the natural and the cultural, connects the two concepts of heritage, enabling the conception of mixed heritage, namely, geo-mining. Based on the principle that mining interventions on the natural landscape can result in outcrops of features and aspects of geodiversity relevant for the understanding of regional evolutionary history, this article analyzes geo-mining heritage based on concepts of anthropogenic geomorphology. A geo-mining classification with three types is proposed based on the intensity and extent of anthropic alterations on the geoforms.

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1 Introduction

The Earth is transformed through time. In the history of geological science, this observation comes from the writings of Nicolaus Steno, in the 17th century. Broadened by the vigorous, consistent and systematized work of James Hutton and Charles Lyell in the following two centuries, it was such an observation that provided support for the texts of Charles Darwin. However, the finding that humanity was an agent of transformation capable of interfering in and transforming the spheres located on the Geosphere was down to Vladimir Vernadsky at the beginning of the 20th century. This idea of humanity's capacity for transformation did not have primacy in Vernadsky, as others had already made this observation (e. g. Lyell cited by Peloggia and Ortega 2016, Eschwege 1833, cited by Fonseca and Sobreira 2001, Sherlock 1922). However, Vernadsly devoted himself to the topic more diligently, including using radio programs to spread these concepts. In the eagerness of humanity to obtain a lasting foundation of food, comfortable habitations, and rapid forms of transportation and communication, humans have taken a wide variety of living organisms and resource materials for themselves. The use of georesources reached a high intensity and was spread around the planet through the industrial revolution and that of modern agriculture and livestock. As a result, there have been modifications to the landscape, whether in urban regions or in regions far from urban centers.

Mining activities are among the most markedly intensive in landscape modification, leaving a long history of records on the Earth's surface. There are remnants of mining from 41,000 years ago in Egypt (Vermeersch 2005) and Swaziland (Beaumont 1973). In Latin America, signs of mining from around 12,000 years ago have been found in Chile (Salazar et al. 2011). The anthropic effects on the surface of the Geosphere caused by mining processes, whether concentrated or spread across a region, may result in peculiar surface features and accumulations of materials that interfere in the natural characteristics of a site or region. Such activity partially established the bases of what Sotchava (1977) defined as an anthropogenic landscape, being that which results from the interaction between the Geosphere and the anthroposphere. The conception of Anthropogenic Geomorphology (Szabó et al. 2010) also arose from these relationships. Anthropic interference can expose significant geological features, which would otherwise not be available to human access (for more information concerning the subject see Drew 1983, Goudie

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1993 and, information related to mining as geodiversity mining heritage see Von Ahn and Simom 2017). Peloggia (1998) indicates that anthropic intervention in the dynamic of nature results in consequences that can be grouped into three levels of approach. The first level is associated with the occurrence of transformations on the relief, that is, modifications related to landforms. The second level corresponds to alterations in the geomorphological dynamic, and the third level is related to the formation of deposits that may have been developed as a result of human agency. Price et al. (2011) and Peloggia et al. (2014) established a taxonomy of features on technogenic ground, providing a foundation for advances in the understanding of human interventions on the landscape and incorporating the anthropogenic dimension into cartographic surveys.

1.1 Modification of the landscape through mining

Mining stands out among the anthropogenic actions that contribute to landscape modification. The geosphere provides humans with more weather-resistant materials that allow the construction of towns and cities with longer-lasting facilities. In addition, some geomaterials are inputs for modern agriculture. If on the one hand mining contributes to the configuration of technogenic features in urban centers, on the other hand, it is also responsible for landscape modifications at the sites of georesource extraction. Thus, upon modifying the landscape, the removal of georesources contributes to generating rocky expositions that would not otherwise be visible. Some may turn out to be unique expositions with relevance for geoheritage.

There is no agreement among those that study geoheritage in respect to the definition of what geo-mining heritage would be. There are authors like Brilha (2016) that suggest that geoheritage should be distinct from other forms of heritage. Despite having direct connections with rocky expositions, as is the case of elements of mining heritage and archeological heritage, they are subject to distinct methodological procedures and analyses, constituting diverse cognitive fields. Others, such as Nascimento and Castro (2019) and Cordeiro (2010), understand that mining heritage can aggregate natural elements such as geomaterials, as well as documental, architectonic and immaterial elements, although they do not indicate the existence of geo-mining heritage. There are also those such as Puche Riart (2000) and Cañizares Ruiz (2011) that consider both geological heritage and mining heritage as one bivalent heritage category.

The geo-mining heritage associated with anthropogenic geomorphology can be recognized on mining landscapes or those exposed through intensive mining activities. They are recognized as significant from the geological or geomorphological perspective by institutions and research groups focused on geoheritage studies. Moreover, heritage value is intensified when local societies identify themselves with landscapes presenting a strong anthropogenic influence. Peloggia (2018) discussed these aspects in the light of Brazilian legislation and compiled the contribution of several national authors in aspects related to landscape modification and classified the initiatives into different categories.

The search for sites of human heritage classified as geoheritage carried out by Migori (2018) recognized that among the 206 natural sites classified as World Heritage by UNESCO, 90 had geoheritage references. On the other hand, Castro (2018), in an analysis conducted on the UNESCO World Heritage list of cultural or mixed heritage (encompassing both natural and cultural criteria), recognized only 28 sites as being relevant for geo-mining heritage, which is 2.56% of all sites. All of these are framed by their cultural aspects. No sites were found that registered the interaction between mining activities and geodiversity.

2. Methodological References

The method used in the classification of geo-mining heritage linked to anthropogenic geomorphology follows the principles of Price et al. (2011) and Sherlock (1922) in regard to anthropogenic geomorphology. It starts with the description of the geoforms built or modified by human action, their dimensions, their location, as well as the possibility of reshaping and requalification for other uses.

There is no specific base containing, in a systematic way, data on mining assets or geosites that are associated with mining. Therefore, a wide review of the subject was carried out in sources of information scattered in the literature. The focus was to investigate those areas where mining, mainly in the open pit type and old or historic mines abandoned or deactivated, was active and resulted in landscape modification. Several sources of information on sites considered important as mining heritage and geoconservation were examined. As a basis for the analysis of mining heritage, the list of Unesco World Heritage Sites (UNESCO 2020) and the works of Migori (2018) and Castro (2018) were reviewed. An attempt was also made to analyze the lists contained in some compilation works of geological heritage (e.g. Dingwall et al. 2005) and which had mining activities as the basis of their exhibition The vast literature on mining heritage organized by Sociedad Española for the Defensa del Patrimonio Geológico y Minero (SEDPGYM 2020) and in the Geological Society (2020) was visited, as well as information about mining in the United Kingdom (e.g. The Mining Institute 2019, Mining Exploration and Mining History 2019, Cornish Mining World Heritage Site 2019).

In Brazil, in addition to the national geosite base (e.g. Geological and Paleontological Sites of Brazil – Sítios Geológicos e Paleontológicos do Brasil – Schobbenhaus et al. 2002, Winge et al. 2009, 2013, CPRM 2019, special focus was given to two regions with historical records of mining activity: the highlands of the southern center of Minas Gerais, near Ouro Preto, the birthplace of the gold cycle, in the 17th to 19th centuries and the Chapada Diamantina, in Bahia, where diamond was the main agent of interiorization of the population in the 18th and 19th centuries. In the Ouro Preto region there are several works regarding the mining heritage and landscape modification (e.g., Fonseca and Sobreira 2001, Sobreira 2014, Barbosa et al. 2018) and in Chapada Diamantina, mainly in the Igatu and Lençois region (e.g., Santos et al. 2010, Russ and Nolasco 2012, Nolasco 2012).

3. Results

From the analysis carried out on the geoheritage and mining heritage sites, based on elements substantiated in the anthropogenic geomorphology, three landscape classes were defined as follows:

1) Re-qualifiable local landscape: places in which the mining activity generates localized pits and mine benches, where the concentration of the mineral resource and the

geomorphological conditions enable low-cost, normally mechanized, extraction. Worked anthropogenic geoforms can be found (in the classification of Price et al. 2011), represented by pits and constructed lands such as spoil heaps. Anthropogenic geoforms are easily recognizable. Two factors contribute to the closure of extractive activities: mineral exhaustion and the conflict between mining and the predominant use of the territory, which is commonly due to the expansion of urban centers. The requalification of the pits and mine benches is necessary and desirable, with their usage normally aimed at tourism and leisure, and, occasionally, for the expansion and maintenance of forested areas;

2) Regional landscape intensely transformed through mining activities: these are regions in which the mining activity is little mechanized and widespread, with blasting, excavations, piling of waste material and the construction of aqueducts and mining flumes. Normally, they are associated with mineral resources of very high value to weight ratio, such as silver or gold, which encourage manual extraction or semi-mechanized work that is scattered and irregular. The intensity of this mining produces several anthropogenic geoforms whose dimensions are relatively small. The result is a mosaic of excavated and produced land, represented by heaps of sterile rocks, which increases the roughness of the terrain. In many cases, this favors the settlement of sparsely populated regions, creating urban centers;

3) Regional landscape exhumed by regional mining activities: regions in which the mineral resources were completely exhausted, in which there have been no processes in use since the end of mineral exploration. Mineral extraction occurred using rustic processes with little industry, which were persistent over time, and there is no recovery of the modified areas. Given the shallow depth of mineral resources in regions where the exhumation of the paleosurface occurs, which is the physical expression of an ancient landscape, their extraction did not require intense mechanization. The result is the exhumation of a visible geological discontinuity (stratigraphic), which clearly marks the separation between geological materials that present cohesive characteristics and disparate mineral concentrations. In terms of anthropogenic geomorphology, excavations predominate, with the constructed ground being locally restricted.

The landscapes that are altered through mining over time have cultural and heritage value, and therefore come to compose geo-mining heritage of that locality or region. Table 1 presents examples of landscapes transformed through mining.

The first defined class, local re-qualifiable landscape, can be exemplified by the Municipal Park of Mangabeiras (Figure 1A), in the Serra do Curral mountains in Belo Horizonte, Minas Gerais (Brasil). In that area, there was an iron mine, which functioned until the 1970s (Ruchkys et al. 2012). The mining bench was requalified and today houses the administrative headquarters of the park and the Praça das Águas, which is a complex of socio-environmental programs that involve environmental awareness and valorization of the natural environment.

The Cumbe quarry, which was in activity from the middle of the 20th century extracting dolomitic marble for cladding in the region of Cachoeira do Campo, Ouro Preto (Brazil), is another example of this class. The extraction was shut down in the current decade as the rocks contain the oldest stromatolites in South America (Dardenne and Campos Neto 1975, Maciel 2014).

The Tanguá quarry (Figure 1B), in Curitiba, Paraná State (Brazil), was the source of rocks for paving and construction. After its shutdown, it was requalified, being transformed into an urban park (Liccardo et al. 2008).

Another example is the 80m-deep pit, 1000 m from the perimeter to the foothill of the Tianma Hill in Shanghai (China), which was an active quarry between 1950 and 2000, when it was abandoned. It currently houses the Shimao Shenkeng hotel, also known as the InterContinental Shanghai Wonderland Hotel, a five-star hotel on the outskirts of Shanghai (Ping et al. 2019).

A notable example in this class is Butchart Gardens, near Victoria, British Columbia (Canada). In 1909, gardens were created on the site of an exhausted limestone quarry, and they are one of the biggest regional attractions until today and recognized as a historic site in Canada (Canada's Historic Places 2019).

The second class, regional landscapes intensely transformed through mining activities, have various stand-out examples, such as the gold-mining areas to the south of the Quadrilátero Ferrífero, especially those in the mountains of the municipality of Ouro Preto, between Ouro Preto and Mariana (Minas Gerais, Brazil). Gold extraction in the mountains of Ouro Preto (Sobreira 2014, Nascimento 2016), (Figure 2A and 2B), and of Antônio Pereira (Nascimento 2016, 2019), (Figure 2C and 2D), which began in the mid-17th century, modified the geomorphological configuration of these mountains. In the 18th century, the Serra de Ouro Preto gold mines provided the base for the main urban center in the Brazilian interior.

TABLE 1. Types of landscapes modified by mining and examples.

Class	Examples	Location	References
Re-qualifiable local landscape	Parque das Mangabeiras	Belo Horizonte, Minas Gerais, Brazil	Ruchkys et al. (2012)
	Pedreira do Cumbe	Ouro Preto, Minas Gerais, Brazil	Dardenne and Campos Neto (1975), Maciel (2014)
	Pedreira Tanguá	Curitiba, Paraná, Brazil	Liccardo et al. (2008)
	Tianma Hill Quarry	Shanghai, China	Ping et al. (2019)
	Butchart Garden	Victoria, British Columbia, Canada	Canada's Historic Places (2019)
Regional landscape intensely transformed through mining activities	Serra de Ouro Preto	Ouro Preto e Mariana, Minas Gerais, Brazil	Sobreira (2014), Nascimento (2019)
	Serra de Antônio Pereira	Ouro Preto e Mariana, Minas Gerais, Brazil	Nascimento (2016)
	Las Médulas	El Bierzo, Castilla e León, Spain	Sánchez-Palencia et al. (2000)
Regional landscape exhumed by regional mining activities	Igatu	Andaraí, Bahia, Brazil	Russ and Nolasco (2012)
	Cerro del Hierro	San Nicolás del Puerto, Andaluzia, Spain	Moreno et al. (2008)

The gold mining carried out by the Romans in Las Médulas, on the border between Galícia, Astúrias and Castela and León, in Northwest Spain, is distributed across approximately 1,200 hectares. According to Sánchez-Palencia et al. (2000), around 100 million m^3 of material was removed in the first two centuries of the Christian era, being considered the largest open-air gold mine of the Roman Empire. It is now a UNESCO World Heritage site, recognized for cultural criteria (Figure 3)

The third class of landscape refers to those regions in which mining provoked the exhumation of paleosurfaces. Two examples stand out - Igatu, in the Andaraí district of Bahia (Brazil) and the Natural Monument of Cierro del Hierro, in the Serra Norte de Sevilha Natural Park (Spain).

Igatu is a record of diamond and carbonado extraction, this being an amorphous variety of diamond, in the Chapada Diamantina, since the 17th century. Diamond and carbonado extraction work was essentially not mechanized and profoundly modified the regional landscape (Nolasco 2012). Two aspects of the diamond mine contributed to the intense landscape modification in Igatu: the sale price of diamonds, which increases exponentially with their weight, and the subsequent extraction processes that preserve their physical integrity. Thus, the mining of diamonds is carried out in alluvial and colluvial deposits in drainage headwaters, accumulated on Proterozoic rocky substrate on the mountainous slopes of the Chapada Diamantina. Extraction occurred in unconsolidated material, removing the pedological material that supported the previously existing vegetation, exhuming the rocky surface (Nolasco 2012, Russ and Nolasco 2012) (Figure 4).

In Cerro del Hierro, San Nicolás del Puerto, Andalusia (Spain), iron extraction was responsible for the transformation of the landscape (Figure 5). Moreno et al. (2008) describe that the iron mining carried out from the pre-Roman period to the mid-20th century created a landscape intensely altered by anthropic action. The iron was concentrated in a surface of stratigraphic discontinuity between Eocambrian limestone

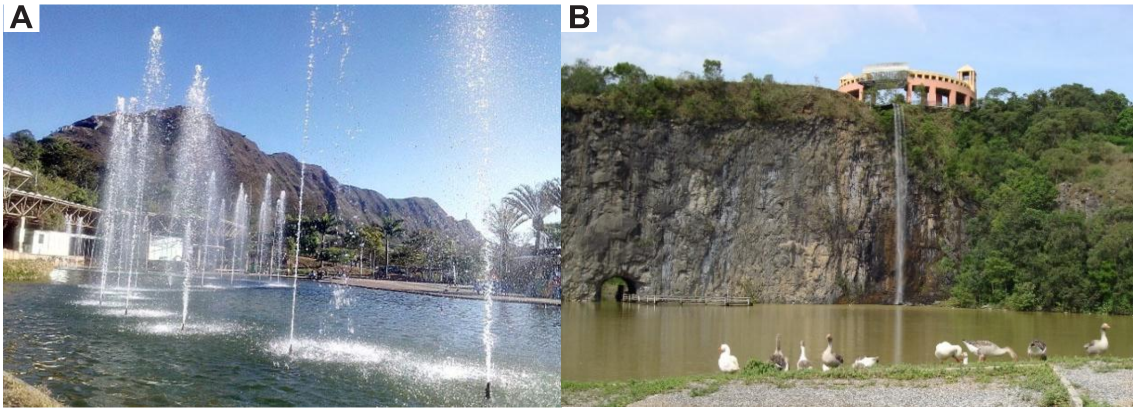

FIGURE 1. Examples of Class 1 Geo-mining Heritage. A - Municipal Park of Mangabeiras, in Belo Horizonte, requalifying an old iron ore mining at the foot of Serra do Curral (photo Eliezer S. Costa). B - Tanguá quarry, in Curitiba, an old quarry of gneiss and diabase re-qualified for tourist use, preserving the exposure of rocks (photo by Leonardo Stábile)

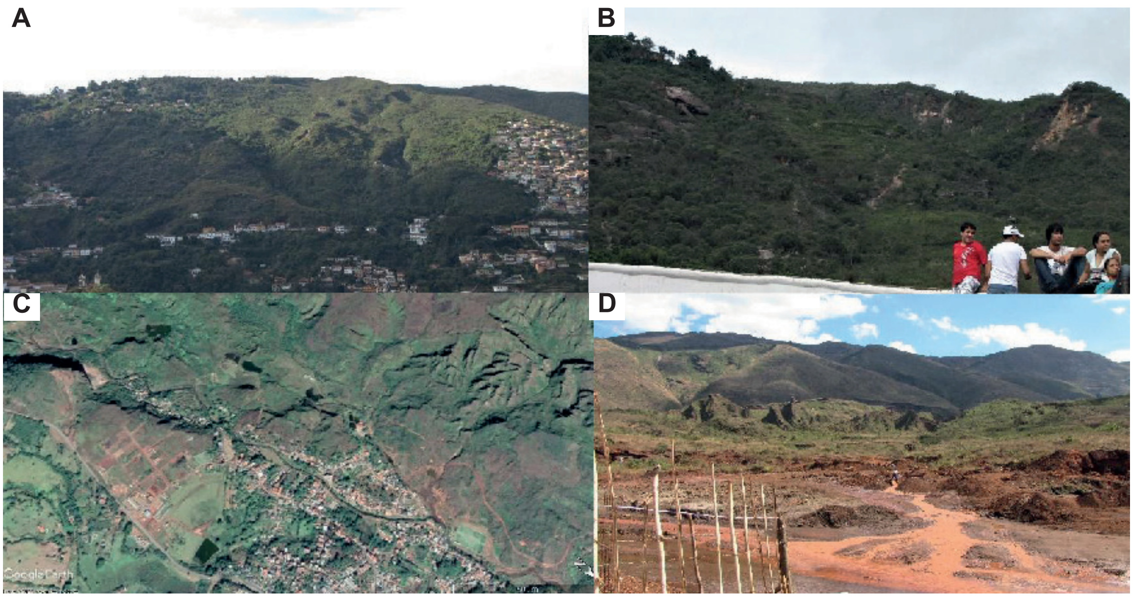

FIGURE 2. Examples of Class 2 Geo-mining Heritage. A - image of the Serra de Ouro Preto showing areas of urban occupation interspersed with areas of dismantling caused by gold mining throughout the 18th century. Note the areas of great roughness that result from dismantling by mining in the neighborhoods of Alto da Cruz and Padre Faria; in the background the Morro da Queimada. B - details of part of the Ouro Preto mountain. C - rough relief, caused by intensive gold mining, west of Antônio Pereira district, Ouro Preto (Google Earth 2020). D - in the middle plane, relief with pinnacles, resulting from the intense mining of gold.

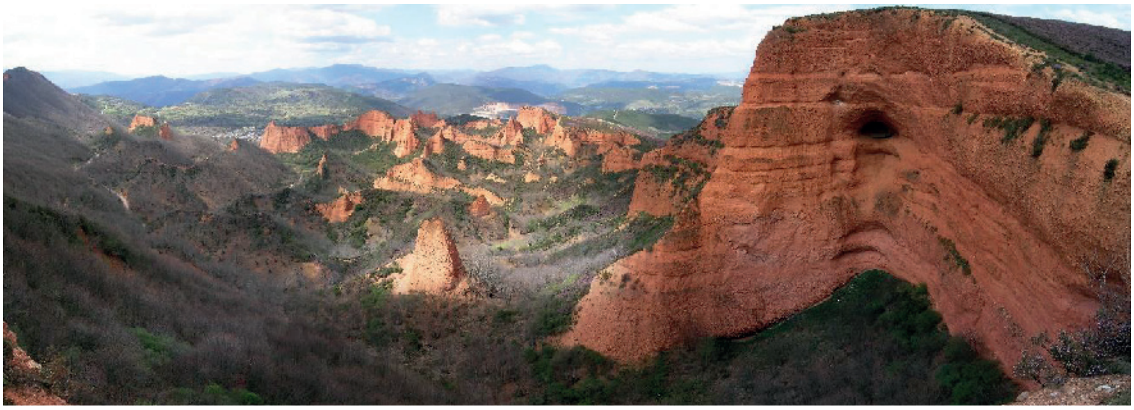

FIGURE 3. Class 2 Geo-mining heritage. Anthropogenic geoforms from Las Médulas (Spain), an ancient gold mine from the Roman period, active throughout the 1st and 2nd century AD (photo Alessio Damato).

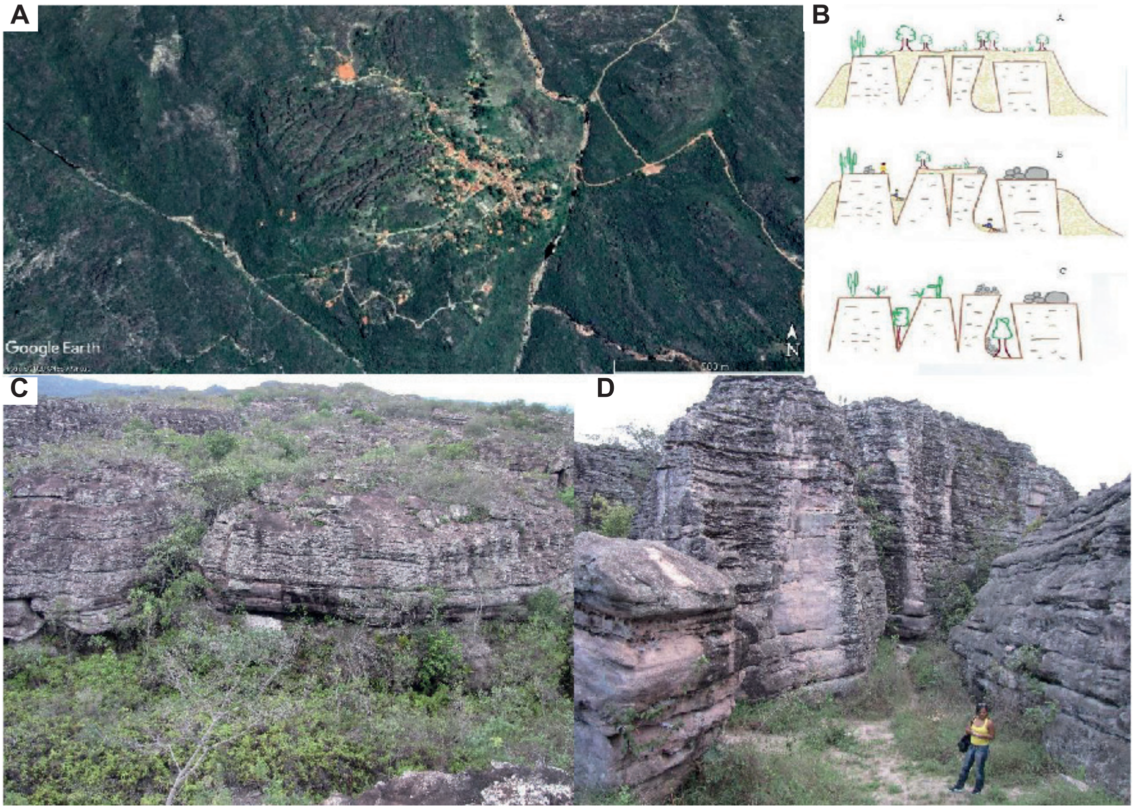

FIGURE 4. Class 3 Geomineer Heritage. A - the village of Igatu and the anthropogenic landscape generated by the extractive action of the diamond and carbonado (Google Earth 2020). B - an evolutionary scheme of diamond mining action over 200 years and the generation of the current landscape (Russ and Nolasco 2012). C and D - the current landscape of the region, showing the exposure of rocks with shrub cover and arboreal vegetation occupying the depressions caused by the emptying of fractures and removal of colluvial-alluvial material by mining.

and Neocambrian mudstone. Karst developed in the limestone that was formed in four stages, the most intense being in the Paleogene, when there was a new subaerial exposition that caused more extensive regional karstification, followed by the current, less developed karstic processes. The iron minerals are formed in the mudstone that fills the karst. The iron mine exhumed a significant part of the features of the exokarst formed in the Paleogene.

4. Discussion

The evolution of concepts in geoheritage and mining heritage has taken many paths. This is partly due to the segmentation of knowledge fields in heritage terms, in which there is a tendency to separate analysis of what is relatable to world heritage into two frameworks, the natural and the cultural. There are few UNESCO World Heritage sites classed as mixed; there were only 38 sites on the 2018 list, which corresponds to 3.48%.

Industrial transformation processes of nature, as in the case of mining, were not initially understood as being the cultural expression of communities. The literature related to the historical evolution of the concept of mining heritage resided, initially, in mining processes, especially historical processes. Only later did it address the way of life and the values of the people of mining regions as an expression of collectiveness,

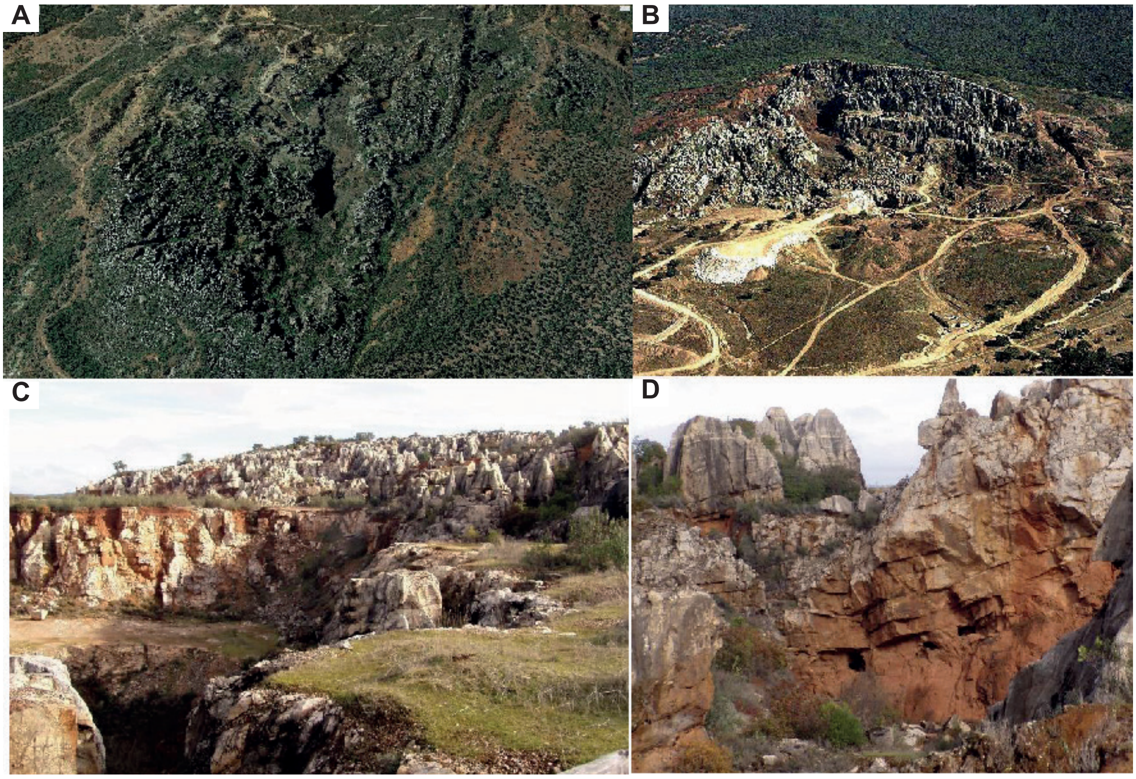

FIGURE 5. Class 3 Geo-mining Heritage. A and B - the general characteristics of the exhumed area, which was generated by mining activities in Cerro del Hierro, Spain (photo A: Google 2020, photo B: J. Alonso). C and D - features of the exhumed paleogenic paleokarst, with cavities emptied by the extraction process.

and, therefore, their heritage. Subsequently, the documents of mining industries were understood as part of the heritage, and, more recently, the landscape, encompassing the natural aspect, transformed through mining, with its industrial buildings and homes, and its form of construction as part of mining heritage (Puche Riart 2000). On the other hand, the origin of geoheritage and its importance occurred based on the understanding that relevant examples of geological materials (*in situ* and *ex situ*), geoforms and their formation processes became important, as they reflect and portray the history of the Earth. Its origin comes from the understanding of the natural heritage of the abiotic component, following the steps of humanity in the conservation of biotic nature since the middle of the 20th century.

The connection between Geoheritage and Mining Heritage has the concept of landscapes that incorporate elements of the natural and the anthropic as an essential element. By associating elements of geoheritage and mining heritage, in the initial analysis, it is recognized that there is a relationship between geomaterials and the extraction processes used throughout the human history. Some of these processes have been used intensely for decades and have played a role in forging a mining culture in certain societies. In the final analysis, this relationship between geomaterials and extraction processes imprinted modifications on the landscapes, which can be described in light of the concepts of anthropogenic geoforms, some of which, given their characteristics, are so conspicuous that they can be distinguished and classified according to their main types.

Some of the most significant examples of geosites and elements of geological heritage (Brilha 2016), such as the mega crystals of Naica (Garcia-Ruiz et al. 2007) and the large trilobites of Canelas-Arouca, in Portugal (Gutiérrez-Marco et al. 2009), were only able to be revealed through mining. There remains a field to be explored in regard to the classification of anthropogenic geomorphology features when focusing on mining, especially open-pit mining or mining at shallow depths.

5. Conclusions

The concept of humans as geological agents, capable of transforming the Earth, has at Vernadsky, not the primacy, but one of its main disseminators in the first half of the 20th century (Vernadsky 1998). At the end of that century, these concepts were expanded, and methods of classification and mapping of forms created and/or modified by humans were applied. Where mining produces and changes geoforms it ends up generating mining landscapes, incorporating the anthropic to the natural. In these places, there is the possibility of a connection between Geoheritage and Mining Heritage.

This text classifies the landscapes generated by anthropogenic mineral geomorphology consisting of three classes of landscapes, determined by their expression in terms of typologies of anthropogenic geoforms constructed, excavated, and exhumed.

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The performance of the Geoparks Commission of the Brazilian Geology Society, from 2018 to 2020

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Abstract

This study presents the context of the creation and development of actions of the Geoparks Commission of the Brazilian Society of Geology (CG-SBG). For this, documentary research of the entity's minutes and existing records in other media was carried out. The results show that the commission has positioned itself as a channel for institutional, political, and social mobilization relative to the topic of geoparks in Brazil, following the objectives established in the CG-SBG bylaws, namely: (a) awaken and conduct debates and reflections on geoparks within SBG; (b) share knowledge about the context and performance of geoparks with the national society, government institutions, and entities of common interest with this topic through publication in its most diverse media; (c) work to benefit the dissemination and implementation of geoparks in Brazil; (d) integrate representatives of the various proposals for geoparks in Brazil and; (e) propose institutional support to geoparks implementation projects in the national territory. In addition, many representatives of regional branches on the commission also form teams of aspirants and geopark projects, further facilitating the interaction between the proposals and the joint discussions. Among the actions carried out is the participation of the commission in several regional, national, and international events, the provision of information through a website, and the manifestation on issues related to geoparks, such as the need to create a National Geoparks Committee, as provided for by UNESCO, in accordance with the statutes of the International Geoscience and Geoparks Programme and guidelines of the UNESCO Global Geoparks (IGGP/2015/ST), to monitor the development of projects and act jointly with UNESCO and aspiring geoparks. Thus, this study concludes that although the commission exists within the scope of a scientific society, it has carried out actions that contribute to the strengthening of the topic of geoparks in various segments of Brazilian society, from the municipalities to national policies.

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1. Introduction

Global Geoparks of the United Nations Educational, Scientific and Cultural Organization (UNESCO) are unique and unified geographical areas, where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development (UNESCO, 2017). Although its territories have a geological heritage of great prominence associated with other aspects of natural and cultural heritage (material and immaterial), a geopark is not a conservation unit nor does it aim to protect geological sites. For this purpose, there are other legal mechanisms in Brazil included in the National System of Conservation Units, for example. A geopark seeks the management of territory through sustainable development, with the involvement of the population and local agents and an emphasis on education and tourism. Currently, the presence of 161 geoparks in the International Geoscience and Geoparks Programme and the Global Geoparks Network in 44 countries shows the relevance of these structures for regional development, especially in Brazil, which has a remarkable geological diversity with the representation of practically all geological periods, rich biodiversity, and important cultural heritage.

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The Geoparks Project of the Geological Survey of Brazil – CPRM, started in 2006, is an expressive milestone in the realization of inventories, with identification and description of places of geological interest in potential areas to become UNESCO global geoparks in Brazil. Seventeen proposals were published in partnership with universities, city halls, and state research agencies (Schobbenhaus and Silva 2012) and 12 new proposals are available on the institution's website (www.cprm.gov.br).

Since the creation of the Araripe UNESCO Global Geopark in 2006, the first and only UNESCO Global Geopark in Brazil to date, there has been a significant and continuous effort to achieve recognition by UNESCO of similar initiatives in the national territory. The following projects started in 2007: Ciclo do Ouro (SP), Caminhos Cânions do Sul (RS-SC), and Fernando de Noronha (PE). The Quadrilátero Ferrífero Geopark (MG) and Bodoquena-Pantanal Geopark (MS) projects in 2009 and 2010, respectively, were the first to attempt to integrate into the Global Geoparks Network, but without success (Ruchkys and Machado 2013, Onary-Alves et al. 2015).

Nascimento et al. (2018) pointed out the difficulties encountered by geoparks projects to obtain the seal of UNESCO Global Geoparks/Global Geoparks Network (UGG/GGN):

a - Difficulty in understanding the geographical concept of territory.

b - Lack of clarity about the UNESCO Global Geoparks Programme, causing geoparks to be confused with parks or another category of conservation unit.

c - Absence of strategic planning for Brazilian geoparks projects to meet the criteria required to obtain UGG/GGN certification.

d - Interaction with communities and public managers so that they can assume their role in the implementation, management, and carrying out of actions to consolidate the projects.

e - Low heritage education for both the population and visitors to the project territories.

f - Lack of an official entity to coordinate discussions on geoparks in Brazil.

Currently, Brazil has four Aspirants and 31 Geoparks Projects (Nascimento 2020). Caminhos dos Cânions do Sul (RS-SC) and Seridó (RN), which submitted applications in 2019 and 2020, respectively, and Caçapava (RS) and Quatro Colônia (RS), with the letters of intent delivered in 2020, are aspiring geoparks. The projects are at different stages of development: (1) becoming aware of what a geopark is; (2) there is still no structure for managing the territory, but they are at the stage of bringing people together and encouraging society to embrace the idea of a geopark; and (3) those who are working in the territory and can fit into the logic of the geopark (Comissão de Geoparques - SBG 2020).

The Brazilian Geology Society, through the creation of its Geoparks Commission, joins the effort to publicize the topic, the creation of the National Geoparks Committee, and the implementation of Brazilian geoparks.

2. History

The Brazilian Geological Society (SBG) is the largest technical-scientific entity in Earth Sciences in Brazil, with more than 70 years of foundation. Headquartered in São Paulo, it has about 5,000 partners linked to 10 regional branches spread across the country. Its mission is to promote the knowledge and development of geosciences, applied geology, and related research and technology, as well as the rational and sustainable use of mineral and water resources (http://www.sbgeo.org.br/home/pages/2).

SBG Bahia-Sergipe Branch began to discuss the topic of geoparks in 2016 when it promoted the roundtable *Brazilian Geoparks: Paths, Difficulties, and Alternatives*, a face-to-face event broadcast nationally by videoconference, with the remote participation of Prof. Dr. José Brilha (University of Minho, Portugal), Prof. Dr. Marcos Nascimento (UFRN – Seridó Geopark), Geologist Carlos Schobbenhaus (CPRM), and MSc. Flávia Lima (Geodiversidade Soluções Ltda.). An interinstitutional group was formed as a result of this debate and, because the geopark is a territorial management model based on sustainable development, a strategic plan for the implementation of geoparks in the State of Bahia (Santos-Pinto et al. 2018) was elaborated and delivered to the Secretariats of Planning (SEPLAN) and Economic Development (SDE). Given this local experience, the group realized the need to create an entity at the national level, a Geoparks Commission, which would encourage discussion about geoparks and could integrate representatives of the different geoparks projects in Brazil. This proposal was taken by the Chief Executive Officer of Bahia-Sergipe Branch to the Society's Board of Directors for consideration. After the proposal was accepted, the proponent was appointed as a leader and tasked with assembling the team with the representatives of the regional branches of SBG for the preparation of bylaws of the Geoparks Commission of the Brazilian Geological Society (CG-SBG). The working group consisted of eight representatives from the Bahia-Sergipe Branch, two from the Brasília Branch, two from the Midwest Branch, one from the Northeast Branch one from the Paraná Branch, one from the Rio de Janeiro/Espírito Santo Branch, and one from the São Paulo Branch. Currently, we also have the representation of the Minas Gerais and Rio Grande do Sul-Santa Catarina Branches (Figure 1).

3. Bylaws

The CG-SBG bylaws was approved on April 21, 2018 (Sociedade Brasileira de Geologia - SBG 2018), with the following objectives:

a - Awaken and conduct debates and reflections on the topic Geoparks within SBG.

b - Share knowledge about the context and performance of geoparks with the national society, governmental institutions, and entities of common interest with this topic through publication in its most diverse media (book, article, booklet, website, or folder).

c - Work to benefit the dissemination and implementation of geoparks in Brazil.

d - Integrate representatives of the various proposals for geoparks in Brazil.

e - Propose institutional support to geoparks implementation projects in the national territory.

Its members must be specialists from teaching and research institutions, agencies, and companies or independent professionals and indicated by the regional branch of SBG.

FIGURE 1. Composition of the Geoparks Commission, biennium 2020–2022 (http://www.geoparques-sbg.org.br)

Members may be added at any time during the Commission's term of office.

CG-SBG must contain the following positions and coordination, which are necessarily effective members of the Company: a) Manager; b) Secretary; and c) Communication and Publications Coordinator. The term of office of the CG-SBG positions and coordination will be two years, renewable for an equal period.

4. Geoparks Commission activities and products

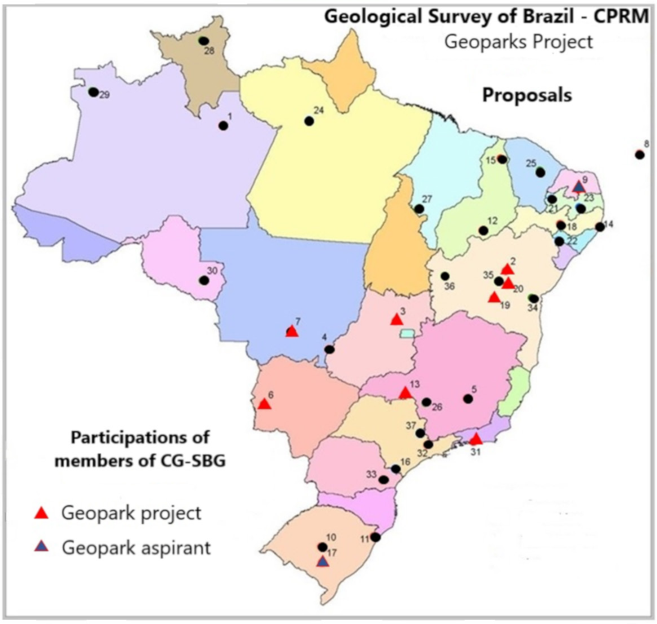
The Geoparks Commission members are indicated exclusively by the regional branches of SBG. Currently, many of them are also directly involved with aspirants and Geoparks projects, standing out the projects Morro do Chapéu, Alto Rio de Contas, Serra do Sincorá, and São Desidério, in Bahia; Uberaba – Terra de Gigantes, in Minas Gerais; Costões and Lagunas, in Rio de Janeiro; Chapada dos Veadeiros and Pireneus, in Goiás; Bodoquena-Pantanal, in Mato Grosso do Sul; and Chapada dos Guimarães, in Mato Grosso. The aspirants are Seridó, in Rio Grande do Norte, and Caçapava, in Rio Grande do Sul. Thus, the Geoparks Commission already promotes a first integration among representatives of several proposals for geoparks in Brazil (Figure 2).

The participation of CG-SBG in regional, national, and international scientific events, in addition to disseminating the topic, favors debate and reflection within SBG with other segments of the community and other institutions. The participation of the geoscientific community is optional in open Commission meetings in the Brazilian Congresses of Geology promoted by SBG, as occurred in 2018 in Rio de Janeiro (49th CBG).

Other types of participation can be mentioned, such as in the 1st International Forum on Innovation and Sustainability in Mining, held on 8/14/2019, in Salvador-BA, where thematic banners and videos and geoproducts were exhibited and explanatory leaflets, tourist itineraries of Chapada Diamantina and publications from the Bahia-Sergipe Branch on geosites and proposals for geoparks in the State of Bahia were distributed (Figure 3) in partnership with the Bahia-Sergipe Branch of SBG and Serra do Sincorá Geopark Association (AGS). Another prominent occasion took place at the Legislative Assembly of the State of Bahia during the opening of the public hearing promoted for the Implementation of the Serra do Sincorá Geopark project in Chapada Diamantina, and three months later the CG-SBG director and secretary performed presentations on the UNESCO Global Geoparks and Geoparks projects in the State of Bahia.

The CG-SBG website (http://www.geoparques-sbg.org.br) is an essential tool for sharing information about the context and performance of geoparks with the national society, government institutions, and entities of interest common with this topic by the publication of scientific articles, dissertations, thesis, geological inventories, events, and websites of interest. In addition, it enables interaction with the public, who can submit their scientific production on the topic of geoparks for publication on the website (Figure 4).

Due to the technical competence of the team, CG-SBG can offer technical assistance in the preparation of proposals for geoparks in compliance with administrative and scientific criteria required by UNESCO. For this, the goal is to prepare didactic material to be made available on the CG-SBG website, such as that already published presenting the discussion on the Self-Assessment Form of the UNESCO International Geoscience and Geoparks Programme (IGGP) (http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/) and the Global Geoparks



Nº	Name	State
1	Cachoeiras do Amazonas	AM
2	Morro do Chapéu	BA
3	Pireneus	GO
4	Astroblema de Araguainha-Ponte Branca	GO/MT
5	Quadrilátero Ferrífero	MG
6	Bodoquena-Pantanal	MS
7	Chapada dos Guimarães	MT
8	Fernando de Noronha	PE
9	Seridó	RN
10	Quarta Colônia	RS
11	Caminhos dos Cânions do Sul	RS/SC
12	Serra da Capivara	PI
13	Uberaba	MG
14	Litoral Sul de Pernambuco	PE
15	Sete Cidades-Pedro II	PI
16	Alto Vale do Ribeira	SP
17	Guaritas-Minas do Camaquã	RS
18	Catimbau-Pedra Furada	PE
19	Alto Rio de Contas	BA
20	Serra do Sincorá	BA
21	Rio do Peixe	PB
22	Cânion do São Francisco	SE/AL
23	Cariri Paraibano	PB
24	Monte Alegre	PA
25	Vale Monumental	CE
26	Serra da Canastra	MS
27	Carolina	MA
28	Tepuis	RR
29	Alto Rio Negro	AM
30	Alto Alegre dos Parecis	RO

Nº	Other Geopark proposals	State
31	Costões e Lagunas do Estado do Rio de Janeiro	RJ
32	Ciclo do Ouro de Guarulhos	SP
33	Campos Gerais	PR
34	Inselbergs de Itatim-Milagres	BA
35	Iraquara	BA
36	Rio João Rodrigues-S. Desidério	BA
37	Corumbataí	SP

FIGURE 2. Aspirants and geoparks projects with the participation of CG-SBG Members (modified from: http://www.cprm.gov.br/publique/GestãoTerritorial/Geoparques-134). Aspirant Caçapava was treated by CPRM as Guaritas-Minas do Camaquã (number 17).

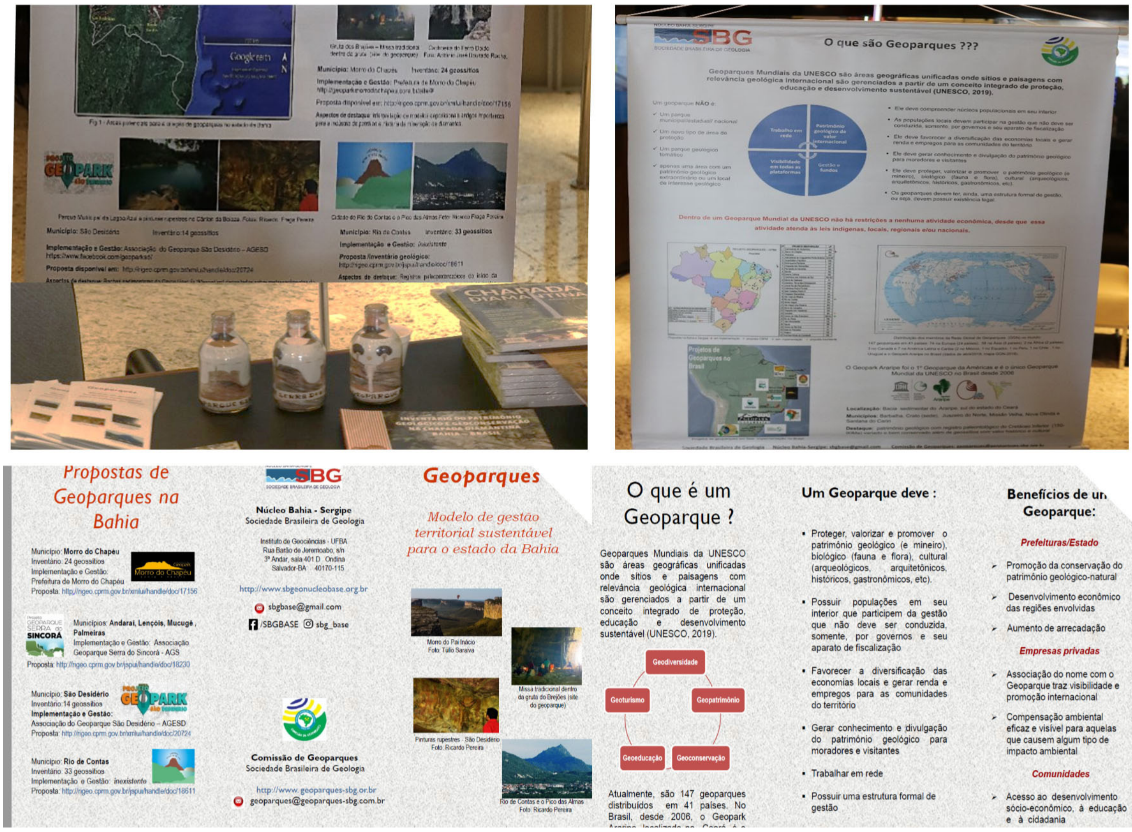


FIGURE 3. Exhibition with explanatory banners on geoparks, geoproducts (colored sand bottles), and free distribution of explanatory leaflets, tourist itineraries of Chapada Diamantina, and publications from the Bahia-Sergipe Branch on geosites and proposals for geoparks in the State of Bahia.

Network (GGN) (http://www.globalgeopark.org/), a mandatory form for applying for the global geopark and an important support tool for the construction of the application dossier (Comissão de Geoparques - SBG 2020).

The request for letters of support from the Brazilian Geological Society for activities on geoparks and related topics demonstrates the consideration given to the work carried out by CG-SBG. Thus, letters were sent in support of the candidacy of the Seridó Geopark Project, for the Araripe UNESCO Global Geopark, and the Regional University of Cariri – URCA to host the next International Conference on Geoparks and the implementation of the International Day of Geodiversity. Besides, at the suggestion of CG-SBG, SBG expressed its opposition to the proposal to modify Federal Decree 6640/2008 of the Ministry of Mines and Energy to remove protection from caves classified as of maximum relevance, as they are classified as Geological Heritage.

5. Discussions

5.1 – Meetings

Although Brazil hosts the 1st Geopark of the Americas and Southern Hemisphere (Araripe UNESCO Global Geopark) and has an increasing number of proposals for geoparks projects and four aspiring geoparks (two under analysis and two with letter of intent sent), we do not yet have an official national entity that coordinates discussions on the topic. This Committee, Forum, or Commission, foreseen in the statutes of the International Geoscience and Geoparks Programme and guidelines of UNESCO Global Geoparks (IGGP/2015/ST) (UNESCO 2015), is responsible for the pre-selection of candidates able to apply for the UNESCO seal, as a country can only submit two proposals per year to the International Geoscience and Geoparks Programme, in addition to other functions within its scope, such as:

FIGURE 4. CG-SBG website: A – partial view of the homepage; B – publications and form for the visitor to submit their scientific production related to geoparks for publication on the page.

a) Coordinate the national contribution to UNESCO Global Geoparks within the International Geoscience and Geoparks Programme.

b) Identify the geological heritage and make the public aware of its importance.

c) Promote the creation and development of new UNESCO Global Geoparks, evaluating and endorsing applications, revalidations, and extensions.

d) Observe the assessment or revalidation missions in the Member State, if desired.

e) Submit to the UNESCO National Commission of that Member State or to the government agency responsible for relations with UNESCO all applications for UNESCO Global Geopark, which will be forwarded to UNESCO.

f) Ensure the adequate removal of the area as a UNESCO Global Geopark within the IGGP in case the area wishes or fails in the revalidation process.

g) Promote international cooperation between UNESCO Global Geoparks.

h) Provide information at the national level on the Global and Regional networks of UNESCO Global Geoparks.

i) Initiate and support strategies and actions for sustainable development within and between UNESCO Global Geoparks.

The joint efforts of Araripe UNESCO Global Geopark, Geological Survey of Brazil-CPRM, and UNESCO Office in Brazil over the last decade to change this situation have not been successful. CG-SBG has made a public statement about the importance and urgency of making the Brazilian Geoparks Committee official, including making available its services to work together with the agencies responsible for its creation. At the beginning of 2019, during the 1st URCA Summer University Course, in Juazeiro do Norte (CE), a meeting was held at the request of CG-SBG to discuss the implementation of the Brazilian Geoparks Committee, with the presence of representatives of Araripe UNESCO Global Geopark, UNESCO in Brazil and Latin America, the Brazilian Association for the Defense of Geological and Mining Heritage, and the Regional University of Cariri. There was consensus on the urgency of this action due to the advanced stage of several proposals for geoparks in Brazil that aspire to integrate the Global Programme and the Global Geoparks Network, and the appointment of CG-SBG as a permanent member in the composition of the Brazilian Geoparks Committee.

This position was ratified in the “Araripe Letter,” the final document of the V Brazilian Symposium on Geological Heritage, held in the city of Crato-CE, in October 2019, which recognized the role of the Brazilian Geological Society, through the Geoparks Commission, supporting the formalization actions of Geoparks projects in Brazil and indicating its participation in the composition of the Brazilian Geoparks Committee (AgeoBR, 2019).

5.2. Holding the event

CG-SBG promoted the “I Webinar Aspiring and Geopark Projects: realities and challenges.” This was the first national event, free of charge, which brought together the representatives of the four Aspirants and several Geopark projects in Brazil, in addition to national and international institutions related to the topic. It had an average audience of 980 people via YouTube and 2137 people via Facebook (data from October 2020) from different professions and educational levels, being carried out from 9/18 to 10/9/2020 once a week (Fridays).

The meeting allowed participants to be introduced to the UNESCO International Geoscience and Geoparks Programme, which certifies a territory as a UNESCO Global Geopark and informed about the application process to the Geoparks Project in Brazil of the Geological Survey and the Araripe Global Geopark of UNESCO.

Noteworthy was the presence of the representative of the United Nations Division III, Ministry of Foreign Affairs, the body that houses the National Commission for UNESCO, and the sector responsible for receiving applications to the UNESCO International Geoscience and Geoparks Programme and forwarding them to the entity’s headquarters in Paris. The representative committed to contribute to the development of the topic in Brazil and look for ways to create the National Geoparks Committee. The UNESCO Office in Brazil and the Ministry of Tourism, represented by the Department of Marketing and Competitive Intelligence for Tourism, also offered to contribute to the various aspirants and projects, and the latter proposed the construction of a discussion agenda on the topic. All entities said they would work together to build strategies to support and strengthen Brazilian candidacies.

The dissemination of successful actions in the territories of Aspirants (4) and the different initiatives of some Geoparks Projects (16) gave greater visibility to the proposals, their stages of development, and instigated the debate on the implementation of geoparks projects in Brazil and the need to work in a participatory and networked way, basic pillars of any geopark in the world.

The lectures were recorded, and the videos are available on the SBG YouTube channel and Facebook.

6. Conclusions

The Brazilian Geological Society, through its Geoparks Commission, is available to continue working towards the creation of the Brazilian Geoparks Committee and the dissemination and implantation of geoparks in Brazil. Although it is part of a scientific society, its actions contribute to the strengthening of the topic of geoparks in various segments of Brazilian society, from municipalities to national policies.

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Three hundred years of geodiversity in the Historic Center of the Gold City, Cuiabá, Brazil

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Abstract

Gold was abundant in the city of Cuiabá and was the starting point for is emergence and development. Bandeirantes (explorers/fortune hunters during the colonial period), mostly coming from São Paulo, made their expeditions into inland Brazil firstly to capture and enslave natives and, in this process, discovered important alluvial deposits associated with the rivers in the region. Today, this precious metal is still present and being prospected in the Baixada Cuiabana region, and is found preserved (impregnated and visible) in the plaster of the walls of the Church of Nossa Senhora do Rosário e São Benedito, for example. Many buildings in the central areas were built and adorned with ex situ geological material such as ironstone and blocks of milky quartz, and some of these buildings are identified in this work as an example of the use of geodiversity as a constructive and historical element. Ironstone is described as a solid, reddish sedimentary rock resulting from a chemical alteration process (lateritization), and the quartz blocks come from gold veins that cut the rocks of the Cuiabá Group, in the Baixada Cuiabana region. In addition to these materials that are present in some locations and represent geodiversity elements, an *in situ* example of geodiversity is described. It is an exposed geological fault that stands out in the landscape, located in an aligned hill where historic constructions were built. Because it is of unique geoscientific interest and preserved within the central urban boundary of the city of Cuiabá, this place can be considered the first geosite, which is described in the present work.

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1. Introduction

The name Cuiabá, capital of the state of Mato Grosso, Brazil, derives from the indigenous word *Cuyaverá*, which means 'bright otter', one of the small animals that lived in these very distant lands. The history of this city begins with an element of geodiversity, with the arrival of explorers in the region searching for primary and alluvium gold, and became known as the Gold City. In the historical evolution of this city, geological materials were used, which are recognized in building restorations in its historic center. As it is in other urban centers in Brasil (Nascimento et al. 2018; Del Lama 2019) (Nascimento et al. 2018; Del Lama 2019), geodiversity is present in various moments of the history of Cuiabá.

The present work aims to describe elements of geodiversity in the central area of Cuiabá. First, the starting point for the development of Cuiabá occurred with the discovery of alluvial gold in the Coxipó and Cuiabá rivers. The historic center grew from the orderly construction of buildings located in prominent locations, such as the top of hills and mounts, which are composed of metarenites of the Cuiabá Group.

2. Materials and methods

This research had the purpose of identifying locations where there are geodiversity elements (stony materials) in the center of Cuiabá, MT. Identification of the geodiversity characteristics was based on Silva and Nascimento (2016).

The places detailed in this paper are buildings where *ex situ* geological materials were used and, based on this cataloged data, a simplified map of the historic center and surroundings was developed, indicating the location of the buildings, which could be used as a proposed guide for the practice of geotourism.

The Institute of Historic and Artistic Heritage of Cuiabá provided bibliographic support for the search of written materials, such as the files of historic, cultural buildings that were preserved as historic heritage, as well as a vast urbanistic literature of books and theses.

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3. Timeline and city space

The story begins to be told from the first incursions of the Bandeirante Pascoal Moreira Cabral Leme into the lands of western Brazil. He went upstream the Coxipó River and discovered gold concentrations, starting, in 1718, the gold rush in this region. A year later, on April 08, 1719, Vila Senhor Bom Jesus of Cuiabá was founded.

With the initial discovery of gold in this region, the first mines were called "Sutil Mines", named after Miguel Sutil in his search for gold and honey. In 1734, the brothers Artur and Fernando Paes de Barros, also from the state of São Paulo, called these mines 'Mato Grosso Mines'. This name, 'Mato Grosso' (in English, thick forest), according to historical records dated to 1866, originates from: "a large extension of seven leagues of tall, thick and almost impenetrable forest". In this period, in the 1730s, the first construction built on top of a hill, on the banks of the Prainha Stream, was the Church of Nossa Senhora do Rosário e São Benedito.

In 1757, two decades after the discovery of gold in Mato Grosso Mines, the history of the mines was officially documented, where the term 'Mato Grosso' was described and identified as the location where the mines were found. In the 18th century, the Cuiabá village belonged to the São Paulo captaincy, and in 1748 it became one of the Captaincy Terms of 'Matto Grosso'. In 1818, the village was raised to the status of town and, in 1835, Cuiabá became the capital of the province and later the capital of the state of Mato Grosso (Conte and Freire 2005). According to the records, in the mid-nineteenth century, the extraction of gold decreased drastically, and as a result, the economy went into a decline with consequent reduction in the population. Only after the implementation of railroads and telegraphs, as well as the arrival of rubber tappers, the economy resumes growing again and new constructions were built.

In the early 20th century, the city began to be urbanized, the Prainha Stream was channeled, the banks were cemented, and bridges for cars and pedestrians were built. Thus, this river, once a large flowing river, became a trickle of water in a closed channel in the center of the avenue, today named Historiador Rubens de Mendonça Avenue (Figure 1). The city has grown from the port and this stream, and numerous buildings were erected and gave form to the central area that we see today.

On the map of the historic center (Figure 1), which was developed from maps available in library of the city hall of Cuiabá, the main buildings that comprise the proposed geodiversity route were indicated. Clockwise, one can see in Figure 1: the Presbyterian Church of Cuiabá (nº1); the Palace of Instruction (n° 2); the Metropolitan Cathedral and Basilica of Bom Jesus de Cuiabá (n° 3); Church of Nossa Senhora da Boa Morte (n° 4); Church of Nosso Senhor dos Passos (n° 5); Church of Nossa Senhora do Rosário e São Benedito (n°6); and outside the central area the Church of Nossa Senhora do Bom Despacho (n°7).

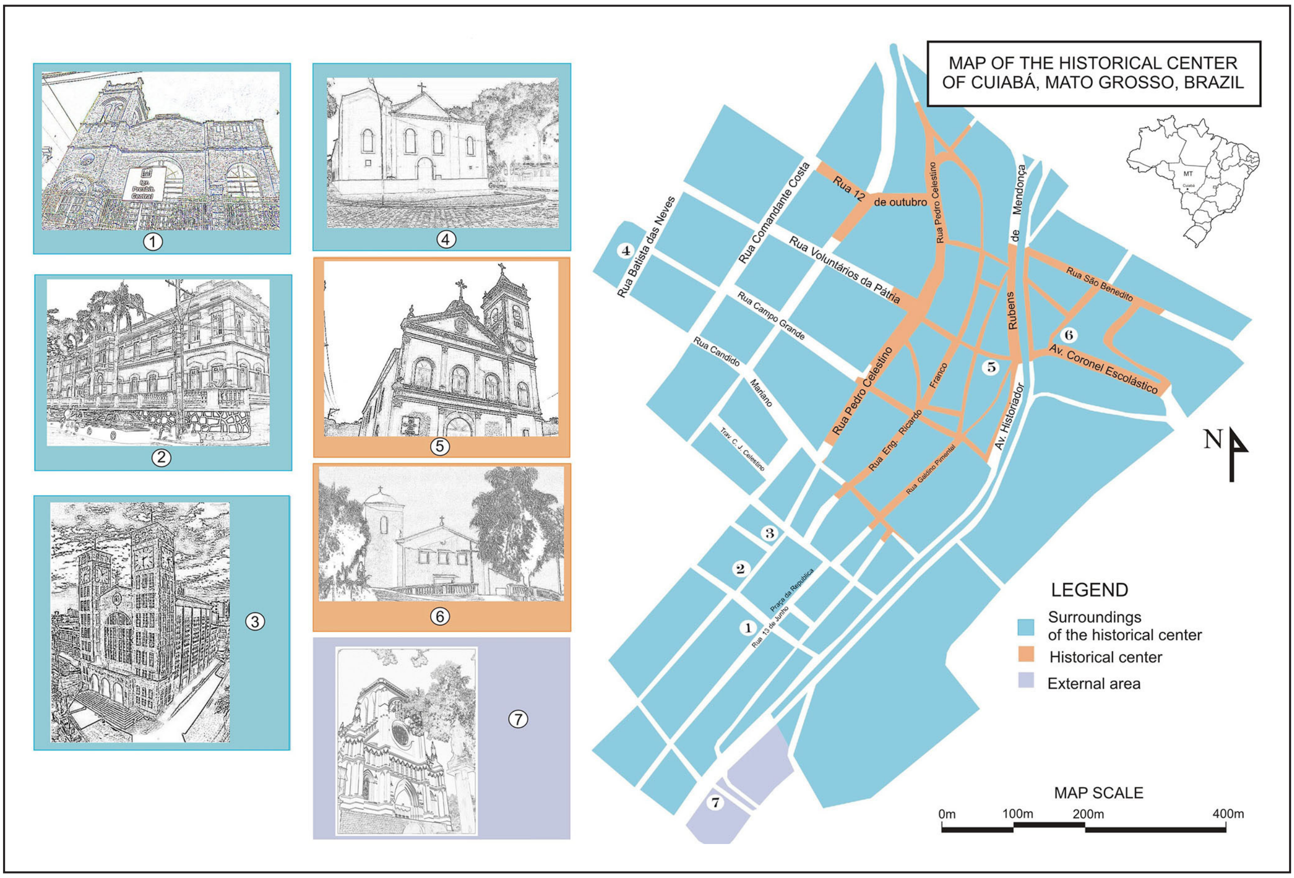

FIGURE 1. Schematic map (basic map of the City Hall of Cuiabá) of the historic center and surroundings of Cuiabá, with the location and drawings of the buildings studied in this work. (1) the Presbyterian Church of Cuiabá; (2) Palace of Instruction; (3) Metropolitan Cathedral and Basilica of Bom Jesus de Cuiabá; (4) Church of Nossa Senhora da Boa Morte; (5) Church of Nosso Senhor dos Passos; (6) Church of Nossa Senhora do Rosário e São Benedito; and outside the central area the (7) Church of Nossa Senhora do Bom Despacho.(Map source: City Hall of Cuiabá; Figures source: Ana Costa, 2020).

4. *Ex situ* geodiversity elements

Stony geological materials can be used in urban constructions and show how important is to keep records of these places. Some works, such as that by Nascimento et al. (2018), indicate a division of geological materials into groups: historical, constructive and functional. In Cuiabá, some buildings and avenues (D. Aquino, Joaquim Murtinho avenues, Barão de Melgaço street) used ironstone, which allows to classify its use into the historical group of buildings. Ironstone is a reddish-brown arenite from the Chapada dos Guimarães region. This rock is part of the Ponta Grossa Formation (Paraná Basin) and is locally in disagreeing contact with the rocks of the Cuiabá Group.

In the place where the first movie theater of the city was built, the Cine Mundial (Gazeta Digital 2017), the first Presbyterian church of Cuiabá was erected. (Figure 2a). This building, which dates back to 1921, is located in the block of commercial stores in the Rua 13 de Junho, the street right in the center of the city. It is an old building, with an external façade made of exposed bricks and ironstone wall, giving the place a unique beauty.

The Instruction Palace is a neoclassical building located next to the Mother Church of Cuiabá and was declared a heritage building in 1983. The Palace was built with ironstone, as well as its wall (Figure 2b), with milky quartz crystal on its foundation and adobe walls with up to 80cm thick.

According to historians, the Mother Church of Senhor Bom Jesus de Cuiabá (Figure 3a) has a peculiar history of construction and de-construction until becoming as it is today. It was built in 1723 (Gazeta Digital 2017), four years after the foundation of the Vila de Bom Jesus de Cuiabá. In 1739, it was rebuilt and in 1745 it gained a bell tower. In 1826, the church was raised to the status of cathedral of the city, and 103 years later, it received another bell tower. In 1968, after 235 years of existence, it was decided to demolish and rebuild it, and only in 1973 it was finally concluded. The altar, 20 meters high, is covered with tiny tiles (Figure 3b) and was built by a Polish artist (Arystarch Kaszkurewicz).

A Baroque-style chapel, built in 1810, is the Church of Boa Morte (Figure 4a). The three altars and the whole ensemble, dated back to the colonial period, belong to the Brotherhood of Color Men, and the church was declared cultural heritage in 1987. Likewise, built in 1792, we have the Church of Nosso Senhor dos Passos (Figure 4b). Typical of the colonial period, it is located within the historic center and has ironstone and quartz fragments (from veins) on an altar built outside the chapel.

The construction of the Church Nossa Senhora do Rosário e São Benedito began in 1725 and ended five years later. Inside the church, the construction of the walls was made with thick rammed earth with 90 cm or 40 cm in width. An important detail inside the church is the presence of gold scattered on the wall. This is because the wall is exposed to the public, and was made with geological material from the Prainha Stream, from which the slaves extracted gold.

The ironstone that is present in the sidewalk and walls of the Church of Nossa Senhora do Bom Despacho (Figure 5a and 5b) and embellishes the entire external area of the Rosário Church (external walls, stairways and sideways; Figures 5c and 5d) was a landscape work designed and executed during the government of Pedro Pedrossian (1966-1971).

Ironstone is a rock formed by a process of laterization and iron oxidation (Figure 6). Partially-lateritized siltstones possibly belong to the Ponta Grossa Formation, from the Devonian Age, outcropping in the Chapada dos Guimarães. Fine arenites may also occur, which vary from reddish to brown color, and a purplish color when presenting some alteration (Table 1). After oxidation, it may expose the primary structure of the oxidated rock

5. *In situ* geodiversity

Based on previous geological studies of the region (Luz et al. 1980; Alvarenga and Trompette 1993; Migliorini 1999; Silva et al. 2002) and a survey of the geodiversity elements present in the central part of Cuiabá (Costa et al. 2019), it was found that in the Morro do Seminário (the hill where the Church of Nossa Senhora do Bom Despacho (Figure 7) was built, there is a ‘reverse fault’, typical of areas where a rock deformation activity occurred. Currently, the fault wall

FIGURE 2. (a) Detail of exposed bricks and ironstone wall of the Presbyterian Church of Cuiabá, MT; (b) Back wall of the Instruction Palace, made with ironstone and currently covered with paint (Source: Ana Costa, 2020).

FIGURE 3. (a) At the right side of the image is the Church of Senhor Bom Jesus de Cuiabá, with two towers and clocks (Source: Instituto do Patrimônio Histórico e Artístico Nacional); (b) Detail of the Interior of the Mother Church, showing the altar built with tiny tiles (Source: Amanda Moura, 2017).

FIGURE 4. (a) Photograph showing the front view of the Church Boa Morte; (b) Also from the colonial period, the Church of Nosso Senhor dos Passos (Source: Ana Costa, 2020).

is covered by a large masonry wall supporting the hill slope, which makes it impossible to observe the fault's structural elements. However, in the continuance of this hill, in the Morro da Luz [in English, Light Hill], it follows in straight line towards the NE until close to the Church of Nossa Senhora do Rosário e São Benedito.

It is, therefore, a unique geosite in downtown Cuiabá (Figure 8) with good intrinsic characteristics (Brilha 2005): small extension, good visibility and studied in a doctorate thesis (Migliorini 1999). Because it is located in the central region, it has association with cultural elements and a preserved flora. With respect to its potential use, it allows that scientific activities be carried out, with good accessibility and no permission to collect materials. It is a place with no interest whatsoever for mineral exploration, if one considers the required protection item. And also in this regard, it is characterized by a high value-added land that is municipal property.

6. Conclusions

Geodiversity is present over the 300 years of Cuiabá's history. Since its discovery in the Coxipó River, gold marks the evolution of city's heritage and history. The metal is still found in quartz veins in the Cuiabá lowlands (Baixada Cuiabana) and continues to be explored in some towns, e.g., Poconé. In this town, according to the Associação Mato-grossense dos Municípios (2016), (in English: Association of Mato Grosso Municipalities), in 2015, 1.5 tons of this metal was explored, while the total production in the state (DNPM) was approximately of six tons. Currently, the economy is not supported by gold, but commerce, agribusiness and touristic attractions of urban areas.

The geodiversity in Cuiabá is present in historic buildings, a cultural asset that may become a geotouristic itinerary for an interested public. The ironstone found in the churches and parks represents the utilization of *ex situ* geodiversity. The hill fault of Morro da Luz can be classified as a singular geosite and represents *in situ* geodiversity. The cataloging work and characterization of *in situ* geodiversity within the boundaries of the city, also encompassing the Cuiabá River, and the existing educational outcrops will enable the proposition of new geosites in the region.

The next steps of this research will consist of making an inventory, i.e., listing out and cataloging *in situ* and *ex*

FIGURE 5. (a) and (b). Side stairway and pillar of the old wall of the Church of Nossa Senhora do Bom Despacho; (c) and (d) Protective wall and sideway/stairway, made with ironstone, of the Church of Nossa Senhora do Rosário e São Benedito, Av. Coronel Escolástico (Source: Ana Costa, 2020).

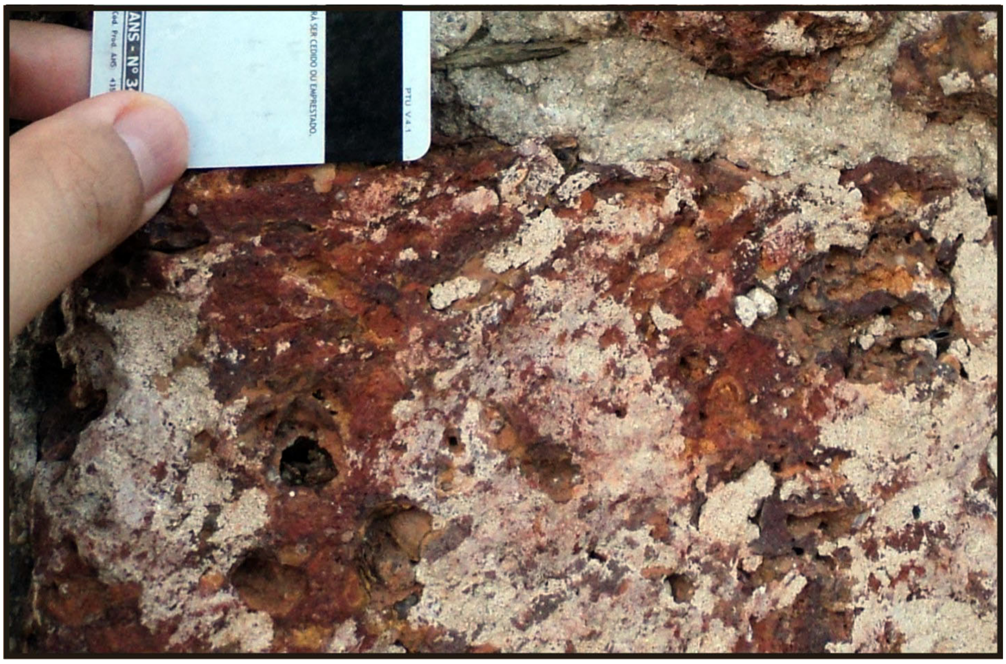

FIGURE 6. Macroscopic detail of ironstone in the column of the Church of Nossa Senhora do Bom Despacho. (Source: Ana Costa, 2020).

TABLE 1. Macroscopic description of ironstone.

Rock	Minerals	Grain size	Nomenclature
Ironstone	Goethite, quartz, hematite, Al and Fe hydroxide	Coarse-grained	Ferruginous laterite

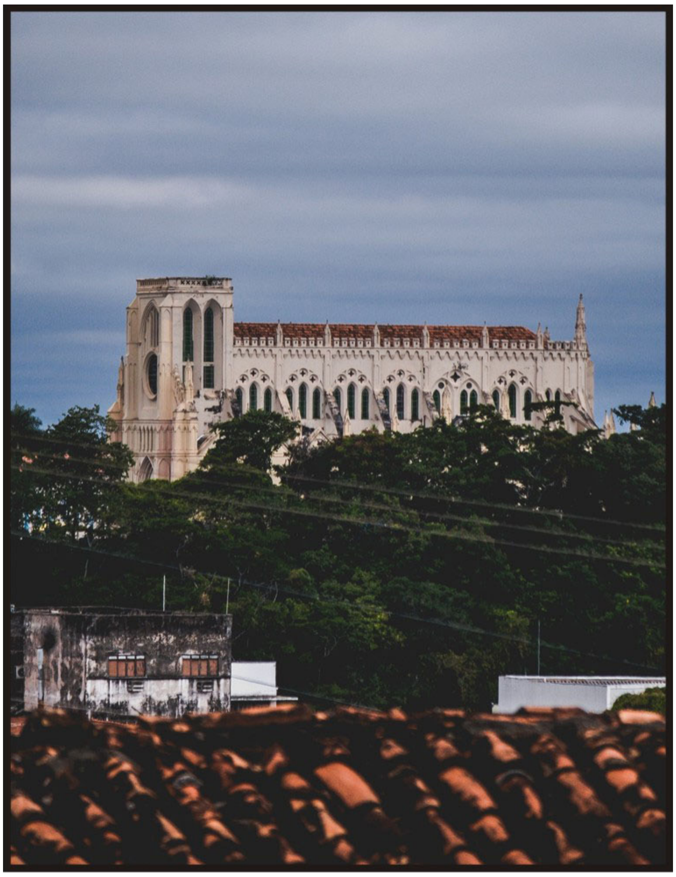

FIGURE 7. Landscape image of the Church of Nossa Senhora do Bom Despacho (Source: Paulisson Miura, 2013. Available on line at: https://commons.wikimedia.org/wiki/File:Bom_Despacho_(Cuiab% C3%A1,_MT,_Brasil)_(9264583453).jpg).

FIGURE 8. Google Earth (2018) (3D) image of the central region, showing the alignment of the Morro da Luz, which translates the reverse fault line (dashed line).

situ elements of geodiversity, to enable the proposition or identification of geosites that could also be part of a geotouristic itinerary.

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A survey of the paleontological heritage of Paraná State, Brazil

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Abstract

The state of Paraná has a considerable area with sedimentary outcrop rocks from the Paraná Sedimentary Basins (Paleozoic and Mesozoic) and Bauru (Mesozoic), Curitiba Basin (Cenozoic), and metasedimentary basement rocks (Proterozoic) with fossiliferous content. The state's paleofauna and paleoflora, geologically distributed over more than one billion years, are diversified and acknowledged in several scientific publications. On this regard, a survey of the main collections and paleontological sites in Paraná state was conducted to provide a basis for the conception of a geoscience museum and with the scope of presenting representative fossils of the geological history of this region. The methodological procedures consisted of literature search, consultations with paleontologists, visits to various state institutions and a selection of the samples in different sectors of the State University of Ponta Grossa (UEPG). The surveyed set of paleontological collections and sites indicate the heritage that is known by the state research institutions and museums and allowed to organize and quantify the set of fossils that comprise the collection of the UEPG's Museum of Natural Sciences, which now exhibits to the public the evolutionary history of Paraná's fossils. The survey identified 25 geosites in the state and 10 museological institutions located in 20 municipalities, which represent the most valuable scientific and educational paleontological heritage, as emphasized in this text.

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1. Introduction

In Paraná State (southern Brazil) important fossils are found in its territory, indicating the existence of a significant geological, paleontological and cultural heritage, which is acknowledged in various recent scientific publications (*e.g.* Bosetti 2007, Liccardo and Weinschütz 2010, Manzig and Weinschütz 2012, Sedor et al. 2017, Kellner et al. 2019, Langer et al. 2019, Fraga and Vega 2020). The paleofauna and paleoflora in Paraná State are diversified, with important discoveries having been recorded in the past years but still unknown to the public in general. Fossil representatives of the different geological periods are found, which together tell the evolution of life on Earth, from the Proterozoic period (about 1.1 billion years ago) to the Cenozoic period (Pleistocene, until 11,700 years ago).

This work aimed to conduct a data survey of the *in situ* paleontological heritage (paleontological sites) and *ex situ* (paleontological collections) in the state of Paraná in order to provide a detailed picture of this heritage and define the representativeness of the fossils on display at the *Museu de Ciências Naturais* (MCN) [Museum of Natural Sciences] of the State University of Ponta Grossa (UEPG).

The records of fossils found in the rocks of the studied region indicate different paleoenvironments, paleoclimates and distinct stages of life evolution in the past, which characterize an *in situ* geological heritage, that is, the outcrop areas that preserve these records or geosites. Brilha (2005) considers as geosites locations of occurrence of one or more elements of geodiversity (outcrops formed by the action of natural processes or human intervention), geographically well-defined and which have a significant value from the scientific, didactic, historical, touristic, or other, viewpoint. Rocks, minerals or fossils collected and preserved in collections comprise the ex situ geological heritage (Ponciano et al. 2011, Viana and Carvalho 2019) and its scientific/cultural contents refer directly to the geological characteristics of the geosites.

In Paraná, the stromatolites in meta limestones and marbles of the Crystallin Basement are the most ancient fossils, roughly 1.1 billion of years ago, and are located in the First Plateau of Paraná, in the rocks of the Capirú Formation (Guimarães et al. 2002, Piekarz 2011).

In the Paraná Sedimentary Basin, in the region that comprises the Second Plateau of the state, there are numerous fossiliferous records along each lithostratigraphic unit (Furnas, Ponta Grossa, Itararé, Rio Bonito, Palermo, Irati, Serra Alta, Teresina, Rio do Rasto, Botucatu Formations) that date back between 419 and 65 million of years ago. Since the discovery of the first fossils in Paraná State (late

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nineteenth century), the Second Plateau has been the focus of numerous paleontological researches that revealed important scientific discoveries throughout the geological units cited (*e.g.* Mac Gregor 1908, Clarke 1913, Rosler 1974, Matsumura et al. 2013). The most representative fossils of this region are ichnofossils and invertebrates of the Devonian period (Furnas and Ponta Grossa Formations), plant fragments of the Permian Period (Rio Bonito Formation), mesosaurids and crustaceous of the Permian Period (Irati Formation), silicified woods and stromatolites and invertebrates of the Permian period (Teresina Formation) and amphibians, fishes and plant leaves of the Permian (Rio do Rasto Formation), found the in the Second Plateau of Paraná.

In the Bauru Sedimentary Basin, Third Plateau, in the Mesozoic period, sedimentary rocks of the Goio-erê Formation (Caiuá Group) preserved important bone fragments from lizards, pterosaurs and dinosaurs dated 145 to 66 million years ago. Also found in rocks of this formation are ichnofossils of Tetrapoda (Silva 2002, Langer et al. 2019).

Finally, from the Cenozoic times, there are records of fossils of crocodylomorphs, testudines, mammals and gigantic birds of the Curitiba Sedimentary Basin (Guabirotuba Formation – Paleogene, 66 to 23 million of years). In addition to these, fossils of Pleistocene mammals (2.5 million of years to 11,000 years) were found in alluvial deposits in Chopinzinho and Pinhão (Third Plateau), recorded by Pillati and Bortoli (1978) and Sedor and Born (1999), as well as records of vertebrates and invertebrates in several caves in Paraná (Sedor et al. 2004).

2. Material and methods

Ponciano et al. (2011) identified a possibility of classifying the geological/paleontological heritage as *in situ* in the case of geosites and *ex situ* heritage for the cases where the material was removed from the place of origin and kept in museums and scientific collections. In the case of paleontological heritage, the connection between the samples in museums and their places of origin (geosites) is very close, which requires a constant correlation between the sample contents and their geological context if an exhibition is considered.

Firstly, a survey of the main paleontological sites of the state of Paraná was conducted, based on the database available from the Brazilian Commission of Geological and Paleobiological Sites (SIGEP, terminated in 2013). According to the publications "Sítios geológicos e paleontológicos do Brasil" [Geological and paleontological sites in Brazil] volumes I, II and III, published between 2002 and 2013, three major sites in Paraná have been found to date. In addition to these three sites identified by SIGEP, other important outcrops and collections were acknowledged in several scientific publications, which, after analysis and selection, were incorporated to this study. Field activities for recognition of these locations were performed for data collection, image recording and videos.

After the geosites' identification, a search for the paleontological collections in the state was carried out. We visited the major research institutions on paleontology, among them, the Federal University of Paraná (UFPR), State University of the Midwest (UNICENTRO), State University of Ponta Grossa (UEPG), which have paleontological collections available to public visitors. Regarding other institutions, e.g., State University of Londrina (UEL), State University of Paraná (UNESPAR) and the Paleontological Museum of Cruzeiro do Oeste), we contacted the coordinators to obtain information about the collections. The relevant data were then organized to allow an appropriate selection and geologically identified according to the maps available from the Institute of Water Bodies and Lands (IAT).

3. Results and discussion

Fossils, records of any kind of life on Earth as belonging to a geological period before the present one (Holocene), i.e., remains and traces of animals and plants older than 11,000 years (Branco 2014) are considered as Natural and Cultural Heritage, article 216 of Brazil's Constitution (Brasil 2016), included as "Union's Assets" and protected by law 4.146/42 (Brasil 1942). Furthermore, due to their scientific and cultural value, they represent the Planet's Biological Memory, which must be preserved for future generations.

Every fossil is a scientific and cultural heritage by definition, but for the development of this work a broad criterion of representativeness was used in the selection of the main fossils found in Paraná which could concisely present the biogeographic history of this region and the scientific evolution. Museological criteria were considered, such as aesthetics, to exhibit it as a collection piece. Thus, a total of 25 fossiliferous deposits of great importance in the state and ten collections from public institutions that preserve important fossils were identified, comprising 20 municipalities (Table 1).

Table 2 describes the paleontological sites of the greatest scientific and educational importance in the state, the geological unit where the fossils are found, the municipality and the geographic coordinates of each geosite. This survey can be useful in the development of future measures of protection of paleontological sites in Paraná. The collected data were synthetized in a map (Figure 1), which shows the geographic distribution of the paleontological sites and collections in the state. This link between the location and institutional preservation, in universities or public museums, for example, where the fossils can be safeguarded for future generations to appreciate and learn from them is of vital importance (Page 2018). On this regard, the Museum of Natural Sciences of UEPG is near the Campus site of UEPG (100 meters away), having fossils of Devonian invertebrates. Part of the material that has been removed over the years is housed or exposed in this museum.

According to Page (2018), the five main factors of degradation of fossiliferous deposits are: 1. Natural degradation and vegetation growth – including chemical and physical actions, weathering and erosion; 2. Agricultural, forestry and other land management practices or contamination of sites and hiding by tree cover; 3. Engineering works, including infrastructure, industrial and housing construction works and coastal protection works / flood protection works – which includes physical damages, filling and contamination, removal, hiding and burial; 4. Extraction of mineral aggregates and restoration of work sites (comprising wastes removal) – which includes physical damages, filling, hiding, burial or removal of deposits; 5. Excessive or improper use - including physical damages, exhaustion / removal of deposits and/or loss of important specimens of interest to the global market and private collections.

Table 1: Main paleontological sites in Paraná State

Town/Site	Age	Stratigraphic Unit	Coordinates	Fossil type	References
Almirante Tamandaré Parque Aníbal Curi	Proterozoic	Capirú Formation	25°18,801’ S 49°17,930’ W	Columnar stromatolites	Guimarães, Neto & Siqueira, 2002; Piekarz, 2011.
Campo Largo/ Rio da Prata	Proterozoic	Camarinha Formation	25° 27' 32'' S 49° 31' 55'' W	Bodies of *Beltanelliformis* organisms	Drefahl & Silva, 2007
Balsa Nova/ São Luiz do Purunã	Devonian	Furnas Formation Paraná Group	25° 28' 03”S 49° 39' 28"W	Worm-like *Palaeophycus* ichnofossils and possibly also *Planolites*. Ichnogenera (*Cruziana* and *Rusophycus*) associated with trilobate arthropods at rest and in locomotion.	Guimarães, Assine; Netto; Melo; Góis, 2013. (SIGEP)
Ponta Grossa/ Estrada do Alagados	Devonian	Furnas Formation Paraná Group	25°04'17.8"S 50°06'23.4"W	Plant imprints assigned to *Psilophytales*	Rodrigues, Pereira, Bergamaschi, 1989
Ponta Grossa/ UEPG Campus	Devonian	Ponta Grossa Formation araná Group	25°05'33.0"S 50°06'20.3"W	In the outcrop area are found species of bivalve and univalve brachiopods, multi-elements of crinoids and trilobites ichnogenus *Zoophycos* isp.	Horodyski, Bosetti, Myszynsky, 2006. Bossetti, Horodyski, Matsumura & Junior, 2013.
Ponta Grossa/ Caniú River	Devonian	Ponta Grossa Formation Paraná Group	25°18'51”S 50°05'33”W	Detailed classification of asteroid and ophiuroid fossils of the following species: *Paranaster crucis; Magnasterella darwini; Encrinaster pontis* and *Marginix notatus*	Clarke, 1913 Fraga & Vega, 2020.
Ponta Grossa/ Sant’ana Airport	Devonian	Ponta Grossa Formation Paraná Group	25°10'48”S 50°08'47”W	Detailed classification of asteroid and ophiuroid fossils of the following species: *Paranaster crucis; Magnasterella darwini; Encrinaster pontis* and *Marginix notatus*	Clarke, 1913 Fraga & Vega, 2020.
Ponta Grossa/ Curve 2 Section Cescage Section	Devonian	Ponta Grossa Formation Paraná Group	25°03'50.0"S 50°07'58.2"W 25°05’86” S, 50°07’95” W	Examples of fossils found in the outcrop sections: Bivalve Brachiopods, *Australospirifer iheringi; Australocoelia palmata; Australospirifer iheringi; Orbiculoidea* spp*; Gigadiscina collis; Derbyina sp; Derbyina whitiorum*; Univalve *Schuchertella* sp. such as *Tentaculites* sp., in addition to Crinoid pluricolumnal, Pygidium of trilobite Calmonyd, Ichnogenus *Zoophycos* isp.	Bossetti, Horodyski, Matsumura & Junior, 2013.
Jaguariaíva-Arapoti railway extension	Devonian	Ponta Grossa Formation Paraná Group	24°14'50.5"S 49°43'18" W	Diverse invertebrate fossils (Conulariida, Brachiopoda Articulata and Inarticulata, Mollusca Bivalvia and Gastropoda, Tentaculitoidea, Trilobita and Crinoidea). Asteroids and Ophiuroids are also found. Microfossils: plant cuticles, sporomorphs, Chitinozoa, Acritarch, Tasmanaceae and scolecodonts. Among ichnofossils are the ichnogenera *Planolites* sp., *Paleophycus* sp., *Bergaueria* sp. and *Zoophycus* sp.	Clarke, 1913 Bolzon, Azevedo, Assine, 2013 (SIGEP). Fernandes (1996) Fraga & Vega, 2020.
Tibagi/Itáytyba Transbrasiliana highway	Devonian	Ponta Grossa Formation araná Group	24° 23 '55 ”S 50° 20 ' 16 ”W	Vascular plants: *Spongiophyton lenticulare; Palaeostigma sewardii Irregular Haplostigma*	Matsumura, Iannuzzi, Bosetti, 2013.
Tibagi/ Wolff Site	Devonian	Ponta Grossa Formation araná Group	24°33'42” S 50°31'00” W	Vascular plants: *Spongiophyton lenticulare; Palaeostigma sewardii Irregular Haplostigma*	Matsumura, Iannuzzi, Bosetti, 2013.
São João do Triunfo/ Permian Flora	Permian	Rio Bonito Formation Guatá Group	25° 40' 58"S 0° 17' 49"W	Plants assigned to the following species: *Sphenophyllum brasiliensis; Annularia occidentalis* and *Annularia readi*.	Rosler, 1974
Figueira/Coal Mine	Permian	Rio Bonito Formation Guatá Group	23°49'17.4"S 50°24'59.4"W	Paleoflora examples: Lycophytes of the genus *Brasilodendron, Sublagenicula* and *Lagenoisporites*. Sphenophytes: *Paracalamites australis; Sphenophllyum brasiliensis*, *Annularia occidentalis.* Phyliciae: *Arterotheca derbyi*. Pteridosperms: *Pecopteris cambuyensis*, *Sphenopteris lobifolia*. and *Glossopteris communis*. Coniferous genera such as *Paranocladus, Buriadia Paranospermum*	Branco & Rösler (2004)
Irati / Gutierrez Station	Permian	Irati Formation Passa Dois Group	25°31'4.45"S 50°39'28.33"W	*Mesosaurus tenuidens; Stereosternum tumidum* and Crustaceous	Mc Gregor, 1908 Gervais, 1864.,
São Mateus do Sul / Petrosix	Permian	Irati Formation Passa Dois Group	25°51'39"S 50°23'50"W,	*Mesosaurus tenuidens; Stereosternum tumidum* and Crustaceous	Mendes, 1954

Table 1: Main paleontological sites in Paraná State (continued)

Town/Site	Age	Stratigraphic Unit	Coordinates	Fossil type	References
Prudentópolis / Prud 1 Quarry	Permian	Teresina Passa Dois Group	25°12'30.8"S 50°57'12.4"W	Bivalves in limestones, coquinas	Neves, Rohn & Simões, 2010
Prudentópolis / Prud 2 Quarry	Permian	Teresina Formation Passa Dois Group	25°12'25.1"S 50°56'56.4"W	Bivalves in limestones, coquinas	Neves, Rohn & Simões, 2010
Prudentópolis / "Pinheiro de Pedra" [Stone Pine Tree]	Permian	Teresina Formation Passa Dois Group	25°22'12"S 51°00'58"W	Fossil trunks of conifers	Pontes-Filho et al. 2019
Jacarezinho/ Bony Fish	Permian	Rio do Rasto Formation Passa Dois Group	23°10'08.40"S 49°57'49.48"W	Shark fin spines of the following species: *Sphenacanthus riorastoensis* and *Sphenacanthus riorastoensis*	Pauliv et al, 2012
Mauá da Serra – Ortigueira (Serra do Cadeado)	Permian	Rio do Rasto Formation Passa Dois Group	23°58'30"S 51°05'30"W; 23°58'30"S 51°09'00"W; 24°00'15"S 51°05'30"W 24°00'15"S 51°09'00"W	Paleontological record of plants (*Schizoneura, Glossopteris, Paracalamites, Pecopteris*), bivalves (*Leinzia, Palaeomutela, Terraia*), gastropods, conchostraceans (*Pseudestheria, Monoleiolophus, Euestheria, Asmussia, Liograpta*), oysters and some insects, and an especially significant fauna of tetrapods. This includes the dicynodont *Endothiodon*, a small-to-medium size terrestrial herbivore, and two forms of temnospondyl "amphibians", one with long rostrum, *Australerpeton cosgriffi*, and another with short rostrum.	Langer et al, 2009 (SIGEP)
Cianorte/ Indianópolis	Cretacean	Rio Paraná Formation Caiuá Group	23°40'26.9"S 52°37'02.9"W 23°25'39.23"S 52°38'0.41"W	Ichnofossils assigned to small theropods, and primitive mammals.	Leonardi, 1977
Cruzeiro do Oeste	Cretacean	Goio-Erê Formation Caiuá Group	23°45'35"S 53°03'53"W	Pterosaur: *Caiuajara dobruskii* Iguanid lizard: *Gueragama sulamericana* Dinosaur (theropod): *Vespersaurus paranaenses* Pterosaur: *Keresdrakon vilsoni*	Manzig et al, 2014 Simões et aL, 2015 Langer et al, 2019 Kellner et al, 2019
Curitiba	Paleogene	Guabirotuba Formation	25°30'30"S 49°20'30"W	First discovery: Ziphodont type tooth assigned to Crocodilomorph. Guabirotuba Fauna: Mammals (Cingulata, Notoungulata, Astrapotheria and Metatheria). Fossil remains of seven armored xenarths are identified, including a description of a new species and genus named *Proeocoleophorus carlinii*. The Guabirotuba ungulates are assigned to Interatheriidae, Oldfieldthomasiidae and Astrapotheria. The metatherian mammals are represented by one sparassodont, one paleotentoid and one argyrolagoid.	Liccardo & Weinschütz, 2010 Sedor et al, 2017
Chopinzinho	Pleistocene	Recent sediments s	25°51'24"S 52°32'11"W	Mastodont: *Stegomastodon waringi*	Pillati & Bortoli. 1978.
Cerro Azul/ " Caverna Toco-que-não-cai" (Cave)	Pleistocene	Recent sediments in caves of the Votuverava Formation of the Açungui Group.	24°46'31.0"S 49°06'45.0"W	Tooth fragment, Pleistocene mastofauna of the genus *Tapirus*	Sedor, Born & Santos, 2004.

Table 2: Main paleontological collections in Paraná State.

	Collections	Institution	Location	Coordinates
1	Museum of Natural Sciences	UEPG	Ponta Grossa	25°05'29.1"S 50°06'13.3"W
2	Laboratory of Paleontology and Stratigraphy	UEPG	Ponta Grossa	25°05'22.6"S 50°05'38.1"W
3	Campos Gerais Museum	UEPG	Ponta Grossa	25°05'47.4"S 50°09'31.2"W
4	Museum of Natural Sciences	UFPR	Curitiba	25°26'51.3"S 49°13'58.3"W
5	Laboratory of Paleontology	UFPR	Curitiba	25°27'04.5"S 49°13'53.9"W
6	Museum of Natural Sciences	UNICENTRO	Guarapuava	25°21'07.0"S 51°28'14.5"W
7	Museum of Geosciences	UNICENTRO	Irati	25°32'00.5"S 50°39'24.7"W
8	Museum of Geology	UEL	Londrina	23°19'35.9"S 51°12'05.1"W
9	Cruzeiro do Oeste Museum	City Museum	Cruzeiro do Oeste	23°46'37.0"S 53°03'57.2"W
10	Museum and Laboratory of Geology	UNESPAR	Campo Mourão	24°02'36.5"S 52°23'12.7"W

Table 2 describes the location of the collections found with samples of high scientific and educational value not only in the state of Paraná but from other Brazilian and world regions. The collections are visited by students from primary and secondary schools, high school, and universities, and the community in general.

According to Mansur et al. (2013), the environment of a collection represents a safety area because the collection can be easily recorded, documented and undergo interventions to maintain its integrity and appropriate housing. In the most institutions, *ex situ* paleontological heritage is protected by the trustee systems in force and by the codes of conduct and guidelines set out by the Brazilian Museum Institute, Law 11.904 of January 14, 2009 (Brasil 2013). These management, preservation, documentation, disclosure and protection procedures must ensure perfect preservation, representation and communication of existing materials (Viana and Carvalho 2019). According to these authors, musealization must therefore potentialize the educational content of the fossil and strengthen the actions of preservation of the cultural heritage.

Carvalho (2016) emphasizes that fossils represent two important elements for the management of a territory and are inseparable from the paleontological heritage. The first one is *social identity*, in which the record of life in a scale of time much larger than the historical time, allows a valorization of the geographic space and the communities that exist there, enhancing the feeling of belonging. The second element is *economic relevance*, because people's interest in paleontology allows the development of job-generating activities in the cultural industry and geotourism.

The first definition of geotourism appeared in England (Hose 1995) proposing to "facilitate understanding and provide service facilities for tourists to acquire knowledge of the geology and geomorphology of the site, going beyond mere spectators of an aesthetic beauty". Thus, the essential idea of geotourism is to aggregate the scientific knowledge to the natural and cultural heritage in a pleasant and understandable manner, valuing it and allowing touristic visitation to occur in a sustainable way (Jorge and Guerra 2016). This tourism segment has used the interpretation of the cultural/scientific content offered by fossils in collections or in geosites as a strategy for valuing the heritage and contributing for its popularization and preservation. Geotourism is closely linked to the strategies of preservation of the geological and paleontological heritage.

4. Conclusion

The survey of the main paleontological collections and sites in Paraná identified 25 geosites and 10 museological institutions located in 20 municipalities, which represent the most valuable scientific and educational paleontological

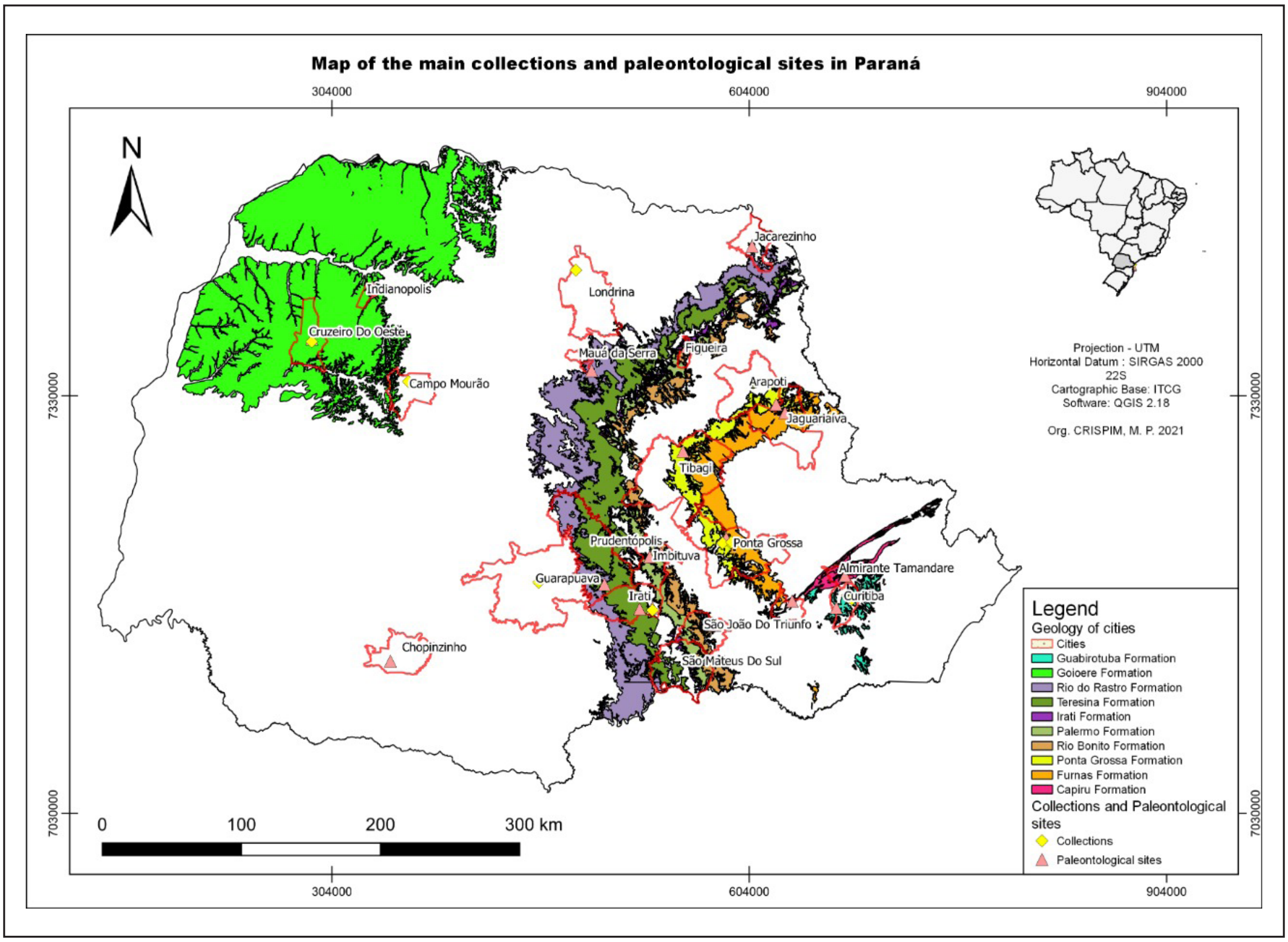

FIGURE 1. Map of Paraná State with location of the cities that house in their territories collections and/or paleontological sites of great scientific and educational importance.

heritage, comprising the main fossils that cover the geological timeline known in the state, from Proterozoic to Cenozoic. This selection illustrates the conception of the paleontological exhibition of the UEPG's Museum of Natural Sciences, which seeks to show the biological memory of Paraná.

The paleontological heritage of the state is diversified, and the institutions that preserve it not always exhibit it according to the evolution timeline over the geological timeline, but fulfill a major role in the preservation of *ex situ* heritage. The surveyed data set indicated the potential educational value of the collections, and the correlation between the fossil and the geosites is shown to be essential to understanding the territory.

Public communication of geoscientific information in museums requires synthesis surveys like the present one for the development of an effective planning and directed to different target audiences among visitors. This set of information can also provide different usages such as the production of catalogues, communication and educational materials based on the data presented here, which also serves as support to appropriate touristic releases.

There is a strong potential for inclusion of this heritage in the development of geotourism in Paraná, and this survey may provide the basis for future actions of protection and preservation of the sites of great paleontological importance and offer access to geoscientific knowledge to the population in general.

The paleontological exhibitions of various institutions in Paraná ensure preservation of the heritage and its scientific-educational communication but tend to underestimate the geotouristic potential of the collections and the geosites as well. A refinement of this analysis may contribute to strategies developed to reframe the paleontological heritage considering the relationship between geotourism and paleontology.

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The geological heritage of the state of São Paulo: potential geosites as a contribution to the Brazilian national inventory

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Abstract

Having a national geoheritage inventory is essential to plan effective geoconservation strategies. Since 2017, the Geological Survey of Brazil (CPRM) has been carrying out a project aimed at the Inventory of the Brazilian Geological Heritage and defined state coordinations to propose indicative lists of potential geosites based mainly on the scientific value (SV) according to the GEOSSIT platform. For the state of São Paulo, which was the first in Brazil to have a systematic geoheritage inventory, with 137 geosites already defined, this study intends to analyze them to propose some criteria to select the ones to compound the national list. Fifty-seven geosites were chosen according to both SV (≥ 300, following the requirements of GEOSSIT) and representativeness within each geological framework (when SV < 300). We also evaluated the selected geosites in other national initiatives, such as SIGEP (nine geosites) and the Geoparks Project (five geosites). The GEOSSIT public lists show only three of the 57 geosites already registered, a low number considering that these registrations are relevant indicators for the national inventory. The geosites were also analyzed according to the main thematic classification (eight main thematic categories, with a large number in the petrology theme - 35.10%) and general geological context (73.70% in the Mantiqueira, Paraná, and Tocantins provinces and 26.30% in Emerged Phanerozoic Basins - Paraná, Bauru, and São Paulo), according to the parameters available on GEOSSIT. The sites were also evaluated according to typology, being 33 points, 22 areas, and two sections. Regarding the statutory setting, 30% are in fully protected areas, 36% in public or private areas with non-effective statutory protection (APAs, marine land, paleontological sites, etc.), and 34% comprise public or private areas with no protection.

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1. Introduction

Inventories of geological heritage have long been considered crucial instruments for making the initial diagnosis of geological interest sites in a particular area. The data originated from these investigations are essential as bases for geoconservation planning. The character of their outcomes controls further actions focused on land use (Brilha and Pereira 2014), scientific communication (Stewart and Nield 2013), dissemination of geosciences (Mansur 2009), geotourism (Moreira 2010) or geoparks planning (Nascimento et al. 2015), among others. One of the classical bases of geological heritage conservation is the GEOSITES Project developed by the Working Group linked to the IUGS and promoted by UNESCO (Wimbledon 1996, 2011). The Project had as its prime objective to generate a world-based inventory of geologically relevant sites following a systematization by establishing frameworks that would guide their selection (Wimbledon 2011). The Project officially finished in 2000, and from then on, it was replaced by other actions. However, its conceptualization and methodology were embraced by several countries members of ProGEO (European Association for the Conservation of Geological Heritage) while carrying out their national inventories. Historically, the recognition and the assessment of the sites that may correspond to the geological heritage in Brazil has accomplished in a non-systematic way, and among the pioneering initiatives carried out to identify potential candidates to compound this list is the SIGEP (Brazilian Commission of Geological and Paleobiological Sites), in 1997. Romão and Garcia (2017) investigated 61 geoheritage inventories developed in Brazil until 2017, based on the methods used for geosite selection and quantitative evaluation. The authors observed a growing number of researches, but not homogeneously distributed in the country. Also, many works do not mention the inventory method applied.

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In the scope of the Geological Survey of Brazil (CPRM), there are some initiatives related to geoconservation. Among them we can emphasize the Project "*Brazilian Geoparks - Proposals*" and the development of the GEOSSIT Platform (Rocha et al. 2016), an online resource to support the national inventory, and both qualitative and quantitative assessment of geosites and geodiversity sites. During the general meeting of the Commission for the Geological Map of the World (CGMW) held in Paris in February 2018, the geologist Carlos Schobbenhaus, from CPRM, proposed a project aiming to produce the Geological Heritage Map of South America on a scale of 1: 5.000.000. The initiative was stimulated mainly by the publication in 2019 of a new Geological Map of South America (Gómez Tapias et at. 2019). As this project was approved, the task for the identification of potential geosites to be included in the Brazilian Geoheritage Inventory has been inscribed in CPRM's Strategic Plan (2017-2021). The method consists of research and evaluation of geosites of national and international relevance, taken from geological mapping, geoparks proposals, and external contributions (academic works, consultation with experts, etc.). The technical coordination of this task was established in CPRM's regional units, aiming to collect potential geosite data from each state and to integrate them into the National Inventory. The State of Rio de Janeiro was chosen as a pilot area to test this method.

The State of São Paulo, the focus of this work, is the first Brazilian state to complete a systematic inventory of geosites made by the geoscientific community (Garcia et al. 2018). Many of these geosites are potential sites to be included in the national inventory, but their selection raises some questions that are addressed in this paper: i) Considering the National inventory, which criteria should be used to identify these geosites?; ii) Is the quantitative assessment an effective way to select the best examples?; and iii) To what extent and detail can the State geological frameworks be applied at the national level?

1.1 The inventory of geoheritage of the state of São Paulo: an overview

The inventory of geological heritage of São Paulo state has identified, selected, and evaluated geosites with scientific relevance in order to set the bases for future geoconservation actions (Garcia et al. 2018). Its first phase was developed during 2013-1016, as a project based at the Institute of Geosciences, University of São Paulo, and supported by the Science Without Borders Program (Project 075/2012 - MEC/CAPES/CNPq). The method involved the definition of geological frameworks and identification of their scientific coordinators, a preliminary list of potential geosites, fieldwork, a final listing of geosites for each framework, and the quantitative assessment of scientific value and risk of degradation for each geosite (Brilha 2016). The inventory had a general coordination, scientific coordinators for each geological framework, and expert teams. The geoscientific community involvement was one of its main strengths, being the working group composed of researchers from different institutions in various geosciences. As a result, 142 geosites representatives of 11 geological frameworks representing the state's geological history were initially selected (Table 1).

TABLE 1. Geological frameworks of the inventory of geoheritage of the state of São Paulo. From: Garcia et al. (2018).

Geological framework	Description	Number of geosites
Precambrian terranes	It represents the domains included in the Mantiqueira (Ribeira and Apiaí orogens) and Tocantins provinces (southern portion of Brasília Orogen), which have a general configuration related to the events of the Brasiliano–Pan African Cycle, in the Neoproterozoic.	21
Shear zones	It reflects the structural organization of the Precambrian terranes, formed by different units occurring as elongated strips bounded by strike–slip shear zones with local thrust components, in a 1000-km length and 200-km wide megastructure.	09
Granitic rocks	More than 200 kilometric to metric granitic bodies, associated with extensional tectonics and collisional events during the Neoproterozoic occur in the region.	10
Precambrian metallic mineralization	Represented by the Mesoproterozoic metavolcano-sedimentary succession of the Serra do Itaberaba Group, which metamorphism gave origin to tourmalinites and the metamorphic product of Algoma-type iron formation, enriched with syngenetic gold mineralization.	07
Paraná Basin	Formed by volcano-sedimentary rocks ranging from the glacial–interglacial cycle during the Upper Carboniferous – Lower Permian interval to the continental environment at the end of the Permian and arid climates that completed the tendency to continentalization during the Mesozoic.	19
Mesozoic magmatism	It represents the intense tectonic magmatic processes represented by the basaltic flows of the Serra Geral Formation (Paraná Basin), dike swarms and alkaline complexes associated with the evolution of the Paraná Basin.	13
Bauru Basin	It is mainly represented by Upper Cretaceous continental sandstones formed within the South American platform, corresponding to a period of isostatic adjustment subsidence after the breakup of Gondwana and opening of the South Atlantic Ocean.	15
Continental Rift of Southern Brazil	A 900-km long Cenozoic tectonic feature, which evolution is related to the latest stage of the tectonic activation event in the South American Platform, associated with the fragmentation of the Gondwana supercontinent and the formation of the South Atlantic Ocean.	10
Continental and coastal Neogene and Quaternary evolution	It represents the processes that formed the current physiography of the state, resulting from a sequence of events controlled by geological, geomorphological, climatic and oceanographic processes.	06
Geomorphological units and landforms	Represented by two main domains, the Atlantic Shield, with limited sedimentary deposits and Jurassic–Paleocene intrusions and the Platform cover, which reflect the general geological setting of the state.	14
Caves and Karst Systems	Most of the caves are mainly composed of sink-resurgence systems, forming river caves, with high depths, and common vadose shafts. Pseudokarst caves in granite/gneiss and other non-carbonate caves also occur.	14

The second phase (2017-present) is based on updating and systematizing the primary information about the geosites. For this purpose, Higa (2019) carried out the quantitative evaluation of both education and tourism potential, based on GEOSSIT's procedures and the assessment of the statutory framework and diagnoses of the current use and protection of these geosites - Table 2. Effective protection regimes were considered to be those with a management plan. An online map of the inventoried locations with the possibility of suggesting geosites using a public form was also elaborated (https://bit.ly/2EoF6Zg).

As the next steps are the establishment of partnerships with institutions such as CPRM and the State Forest Foundation, the government agency responsible for São Paulo State conservation units, the registration of the geosites on the GEOSSIT platform, the identification of gaps and fragilities in the defined geological categories, and the elaboration of specific management actions in the priority geosites, including their promotion.

TABLE 2. Main statutory protection for the geosites (2018).

Effective legal framework
Fully Protected Units (Law nº 9.985/2000): conservation units of relevant natural characteristics instituted by the Government. Only the indirect use of its natural resources is allowed. They are classified into Ecological Station, National Parks (which can be state and municipal as well), and Natural Monuments among others.
Non-effective legal framework
Sustainable Use Units (Law nº 9.985/2000): conservation units with relevant natural characteristics instituted by the Government. The sustainable use of part of its natural resources is permitted. They are classified as APAs among others.
Sites Listed as Heritage (Decree-Law nº25/1937): set of movable and immovable property of the country whose conservation is of public interest. These areas cannot be destroyed, demolished or mutilated
Marine Terrains (Decree-Law nº 9.760/1946): marine terrains are considered as movable assets of the union, therefore susceptible to the Penal Code Law nº 2,848 / 40, which makes the depredation of public heritage sites a crime.
Paleontological site (Decree-Law nº 4.146/1942): fossiliferous deposits are considered as property of the nation, so their extraction depends on prior authorization and inspection.
Speleological site (Decree nº 6.640/2008): activities considered being effectively or potentially polluting or degrading of underground natural cavities will depend on prior licensing.

2. Methods

2.1 Selection of potential geosites

The selection of geosites of the São Paulo State inventory to be possible candidates for the national inventory was based on two main criteria:

i) Quantitative assessment, using the GEOSSIT platform (Higa 2019).

For this evaluation, we consider the geological frameworks used in the São Paulo State inventory to classify the geosites (Garcia et al. 2018). We follow the concept established by Brilha (2016), which calls geosites those with scientific value (SV). The geosites that achieve SV ≥ 300 within the quantitative assessment of the GEOSSIT platform, were characterized as geosites of international relevance.

ii) Representativeness of the geosite within the state geological framework.

In the GEOSSIT platform, the quantitative assessment of scientific value is based on the quality of scientific publications and the possibility of collecting samples. However, many places show a few number of international scientific publications, despite being representative and rare examples of a specific context. In these cases, geosites with a scientific value of less than 300 but which constitute unique representatives of a particular event or geological element/unit were also selected.

2.2 Characterization of geosites

The selected sites were described regarding the following features:

i) Primary geological interest, according to the parameters described in the GEOSSIT platform, which represent the major geological relevance of the geosite (e.g. paleoenvironmental, geomorphological, or petrological);

ii) General geological framework, also based on the GEOSSIT platform, associated with the main Brazilian geological contexts (e.g., Phanerozoic Emerged Sedimentary Basins and Brazilian Structural Provinces);

iii) Site typology, according to Fuertes-Gutiérrez and Fernández-Martínez (2010): area (>1 ha with just one type of interest), complex area (large areas with several interests), point (<1 ha with only one geological feature), section (<1 ha with elements having a linear spatial development) and viewpoints (an area of geological interest and its better observatory spot);

iv) Brazilian statutory framework, according to which the geosites were classified into areas with no protection and areas with effective and non-effective protection, as described in Table 2.

3. Results

The selection based on the above criteria has resulted in 57 geosites, distributed within the 11 geological frameworks established for the São Paulo State inventory (Figure 1). The range of the Scientific Value of the geosites in each geological framework is presented in Table 4. Among the selected sites, 47 present SV equal to or higher than 300 and 10 show SV lower than 300. Precambrian Terranes is the geological framework with the largest number of selected sites (13), which corresponds to 22,81% of the total number of the sites, followed by Geomorphological Units and Landforms (14,03%), Paraná Basin (10,52%), and Mesozoic Magmatism (10,52%), Bauru Basin (8,77%). Granitic Rocks and Southeastern Continental Rift (7,02% each), Shear Zones, Precambrian Metallic Mineralizations, and Neogene and Quaternary Evolution (5,26% each) and Caves and Karst Systems (3,51%).

From the sites selected, seventeen are included in other initiatives, directly or indirectly related to the survey of geosites in a national scope (SIGEP, Geoparks Project, and GEOSSIT platform registers). The classification according to typology resulted in 33 geosites classified as points, 22 as areas, and 2 sections (Table 5).

TABLE 3. Criteria and respective parameters in GEOSSIT for quantitative evaluation of Scientific Value (SV).

Scientific Value
A1. Representativeness
The geosite is the best example in the study area to illustrate elements or processes, related with the geological framework under consideration (when applicable) – 4 points The geosite is a good example in the study area to illustrate elements or processes, related with the geological framework under consideration (when applicable) - 2points The geosite reasonably illustrates elements or processes in the study area, related with the geological framework under consideration (when applicable) – 1 point Not applicable - 0
A2. Key locality
It is considered to be a key-locality (location where the geological unit to which it belongs was originally described and / or named) – 4 points Is considered a secondary key-locality – 2 points Not applicable - 0
A3. Scientific Knowledge
There are scientific publications related to the site in books, international scientific journals, directly associated to the geological framework (when applicable) – 4 points There are scientific publications related to the site in national scientific journals, directly associated to the geological framework (when applicable) – 2 points There are abstracts associated to the site published in annals of scientific events, or in unpublished reports, directly related to the geological framework (when applicable) – 1 point Not applicable - 0
A5. Geological Diversity
Geosite with 5 or more different geological elements, with scientific value – 4 points Geosite with 3 or 4 distinct types of geological elements, with scientific value – 2 points Geosite with 1or 2 distinct types of geological elements, with scientific value – 1 point Not applicable - 0
A6. Rarity
The Geosite is the only known example in the study area, associated with the geological framework (when applicable) – 4 points There are 2 to 3 examples known in the study area, associated with geological framework (when applicable) – 2 points There are 2 to 5 examples known in the study area, associated with geological framework (when applicable) – 1 point Not applicable - 0
A7. Use Limitations
The site has no limitations (legal permissions, physical barriers, etc.) for sampling or fieldwork – 4 points It is possible to collect samples and do fieldwork after overcoming the limitations – 2 points Sampling and fieldwork are very hard to be accomplished due to limitations difficult to overcome (legal permissions, physical barriers, etc.) – 1 point Not applicable - 0

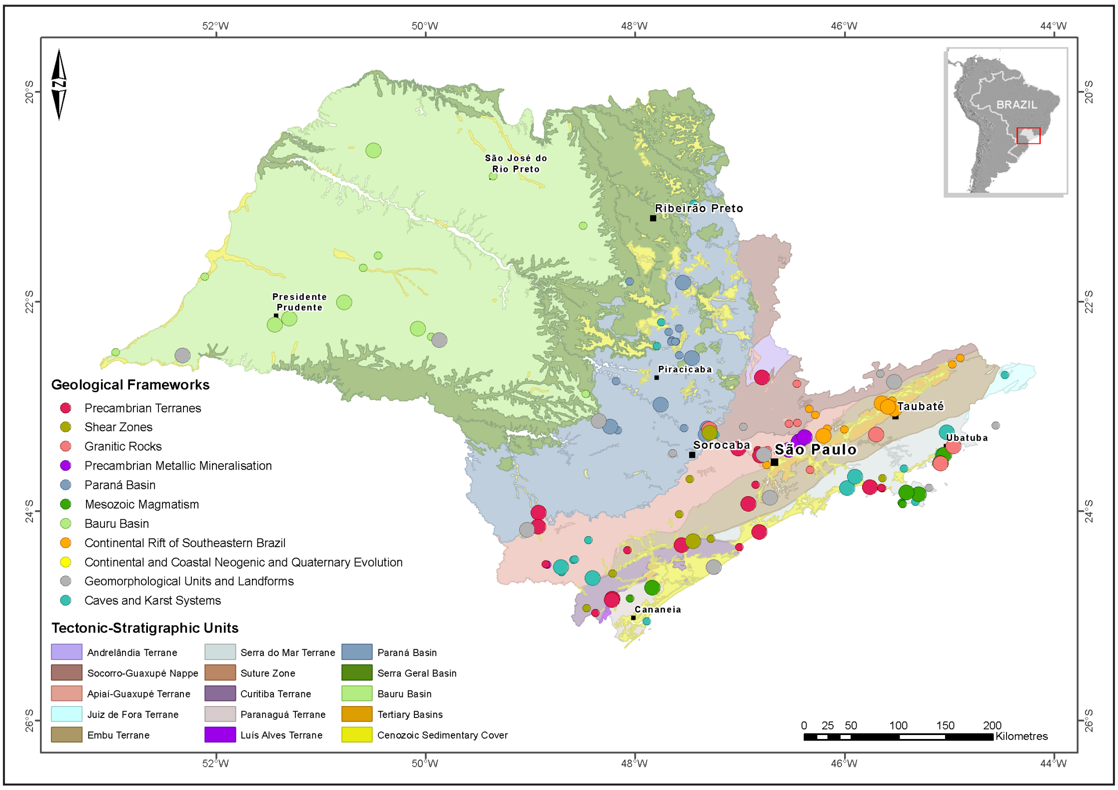

FIGURE 1. Map of the Geological Heritage of the State of São Paulo with the location of the geosites in their respective geological framework. The larger dots correspond to the 57 geosites selected in this work. Modified from Garcia et al. (2018).

TABLE 4. Potential geosites in the State of São Paulo to compound the national Inventory.

Geological Framework	Number of Potential Geosites	Number of Geosites with value ≥300	Number of Geosites with value <300	Range of SV values
Pre Cambrian Terranes	13	11	02	250-360
Shear Zones	03	02	01	180-370
Granitic Rocks	04	01	03	200-330
Precambrian Metallic Mineralizations	03	03	00	325-385
Mesozoic magmatism	06	04	02	235-360
Paraná Basin	06	05	01	295-390
Bauru Basin	05	05	00	310-350
Southeast Continental Rift	04	04	00	300-380
Neogene and Quaternary Evolution	03	02	01	270-355
Geomorphologic Units and Lan-dforms	08	08	00	310-390
Caves and Karst Systems	02	02	02	310-320
Total of Potential Geosites	57	47	10	

According to the main thematic classification of the GEOSSIT platform, the geosites are distributed among eight main interest categories: 35,10% geosites classified as Petrology, 14,03% Paleontology, 14,03% Geomorphology, 10,50 Tectonics, 10,50 Stratigraphy, 7,01% Paleoenvironmental, 5,26% Mineralogy and 3,51% Speleology.

Regarding the geological contexts available in GEOSSIT, it was possible to distribute the geosites between the Brazilian Structural Provinces (32 Mantiqueira Province, 9 Paraná Province, 1 Tocantins Province) and Emerged Phanerozoic Basins (6 Paraná Basin, 5 Bauru Basin, 3 Taubaté Basin and 1 São Paulo Basin) - Table 5.

Among the selected geosites, 34% have no protection and, 36% of geosites are located in areas with non-effective statutory protection (APAs, marine terrains, paleontological sites, etc.), and 30% are located in protected areas (Figure 2).

4. Discussion

Pioneering initiatives in geoconservation in Brazil, such as SIGEP, GEOSSIT Platform, and Geoparks Project, developed non-systematic, AD HOC-based inventories. Although these initiatives are useful in tracing an overview of the current status of the geological knowledge of the territory, this type of survey fails in promoting an adequate sampling of the most representative sites according to the national geological contexts. As a result, the proportion of high relevance geosites that are effectively registered is low, which can be observed by the low number of potential geosites selected in this work that is included in these reports.

In this work, the geosites inventoried in the São Paulo state (Garcia et al. 2018) were analyzed regarding their representativeness to compound the national inventory. Being a systematic initiative, this inventory allowed to bring up a considerable number of high relevance geosites, in which high scientific values were calculated with the use of well-defined criteria. From the 57 selected geosites, 47 achieved > 300 on the SV, which, according to GEOSSIT, would indicate an international relevance. The other ten geosites with < 300 SV present low values mostly in the A1 criteria (key-locality), followed by A5 (geological diversity) and A6 (rarity), despite being important examples within their geological framework. It is worth noting that this numerical parameter is not described in the original paper on which the platform was based (e.g., Brilha 2016).

These 57 sites selected in the state of São Paulo (41.6% of the initial inventory) compose a robust indicative list of candidates to form a basis for a systematic inventory of the Brazilian geoheritage. However, it is essential to note the low registration of these geosites in the GEOSSIT platform, which aims to be a relevant indicator for the national inventory project and that was initially created with the goal of being a geosite's database. The broad record of geosites in the platform is essential, once it is considered as a vital tool for building the nationwide inventory and also for the systematic assessment of geological heritage in the country (Schobbenhaus et al. 2015). This will only be possible when the number of geosites on the platform is substantially higher than today. Some topics may be raised as possible reasons for this low registration. One of them is the incompatibility of the platform with local or regional systematic inventories with large numbers of geosites and that do not always comply with national parameters. The input of geosites is made by ad-hoc criteria and does not follow any systematic method, making their comparison with others from the same context difficult. After being registered by a user, the geosite must be evaluated by an internal commission, which has as parameters the description input, the number of publications, or the personal knowledge. This may favor the input of geosites with superlative characteristics without considering their context. Another point that arises from this insertion dynamics is the authorship. Many of the users register a few geosites, normally the ones they have studied personally. In this scenario, how would systematic inventories, with hundreds of geosites, work? These issues may represent an additional challenge for the national inventory.

The experience with large areas inventories suggests that the use of tectonic domains approaches, such as those performed by Mansur (2010) and Moura (2018), has promising results to classify the geosites according to representative frameworks. This strategy can also be used as a basis for the National Inventory. However, Brazil is a country of continental dimensions and the work of surveying these domains is a complex task still in progress.

TABLE 5. Geosites, typology, primary thematic classification, general geological framework, legal framework/ownership and scientific value.

Nº	Geological Framework / Geosite Name[1]	Tipology[2]	Main Thematic Classification[3]	General Geological Framework[3]	Legal Framework/Ownership[4]	Scientific Value[4]
Precambrian Terranes						
1	Amparo Migmatites	Area	Petrology	Tocantins SPB	APA (Law nº 9.985/2000) – private area	250
2	Nova Campina and Itapeva Stromatolites[A]	Area	Paleontology	Paraná SPB	Paleontological site (Decree-Law nº 4.146/1942) – private area	260
3	Atuba Complex TTG	Point	Petrology	Mantiqueira SPB	Nonexistent – public area	340
4	Guaraú/ Prainha Granulites	Area	Petrology	Mantiqueira SPB	Marine Terrain (Decree-Law nº 9.760/1946) – public area	330
5	Pirapora do Bom Jesus Pillow Lavas	Point	Petrology	Mantiqueira SPB	Nonexistent – public area	325
6	Turvo-Cajati Formation in Serra do Azeite	Point	Petrology	Mantiqueira SPB	APA (Law nº 9.985/2000) – public area	320
7	Migmatites and Gneisses from Cama de Anchieta	Area	Tectonics	Mantiqueira SPB	Marine Terrain (Decree-Law nº 9.760/1946) – public area	320
8	Contact between Itaiacoca Group and Furnas Formation in Itapeva	Area	Stratigraphy	Paraná SPB	Nonexistent – private area	310
9	Metagabbro with injection features of Juqueí	Section	Petrology	Mantiqueira SPB	Marine Terrain (Decree-Law nº 9.760/1946) – public area	310
10	Rodoanel Metaconglomerates	Point	Tectonics	Mantiqueira SPB	Nonexistent – public area	300
11	Embu Complex in São Lourenço da Serra	Point	Petrology	Mantiqueira SPB	Nonexistent – private area	300
12	Atuba Complex in Serra do Azeite	Point	Petrology	Mantiqueira SPB	APA (Law nº 9.985/2000) – public area	330
13	Itapeva Peak	Point	Petrology	Mantiqueira SPB	APA (Law nº 9.985/2000) – public area	370
Shear Zones						
14	Mylonites of Cubatão Shear Zone	Point	Tectonics	Mantiqueira SPB	Nonexistent – public area	180
15	Guaratuba river capture	Area	Tectonics	Mantiqueira SPB	Ecological Station (Law nº 9.985/2000)	370
16	Itapira Complex in Itu Shear Zone	Point	Tectonics	Paraná SPB	Nonexistent – public area	285
Granitic Rocks						
17	Ubatuba Charnockite	Point	Petrology	Mantiqueira SPB	APA, Marine Terrain (Law nº 9.985/2000, Decree-Law nº 9.760/1946) – public area	200
18	Rapakivi granite from Itu Province in Lavras Park	Area	Petrology	Paraná SPB	Municipal Park – public area	255
19	Paleoproterozoic Granitoid form Capivari River	Point	Petrology	Mantiqueira SPB	Nonexistent – public area	230
20	Ilha Anchieta Monzonite	Point	Petrology	Mantiqueira SPB	State Park (Law nº 9.985/2000) – public area	330
Precambrian Metallic Mineralizations						
21	Cabuçu Topazites[B]	Point	Mineralogy	Mantiqueira SPB	Nonexistent – public area	385
22	Fazenda Soledade Tourmalinites	Point	Mineralogy	Mantiqueira SPB	State Park (Law nº 9.985/2000) – public area	330
23	Rocks with anthophyllite and cummingtonite from Itaberaba[B]	Point	Mineralogy	Mantiqueira SPB	State Park (Law nº 9.985/2000) – public area	325
Mesozoic Magmatism						
24	Magmatic Breccia from Anchieta Island	Point	Petrology	Mantiqueira SPB	State Park, APA, Marine Terrain (Law nº 9.985/2000, Decree-Law nº 9.760/1946) – public area	360
25	Mafic Syenite from Pariquera-Açu	Point	Petrology	Mantiqueira SPB	Nonexistent – private area	310
26	Ponta Do Araçá Dykes	Point	Petrology	Mantiqueira SPB	Marine Terrain (Decree-Law nº 9.760/1946) – public area	310
27	Mantle Xenoliths from Northern Praia Vermelha	Point	Petrology	Mantiqueira SPB	Marine Terrain, APA (Decree-Law nº 9.760/1946, Law nº 9.985/2000) – public area	305
28	Diabase with columnar disjunctions of Santa Bárbara do Oeste	Point	Petrology	Paraná SPB	Nonexistent – private area	260
29	Ilhabela's syenitic magmatism	Point	Petrology	Mantiqueira SPB	State Park (Law nº 9.985/2000) – public area	235
Paraná Basin						
30	Giant stromatolites of Santa Rosa de Viterbo[A]	Area	Paleontology	Paraná EPSB	Paleontological site (Decree-Law nº 4.146/1942) – private area	390

TABLE 5. Geosites, typology, primary thematic classification, general geological framework, legal framework/ownership and scientific value. (Continuação)

31	Itu's Varvite[A]	Area	Stratigraphy	Paraná EPSB	Listed as Heritage Site (Decree--Law nº25/1937), Municipal Park – public area	370
32	Itararé Group's temperate forest record	Point	Paleontology	Paraná EPSB	Paleontological site, APA (Decree--Law nº 4.146/1942, Law nº 9.985/2000) – public area	340
33	Clastic dykes in Bandeirantes Highway	Section	Stratigraphy	Paraná EPSB	Nonexistent – public area	300
34	Asphaltic sands from Betumita Farm	Point	Petrology	Paraná EPSB	Nonexistent – public area	300
35	Moutoneé Rock in Salto[A]	Point	Paleoenvironmental	Paraná EPSB	Municipal Park – public area	295
			Bauru Basin			
36	Presidente Prudente Fm. Type--section	Point	Stratigraphy	Bauru EPSB	Nonexistent – public area	350
37	Fossil Reptiles from General Salgado[A]	Area	Paleontology	Bauru EPSB	Paleontological site (Decree-Law nº 4.146/1942) – private area	345
38	Pirapozinho Fossiliferous Site[A]	Point	Paleontology	Bauru EPSB	Paleontological site (Decree-Law nº 4.146/1942) – public area	330
39	Vale do Rio do Peixe Fm. in its Type-section	Point	Stratigraphy	Bauru EPSB	Nonexistent – public area	320
40	Calcretes from Marília Formation	Point	Stratigraphy	Bauru EPSB	Nonexistent – public area	310
			Continental Rift of Southeastern Brazil			
41	Tremembé Paleo Lake in Santa Fé Farm[A]	Area	Paleontology	Taubaté EPSB	Paleontological site (Decree-Law nº 4.146/1942) – private area	380
42	Phyto Fossils and palynomorphs from Itaquaquecetuba	Point	Paleontology	São Paulo EPSB	Paleontological site (Decree-Law nº 4.146/1942) – private area	350
43	Tremembé Paleolake in Quiririm[A]	Area	Paleontology	Taubaté EPSB	Paleontological site (Decree-Law nº 4.146/1942) – public area	330
44	Post-Sedimentary faults from Taubaté	Point	Tectonics	Taubaté EPSB	Nonexistent – public area	300
			Neogenic and Quaternary Evolution			
45	Ubatuba Beachrock	Point	Paleoenvironmental	Mantiqueira SPB	APA, Marine Terrain (Law nº 9.985/2000, Decree-Law nº 9.760/1946) – public area	355
46	Holocene marine terraces from Itaguaré Beach	Point	Paleoenvironmental	Mantiqueira SPB	State Park, Marine Terrain (Law nº 9.985/2000, Decree-Law nº 9.760/1946) – public area	350
47	Pleistocene marine terraces from Praia Vermelha do Norte	Point	Paleoenvironmental	Mantiqueira SPB	State Park, Marine Terrain (Law nº 9.985/2000, Decree-Law nº 9.760/1946) – public area	270
			Geomorphological Units and Landforms			
48	Furnas structural escarpment [A]	Area	Geomorphology	Paraná SPB	Nonexistent – private area	390
49	Morro do Diabo (Devil Hill's)[C]	Area	Geomorphology	Paraná SPB	State Park (Law nº 9.985/2000) – public area	360
50	Juréia Massif	Area	Geomorphology	Mantiqueira SPB	Ecological Station (Law nº 9.985/2000)	360
51	Colônia Impact Crater[A]	Area	Geomorphology	Mantiqueira SPB	Listed as Heritage Site, APA, Municipal Park (Decree-Law nº25/1937, Law nº 9.985/2000) – public area	355
52	Marília Plateau	Area	Geomorphology	Paraná SPB	Nonexistent – private area	320
53	Jaragua Peak	Area	Geomorphology	Mantiqueira SPB	State Park (Law nº 9.985/2000) – public area	320
54	Itapeva Peak	Area	Geomorphology	Mantiqueira SPB	APA (Law nº 9.985/2000) – public area	310
55	Basaltic Cuestas from Pardinho	Area	Geomorphology	Paraná SPB	APA (Law nº 9.985/2000) – private area	310
			Caves and Karst Systems			
56	Devil's Cave[B]	Area	Speleology	Mantiqueira SPB	Speleological site, State Park (Decree nº 6.640/2008, Law nº 9.985/2000) – public area	320
57	Santana's Cave[ABC]	Area	Speleology	Mantiqueira SPB	Speleological site, State Park (Decree nº 6.640/2008, Law nº 9.985/2000) – public area	310

[1]Garcia et al. (2018); [2]Higa (2019, according to Fuertez-Gutierrez and Fernández-Martínez 2010); [3]GEOSSIT (https://www.cprm.gov.br/geossit/), [4]Higa (2019), [A]Geosites with registration in Sigep Volumes, [B]Geosites from Geoparks's Project, [C]Geosites with public register in GEOSSIT's platform.

In this work the selected geosites were distributed according to the geological frameworks as currently available on the GEOSSIT platform, which may allow future comparison with other geosites within the same structural province in contiguous states. Some other characteristics, such as main geological interest, may constitute useful guides for a further diagnosis regarding use and management of these geosites. Although not perfect, the GEOSSIT platform seems to be the most suitable tool for integrating national data on geoheritage sites.

5. Conclusions

The selection of exceptionally relevant geosites that can be included in a broader geoheritage inventory is a task that includes, primarily, questions on the adequacy of the criteria and the methods used. In the case of the Brazilian National Inventory, which will be part of a survey that will include other South American countries, this mission may be challenging due to two main factors: its continental size and heterogeneous geological knowledge. One of the options to achieve this objective is to use both geological limits and administrative division as bases for this selection. The national geological frameworks would guide geosites representativeness regarding the main geological events and processes that shaped Brazilian geology. On the other hand, being the National geological survey, CPRM has offices in several states of Brazil and geologists specialized in distinct geological contexts, which can be a great advantage to compatibilized the state contexts.

Previous systematic information regarding potential geosites provides an excellent starting point for such a broad initiative. The data obtained in these surveys should be taken into account and serve as a guide in selecting the complementary sites. This is the case of the State of São Paulo, in which national and international geosites, defined according to well-defined and solid criteria with the participation of the geosciences community, are potential candidates for an initial national list.

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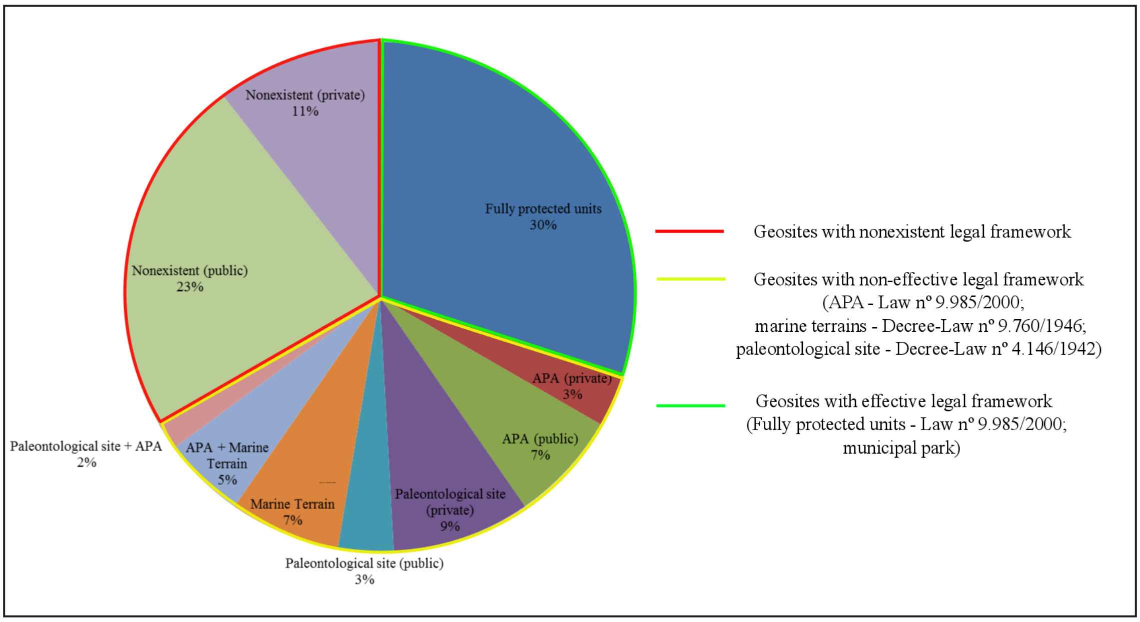

FIGURE 2. Distribution of the geosites regarding their protection regime.

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Characterization of the potential demand of geotourists in Lençóis, state of Bahia, Brazil: Serra do Sincorá Geopark Project

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Abstract

Geotourism has in its geodiversity its main touristic use. Understanding consumer demand is essential to direct strategies for the elaboration of touristic products and plan the touristic offer, aiming to serve tourists effectively and satisfy their preferences and needs. The characterization of the tourist serves to segment the touristic market, contributing to make geotourism a touristic segment in Brazil and worldwide. This research aimed to analyze the demand of geotourists to provide a contribution to the management and planning of geotourism in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia, Brazil. A self-administered questionnaire was used as a research instrument, which was distributed at random to 135 tourists approached on the Baderna Street, Pedras Street, Pedras Square, and Sete de Setembro Avenue Square (Horácio de Matos Square) who were seated at the tables between 19:30 and 22:30 h during 15 days of the second semester of 2018. The demand of geotourists – the one with a strong affinity for the practice of geotourism – was determined from the hierarchical cluster analysis and multiple comparisons between groups based on attitudes, behaviors, preference, and importance of travel analyzed from the perspective of social psychology. The results allowed identifying that 29% of tourists are geotourists; with female predominance; they do not seek luxury or elite environments, but singularity and authenticity; protected environment; good touristic service with a fair price; basic infrastructure in the attractions; and they do not have geoscientific knowledge. It is expected that our results will be used by public and private managers in the territory of the Serra do Sincorá Geopark and the Serra do Sincorá Geopark Association, and that the characterization of the demand will contribute to the consolidation of geotourism as a touristic segment in Brazil. This research can be expanded to other geopark territories.

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1. Introduction

The Serra do Sincorá Geopark Project is located in Chapada Diamantina, the central region of the state of Bahia, and comprises the municipalities of Andaraí, Palmeiras, Lençóis, and Mucugê. The history of the occupation of the territory and socio-spatial formation goes back to the diamond mining that existed in the 18th and 19th centuries (Nolasco 2002, Teixeira and Linsker 2005). Located in the São Francisco craton, it has sedimentary and metasedimentary sequences of Proterozoic age, with a low degree of metamorphism (Pereira 2010). The area integrates elements from the Caatinga, Cerrado, and Atlantic Forest biomes (ICMBio 2007).

Tourism was encouraged in the region with the prohibition of mining and occurred in the same period of the delimitation of the Chapada Diamantina National Park. From this, the touristic infrastructure has developed differently in each of the municipalities, which have different socioeconomic characteristics (Eschiletti and Lanzer 2019). The relationship with geodiversity and activity under the focus of geotourism is developed due to these geological, biological, scenic, and historical elements, in addition to the presence of touristic offer.

Geotourism is a concept defined by several authors under three approaches: geological (Hose 1995, 2000, 2012, Brilha 2005, Newsome and Dowling 2006, Azevedo 2007, Gray 2008, Robinson 2008, Moreira 2008, Dowling 2011); geographic (Stueve et al. 2002, Stokes et al. 2003, Buckley 2003); and holistic, as it refers to the notion of belonging to the Earth Mother (Arouca 2011). However, everyone agrees that geotourism should promote educational experiences, interpretation, and knowledge about what they are experiencing. Considering that most of the attractions of the municipalities of the project are related to the abiotic typology associated with history and biodiversity (Eschiletti 2020), it appears that there is potential to provide the interpretation of the natural and historical processes related to these touristic attractions.

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However, the demand needs to be known to prepare the offer and geotouristic products, understanding what type of tourist has an affinity with the practice of geotourism and, consequently, whether geotourists consider it important to interpret and understand the place they are visiting. Quantifying, characterizing, knowing the profile of tourists, and knowing which activities serve each demand of those who visit geosites in the proposed area for geoparks is essential to guide planning, implementation, and management actions (Pereira 2010, Castro et al. 2017).

The city of Lençóis was the capital of Lavras Diamantinas and today concentrates the largest number of services and equipment for tourism (Eschiletti 2020) and, consequently, the highest number of tourists in the region. The local identity of the municipalities and the promotion of what is authentic and unique in the territory need to be recognized and strengthened to guarantee, through geotourism, sustainable economic development, social justice, and the achievement of environmental integrity (Arouca 2011).

Considering that geotourism has a geological form (geodiversity), its processes can be seen as a primordial aspect for its development, and that the socio-spatial formation in Lençóis goes back from the mining of diamonds to tourism, it is questioned: What are the attitudes, behaviors, preferences of travel, and affinity with the 3G knowledge (geological heritage, geotourism, and geopark) tourists of Lençóis that visit geodiversity attractions in the territory of the Serra do Sincorá Geopark Project (PGSS) have?

Thus, the objective of this research was to analyze the demand of geotourists to provide a contribution to the management and planning of geotourism in the PGSS territory, aiming at a better use, adequacy, and expansion of the offer of geodiversity and the historical and cultural aspects of the municipalities included in the proposal. The profile of the geotourist, the one with "strong affinity for the practice of geotourism," was determined from the statistical analysis of cluster and multiple comparisons between groups based on attitudes and behaviors analyzed from the perspective of social psychology (Braghirolli et al. 2011).

2. Theoretical framework

2.1. Geotourism

There are different ways of understanding geotourism when considering its characterization, either through the geological and geographic bias or as Earth Mother. Therefore, the discussion about this term started to take place in 1995, when Thomas Hose, in the United Kingdom, defined geotourism for the first time, which should go beyond aesthetic appreciation, allowing tourists to acquire knowledge and understanding of geology through interpretive facilities. The author emphasizes again the importance of interpreting heritage as a form of protection, pointing out that there is little public awareness about the wealth, cultural significance, and threats "of geological and geomorphological places and materials" (Hose 2000), emphasizing the educational use and the essential component of geological conservation in geotourism.

According to the Australian authors Newsome and Dowling (2006) "[…] the prefix 'geo' of the word geotourism belongs to geology, geomorphology, and the other natural resources of the landscape" (Newsome and Dowling 2006). Also, most geotourism occurs in the natural environment and can happen in urban environments.

In Brazil, Azevedo (2007) and Moreira (2008) considered that geotourism has a geological heritage as its main attraction and emphasizes the interpretation of heritage and the motivation of people interested in knowing more about the geological and geomorphological aspects of a given location. On the other hand, according to Mantesso-Neto et al. (2012), geotourism is an activity that combines natural and cultural elements. Australians Robinson (2008) and Dowling (2011) pointed out that geotourism is sustainable and geological tourism related to ecotourism.

On the other hand, the definition provided by the National Geographic Traveler and The Travel Industry Association of America considers the term geotourism closely related to sustainable tourism, with a concern to preserve the geographic character of a destination, being the whole combination of natural and human attributes that make one place distinct from the other, encompassing cultural and environmental concerns related to travel, as well as the local impact that tourism has on communities and their individual economies and lifestyles (Stueve et al. 2002).

The definition established in the Arouca's "Geoletter" understands geotourism with a holistic Earth Mother approach because "we are all connected to the Earth and it is the link between us" (Digne 1991), defining it as "the tourism that sustains and values the identity of a territory, taking into account its geology, environment, culture, aesthetics, heritage, and well-being of its residents" (Arouca 2011), encouraging territories to develop geotourism with a focus on cultural, historical, and scenic value, in addition to the environment and geological heritage. This concept has a clear relationship with Geoparks, the conservation of geodiversity (Gill 2017), and is also in line with the objectives of the 2030 Agenda (ONUBR 2016) for Sustainable Development and the document of the World Tourism Organization for Sustainable Tourism (UNWTO 2017).

Martini et al. (2012) highlight that geology remains a fundamental point in geotourism, with "the interpretation of the geological character of the territory is always the main objective of this type of geotourism," and understand that the broader approach of the concept should improve the public appreciation for geology. The advantages of expanding the concept of geotourism beyond geological tourism are related to the fact that tourists need to understand that geology/ geodiversity is closely related to other elements of the territory, such as biodiversity and archaeological, cultural, and gastronomic values because the number of people interested in geology is low and geotourism is an economic activity that needs tourists to ensure sustainability.

According to Dowling (2013), geotourism is based on the geological environment and the difference between the geological and geographic definitions lies in the fact that the former understands geotourism as a "form" or type of tourism, while the latter sees geotourism as an "approach" to tourism. Thus, the best way to understand geotourism would be from the two understandings, firmly related to the geological nature of the "sense of place" of an area.

Dowling and Newsome (2018), in turn, created a defining spectrum for geotourism, in which its focus at one end of the spectrum is on geological tourism and, at the other end of the spectrum, there would be a broader geographic situation, which still has its geological basis that is used to inform the biotic and cultural elements of a geosite.

In addition, tourism is “an economic, political, social, cultural, and environmental phenomenon whose basic components for reflection are human, space, and time” (Ueda and Vigo 2000) and should be considered as an important global phenomenon in the 21st century, which was responsible for generating US$ 8.9 trillion (equivalent to R$ 51.26 trillion today) for the world gross domestic product (GDP) and 330 million jobs in 2019 (WTTC 2020). Moreover, an estimated 100.8 million jobs have been put at risk due to the 2020 pandemic, generating a 30% drop in world GDP revenue.

2.2. Geotourist

Nascimento et al. (2008) pointed out that many places of geotouristic interest in Brazil (even without defining and elaborating touristic products) are already geotouristic attractions. It is worth noting that the touristic product “is composed of tourist attractions plus infrastructure, services, and equipment marketed in an organized manner to satisfy the needs and desires of the tourist” (MTUR 2011). Also, “products and touristic itineraries, in general, are defined according to supply and demand to characterize specific touristic segments” (MTUR 2011).

A segment requires touristic identity, supply, and demand, but geotourism cannot be considered a touristic segment in Brazil because there is still an incipient identity for geotourism, and the demand is not fully characterized (MTUR 2010). The World Tourism Organization (UNWTO 2019) also does not recognize geotourism as a segment. Therefore, quantifying and characterizing the profile of tourists who visit the geosites of geopark projects are essential for effective implementation and management (Pereira 2010), developing touristic products, and contributing to a possible segmentation.

The studies by Lourenço (2012) showed the need to know the behavior of the consumers to adapt the available itineraries to their preferences. According to the author, “adapting marketing strategies to consumer preferences can be a competitive advantage in relation to other competitors” and “the consumer, in general, has a behavior regarding consumption that can be determined to suit the marketing strategies to it” (Lourenço 2012).

Castro et al. (2017) contributed to this sense by stating that knowing the tourist profile contributes to guiding planning and management actions, allowing to know which activities serve each tourist demand. In addition, Nascimento et al. (2008) added that tourists need to interpret the heritage they are visiting to practice geotourism. We will present below several studies that tried to define and describe the geotourist profile.

British geotourists are usually casual, few are competent in Earth Science (Hose 1995). Thus, users of specific attractions of the geological heritage tend to be above the national educational average and have some particular interest in the subject, are unaware of the importance of the geological heritage, are over 30 years old, and travel in couples or small family groups with children. Satisfying the educational needs perceived in children motivates adults to be users.

The author (Hose 2000) also analyzes that there is a difference between specialized and occasional geotourists. Specialized geotourists would be “individuals who intentionally select visits to places and exhibitions of geological and geomorphological interest for their personal education, intellectual improvement, and enjoyment,” while occasional geotourists would be “individuals who visit places and exhibitions of geological interest with the fundamental aim of personal pleasure and some limited intellectual stimulation” (Hose 2000).

Stueve et al. (2002) carried out a study on the profile of American tourists and obtained eight profiles of tourists, three of them being geotourists. They are also called sustainable tourists, vary in age range, being partly young and partly older, have higher education, high income, are frequent and environmentally conscious travelers, are of working age and working, 40% have children under 18 years old, have strong preferences for the cultural and social aspects of travel, and most live in urban areas.

Buckley (2003) states that geotourists choose the place they will visit and travel to see particular scenery and wildlife, experience specific local culture, and practice sports such as climbing and kayaking. Moreover, Robinson (2008) found that 72% of respondents were between 45 and 70 years old and men, 96% of respondents had a first or second level education, social needs and desires, different esteem, and a good gross income, which would make it possible to pay for trips to geotourism sites in Australia and abroad. In addition, the most important purposes for travel would be to increase knowledge of geological sites and landforms; satisfy curiosity; have a memorable experience; obtain intellectual stimulation; and visit destinations that offer a unique set of resources, such as ecology, the experience of different cultures and history, satisfying your curiosity. The interviewees attribute a higher level of importance to the visited destinations, offering an exclusive package of these resources, as well as tasting good foods and wines.

Mao et al. (2009) analyzed the study by Robinson (2008) and concluded that geotourists prefer to travel alone, without organized tours or excursions, and most of them want to increase their knowledge about geological sites and landforms.

Dowling (2011) notes that defining geotourism is easier than defining who the geotourist is and points out a spectrum of geotourists from the study by Grant (2010 apud Dowling 2011), which defined five levels ranging from geoexperts to general visitors who are not aware of what they are visiting.

Hurtado et al. (2014) adapted the typology of tourists from cultural tourism to geotourists, creating a model with five types of geotourists based on a survey conducted with 119 respondents and based on the experience and satisfaction of tourists when visiting the Crystal Cave, in Australia. Allan et al. (2015) carried out another study on the same attraction to define the profile of geotourists based on their motivations and concluded that the main motivations were relaxation, escape from the hectic life, the feeling of admiration, and to gain knowledge.

Božić and Tomić (2015) defined the profile of pure (dedicated) geotourists and general (accidental) geotourists who visit canyons and gorges in Serbia. When applying a geosite assessment model, the experts evaluate it and consider the opinion of tourists on the importance of each indicator and which geosites they would choose to visit. They conclude that pure geotourists prefer basic touristic infrastructure, while general geotourists prefer comfort.

In Brazil, surveys on geotourists are more recent and seek to characterize their profile relating to the motivation and interest in the knowledge of 3G (geological heritage, geotourism, and geopark), with three studies on the geotourist profile pointing out characteristics for the Brazilian territory, both in Conservation Units (CU) that are part of a geopark proposal.

According to Fonseca Filho and Ribeiro (2016), knowing the tourist profile is fundamental, as tourism is a complex activity and, for this reason, it has been segmented to understand the identity of the supply and the specificities and variables of the demand. Thus, Fonseca Filho and Ribeiro (2016) classified the potential geotourists into three levels: casual and curious visitors are in the first two levels, respectively, and those who decided to consciously visit the park are in the third level. The authors concluded that geotourism in the Serra do Rola-Moça State Park (MG) is not a consolidated segment in the park, being possible that geotourists have been practicing geotourism unconsciously, as well as there may be potential tourists to this practice, also clarifying that the geotourist appreciates the geological characteristics and features and acquires knowledge about the heritage.

Visitors were interviewed at Itacolomi State Park, Minas Gerais, to present results on "[…] origin, stay in the municipality, transportation, monitoring, information, means of accommodation, motivation, attractions, satisfaction, unprecedentedness, and returnability" (Fonseca Filho and Moreira 2017), considering that "the attraction needs to be consistent with the visitor, as well as the entrepreneur with the client" (Fonseca Filho and Moreira 2017), but many managers do not know their clients. According to these authors, the profile of tourists, regarding the affinity with geotourism, is "geologically motivated; knows what geological heritage is, has the interested in getting to know geological heritage better; does not know what geotourism is; do not know what a geopark is and do not know that the Itacolomi State Park is in the proposal for the Quadrilátero Ferrífero Geopark (Fonseca Filho and Moreira 2017).

Fonseca Filho et al. (2018) carried out a study in the National Park (PARNA) of Serra do Cipó (MG) to define whether the demand was for geotourists. The authors correlated the visitors' knowledge about 3G and conclude that tourists who know the concepts of Geological Heritage, Geotourism, and Geoparks are considered typical geotourists (4%) and those who have heard about it are considered accidental geotourists (34%) with the potential to become aware. Thus, geotourism would be a niche since the tourist from PARNA Serra do Cipó (MG) has an authentic behavior of geotourists, as they seek waterfalls, which are geomorphological geosites. However, this tourist aims at more contemplation than interpretation and understanding, being an "ecotourist by segmentation, but geotourist by market niche" (Fonseca Filho et al. 2018).

Hose (2012) points out that, in general, readily observable characteristics attract geotourists more than the complex geological history, and that it is possible to take more complex messages to geotourists by developing appropriate ways of communicating the knowledge of 3G (geological heritage, geotourism, and geopark). Also, the biggest desired change in geotourism and geotourists is the enjoyment nature of the relationship between modern geotourists with the landscape compared to their predecessors. In other words, it is possible to qualify the leisure of tourists, placing greater emphasis on pleasure and leisure than on intellectual effort and spiritual awareness, which does not prevent the adoption of geotouristic practices to educate them about the scientific and cultural significance of geology in the past and the present. These geotouristic practices must seek to harmonize relationships in the touristic space and must value the local identity and well-being of residents, as suggested by Arouca (2011). These characteristics make up the structure of a geopark, a place of excellence for the occurrence of geotourism and destinations for geotourists.

2.3. Serra do Sincorá Geopark Project

The most important feature of this territory is Serra do Sincorá, "located on the central-eastern border of Chapada Diamantina" (Pedreira 2002) and the northern portion of Serra do Espinhaço. The Bahia's municipalities of Andaraí, Lençóis, Mucugê, and Palmeiras, located between the coordinates 41°69′–40°69′ W and 12°14′–13°42′ S (Figure 1), are inserted in a very old portion of the Brazilian territory, the São Francisco craton, which has been consolidated since the beginning of the geological history of the planet (Pereira 2010). Chapada Diamantina occupies about 10% of the area of occurrence of sedimentary and metasedimentary sequences (with a low degree of metamorphism) in Brazil, illustrating the succession of environments and the landscape evolution on the South American Platform since the Proterozoic (Pereira 2010). This territory has geotouristic potential due to the geological constitution, the shape of relief, and the cultural relationship with mining and biodiversity, which presents characteristics of the Atlantic Forest, Caatinga, and Cerrado biomes, and all these associated elements can be observed in the main tourist attractions (Eschiletti 2020).

It is worth noting that the city of Lençóis is considered the gateway city for tourists to enter Chapada Diamantina (Brito 2005, Santos 2006) (Figure 1) and has the largest number of touristic equipment and service providers (Eschiletti and Lanzer 2019), being the main responsible for sending tourists to the other municipalities of the Serra do Sincorá Geopark Project, Bahia.

3. Methodology

Geotourism supports and values the identity of a territory, taking into account its geology, environment, culture, aesthetics, heritage, and well-being of its residents (Arouca 2011). Geotourists would be individuals interested in learning about geodiversity, with "general attitudes about leisure travel," "environmental/cultural attitudes," "cultural behavior," "travel and destination preferences," and "importance of travel aspects" (Table 1) (Stueve et al. 2002), showing affinity with the 3G concepts (geological heritage, geotourism, and geopark) (Fonseca Filho and Moreira 2017), analyzed from the perspective of social psychology (Braghirolli et al. 2011).

The geotourist demand was analyzed using 20 statements (Table 1) on a Likert scale (1934) Likert et al. (1993), between 1 ("strongly disagree") to 5 ("strongly agree"). The statements were elaborated from the dimensions "general attitudes about leisure travel," "environmental/cultural attitudes," "cultural behavior," "travel and destination preferences," and "importance of travel aspects" (Stueve et al. 2002). The answers to the questions of the structured instrument were

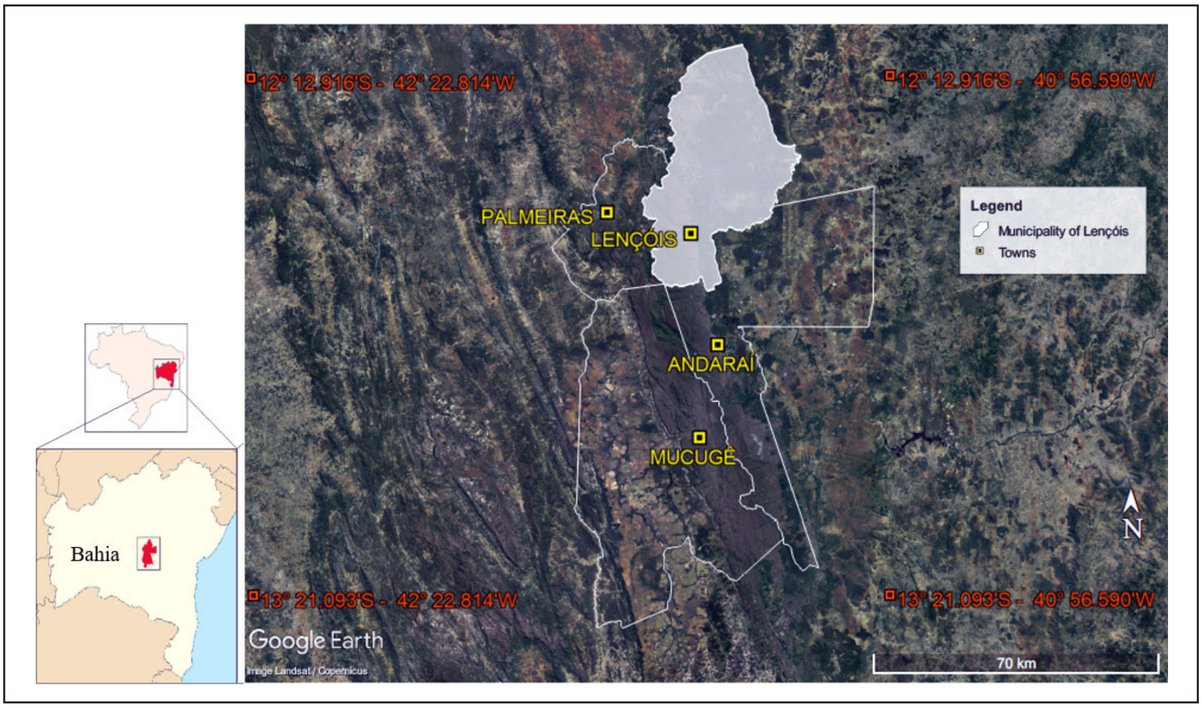

FIGURE 1. Location map of municipalities in the territory of the Serra do Sincorá Geopark Project, Bahia. Modified from Google Earth (2020).

considered to perform the hierarchical cluster analysis using Euclidean similarity and distance. The Shapiro and Francia (1972) normality test was performed for each group generated from the cluster analysis to verify the data distribution. Subsequently, the non-parametric Mann-Whitney U test was carried out for multiple comparisons between dimensions and between groups.

The descriptive characterization of geotourists was carried out followed by the cluster analysis considering the affinity with the concepts of geological heritage, geotourism, and geopark (3G), elaborated from Fonseca Filho and Moreira (2017), the socio-economic profile, the reason, and the developed activities (CET-UNB 2008). The inventory of geosites, developed by Pereira (2010) for Chapada Diamantina and which indicates accessibility and the touristic, didactic, and scientific values, was used to list the geodiversity. The affinity analysis with 3G and the sociodemographic profile were carried out using multiple-choice questions. Aiming to deepen the description, the mean and standard deviation were also calculated for each of the 20 questions used in the cluster analysis to describe the statements with which the tourists have a greater agreement for the value of the mean cluster.

The questionnaire was applied in the second half of 2018, totaling 135 participants in Lençóis. The questionnaires were distributed at random to tourists who were seated at bars and restaurants on the main streets of the city between 19:30 and 22:30 h. A total of 124 responses were used (92% of the sample universe), as tourists who had not visited any touristic attraction related to geodiversity (11 respondents) were excluded from the sample because, according to Brilha (2005) and Gray (2008), geotourism makes use of geodiversity to happen.

4. Results and discussion

Knowing the profile of the tourists/clients who frequent the touristic destination contributes to the planning of tourism management, aiming to minimize negative impacts arising from this activity and promoting positive impacts and the tourist experience (CET-UNB 2008). Segmenting the demand allows directing strategies to serve the tourist effectively, planning the offer and elaborating touristic products adapted to their preferences and needs, in addition to being competitive in the tourism market (Keller and Kotler 2006, MTUR 2011, Castro et al. 2017). Additionally, geotourism needs a volume of buyers of geotouristic products and a touristic offer with defined characteristics to become a touristic segment in Brazil and worldwide.

Thus, four groups, arranged in a dendrogram, were generated to characterize the demand for geotourists in the Serra do Sincorá Geopark Project (Figure 2). The data did not present a normal distribution and the non-parametric Mann-Whitney U test indicated a difference between groups (Table 2). This test showed a difference for all dimensions between groups 3 (n=36) and 4 (n=9).

The results show that group 3 (n=36) presented a higher value in the dimensions "general attitudes," "cultural behavior", "travel and destination preferences among travelers" and "importance of travel aspects" compared to the other groups through the measure of central tendency (Table 3). The other groups were not considered to have a strong affinity for the practice of geotourism because they did not present significant values for all dimensions. Groups 1 (n=24) and 2 (n=55) showed significant differences between the dimensions "environmental and cultural attitudes" and "importance of travel aspects." Group 1 has a higher value for "importance of travel aspects" than group 2, which indicates that education and learning during travel are important for tourists in that group, while group 2 has "environmental and cultural attitudes" with a higher value than group 1. Group 4 (n=9) presented the lowest values in all dimensions compared to the others (Table 3), with the lowest affinity for the practice of geotourism.

The highest value for the dimensions of groups was considered relevant because it is understood that "a person's

TABLE 1. Questions corresponding to each dimension for the definition of the geotourist profile.

General attitudes about leisure travel (GA)	Q1	My travel experience is better when my destination preserves its natural, historical, and cultural sites and attractions.
	Q2	My travel experience is better when I see or do something unique.
	Q3	My travel experience is better when I learned as much as possible about the customs, geography, and culture of my destination.
	Q4	My travel experience is better when I learned as much as possible about the landscape and geology of my destination.
	Q5	It is important to me that the travel companies I use employ local residents and support the local community.
	Q6	It is important to me that my visit to a destination does not damage its environment.
	Q8	It is important to me that the attractions of my interest are easily accessible to me and those who are with me.
Environmental and cultural attitudes (EC)	Q7	I think urban development is a big problem.
	Q9	I agree that there should be more public and/or private funding for the preservation of the country's historic sites, fauna, and flora.
	Q10	I agree that there should be more public and/or private funding for the conservation of the country's geological heritage and natural monuments.
	Q11	There must be more careful monitoring of the use of our National Parks and public lands.
	Q12	I agree to control access to National Parks and public lands so that the environment can be preserved and protected.
Cultural behavior (CB)	Q15	Very/extremely likely to buy products and services from specific companies because I know they donate part of their profits to charitable organizations.
	Q16	Very/extremely likely to participate in art events (e.g., theater, symphony, opera, and ballet) in my local area.
	Q17	Very/extremely likely to visit historical sites and/or museums in my local area.
Travel and destination preferences among travelers	Q14	Very/extremely important that the trip offers the opportunity to be in luxury and be pampered (i.e., luxury hotels and good restaurants).
	Q18	It is very likely I travel to places where I can experience people, lifestyles, and cultures very different from mine.
	Q19	Very/extremely likely to trip to destinations that have authentic historic or archaeological buildings and sites.
	Q20	Very/extremely likely to travel to destinations that have natural areas and authentic geological features.
Importance of travel aspects	Q13	Very/extremely important that the trip provides educational experiences for me and my family.

behavior is usually consistent with their attitudes" and that "knowing someone's attitude about something can assist in understanding and, to a certain extent, predicting their actions in relation to this 'something'" (Braghirolli et al. 2011). Thus, the presented dimensions were considered to point out the trend towards the practice of geotourism. Therefore, tourists who have a "strong affinity for the practice of geotourism" also have an affinity with the concept of Arouca (2011), which considers the search for sustaining and valuing the identity of the territory, covering geology, environment, culture, aesthetics, heritage, and well-being of the inhabitants of the territory.

The agreement for the statement "Very/extremely important that the trip provides educational experiences for me and my family," inserted in the dimension "importance of the travel aspects," showed that tourists with "strong affinity for the practice of geotourism" value the educational experience and increased knowledge during the trip, which is very desirable for geotourists (Hose 1995, 2000, 2012, Stueve et al. 2002, Stokes et al. 2003, Newsome and Dowling 2006, Nascimento et al 2008, Robinson 2008, Mao et al. 2009, Dowling 2011, 2013, Arouca 2011, Martini et al. 2012, Dowling and Newsome 2018).

According to Braghirolli et al. (2011), "we are more exposed, and we are better at learning what is not inconsistent with our attitudes" when we have positive attitudes about something. It implies that tourists in Lençóis present attitudes in line with the educational aspects of geotourism. Thus, these 36 tourists (group 3), 29% of respondents, are considered geotourists (Figure 2).

4.1. Reason for travel and developed activities

Most trips are motivated by leisure, corresponding to 97.1% of occurrence in the responses of tourists. Nature (37.1%), sport (17.1%), visits to relatives/friends (14.3%), history (11.4%), and architecture (11.4%) appear as indirect reasons for geotourism to happen. Geology, which would be the direct motivation for the practice of geotourism, appears in 8.6% of the responses (Figure 3). These results on motivation are in line with what Allan et al. (2015) identified as reasons for geotourists, ranging from escaping the hustle and bustle of everyday life, relaxation, pleasure, and a sense of wonder to gaining knowledge.

According to Braghirolli et al. (2011), reasons trigger the action to visit, while attitudes predispose to visit. Thus, considering the "general attitudes towards leisure travel" that did not show the dispersion of responses and have a high mean, one can observe the high agreement of tourists to the statements "My travel experience is better when my destination preserves its places and natural, historical, and cultural attractions" and "My travel experience is better when I learned as much as possible about customs, geography, and culture of my destination." Social and cultural aspects are relevant to tourists, even if there is a geological motivation due to the visit to the attractions of geodiversity (Fonseca Filho and Moreira 2017). These tourists, when traveling from their cities of origin, are also motivated by history, architecture, and nature, strongly agreeing that "It is important that my visit does not damage the environment."

The motivation related to the sport can be identified when considering the developed activities since trekking practices stood out, as this option was mentioned in 95.1% of the responses of tourists. Tourists can observe the geodiversity, biodiversity, and historical and cultural characteristics when performing this activity. According to Stueve et al. (2002), the profile of geotourists who are newer than 35 years old has a touch of adventure, corroborating the result of the developed activities (Figure 3).

The activities city tour (42.9%), contemplation of scenic beauty (34.3%), and cultural tourism (34.3%) were related to

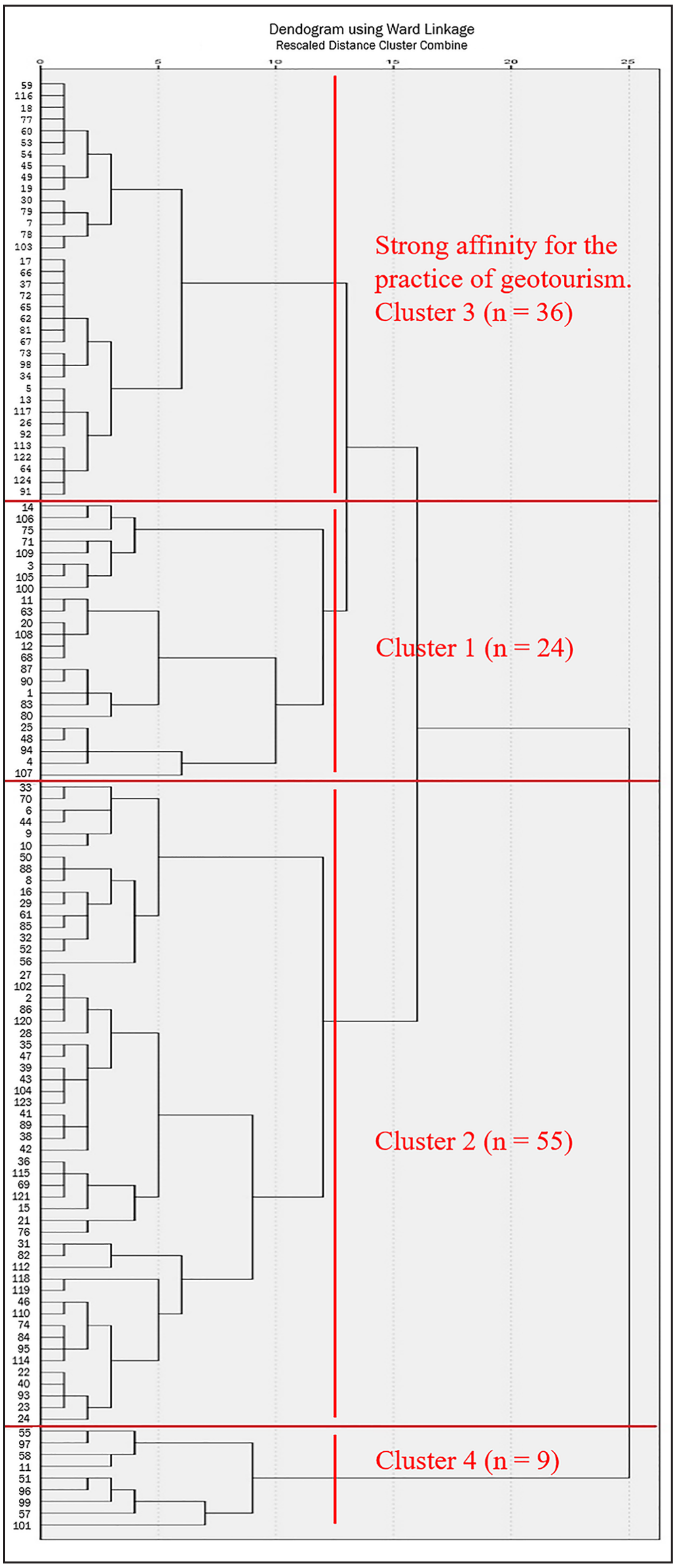

FIGURE 2. Dendrogram with the four tourist groups in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

the reasons "architecture," "nature," and "history," which are related to "general attitudes to leisure travel." Geotourism (11.4%), caving (8.6%), and rural tourism (8.6%) are the activities that appear less prominently due to the choice of tourists with "strong affinity for the practice of geotourism" (Figure 3). Even though touristic activities focusing on the abiotic portion of nature were not the most mentioned, tourists agree that "My travel experience is better when I learned as much as possible about the landscape and geology of my destination." This statement directly shows the geological reason, but it is possible to infer that knowledge about the geological shape and processes (Newsome and Dowling 2006, Dowling 2011) are more difficult for tourists to understand, possibly due to the language, which is not accessible, as pointed out by Hose (1995, 2000, 2012), or because this knowledge is still a bottleneck to be extended to what concerns the geosciences and the reach to society.

The "environmental and cultural attitudes" showed a positive agreement without the dispersion of responses regarding "public and private financing for the preservation of historic sites, fauna, and flora and conservation of the country's geological heritage and natural monuments." Thus, this agreement corroborates with the creation of a geopark, which requires a public-private articulation for planning and managing the territory. In addition, the geological and sociocultural character appears again as fundamental, relating the non-dissociation of geology, geography, and history in the context of Chapada Diamantina. "Attitudes include a behavioral component" (Braghirolli et al. 2011, p. 82) and it is more likely for a person to have a coherent behavior if s/he has an attitude favorable to natural and cultural aspects. Considering the dimension of the "cultural behaviors" carried out in the tourists' place of origin (Stueve et al. 2002), a positive agreement was evidenced for "participation in art events" and "visitation of museums in the place of origin", thus showing that these tourists appreciate the culture and learning in their different possibilities.

4.2. Affinity with 3G (geological heritage, geotourism, and geopark)

Morro do Pai Inácio (Figure 4) was visited by all tourists and is located in the municipality of Palmeiras, the same municipality where the Fumaça waterfall and Vale do Capão, which were also visited. The two most visited attractions in the municipality of Lençóis were Mucugezinho River Balneario and Serrano (Figure 4), located downtown (Table 4).

According to Fonseca Filho and Moreira (2017), the attractions of geodiversity are associated with the geological motivation and the attractions/geosites are highly visited by tourists, such as waterfalls, rivers, caves, hills, and places with exposed rocks. On the other hand, nature, history, archeology, architecture, and sports can appear as indirect motivations for geotourism to happen.

A positive agreement is observed in the statement "It is important to me that the attractions of my interest are easily accessible to me and to those who are with me" when considering accessibility as a "general attitude". In practice, it is not fully confirmed, as some tourists visit attractions with difficult access (Eschiletti 2020), while others are poorly accessed, even if easily accessible, such as the Luís Santos neighborhood, Donana waterfall, Marimbus wetland, and Monte Tabor (Pereira 2010). It is possibly due to the lack of planning for touristic attractions and promotion.

Material and immaterial cultural attractions, such as the Senhor dos Passos Festivity, are the connection point between geology and culture. In this sense, geotourists have a positive agreement with "travel and destination preferences": "Take trips to destinations that have natural areas and authentic

TABLE 2. Mann-Whitney U test and significance by groups of visitors of the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia. Significance by groups is identified when the p-value is <0.05 and is highlighted with gray color.

Group	p-valor				
	General attitudes about leisure travel	Environmental and cultural attitudes	Cultural behavior	Travel and destination preferences	Importance of travel aspects
1 and 2	0.487	0.005	0.596	0.336	0.007
1 and 3	0.000	0.068	0.001	0.003	0.091
1 and 4	0.041	0.001	0.347	0.029	0.062
2 and 3	0.000	0.414	0.000	0.000	0.000
2 and 4	0.062	0.000	0.499	0.069	0.909
3 and 4	0.000	0.000	0.011	0.000	0.001

TABLE 3. Mean, median, and standard deviation of attitudes, behaviors, preferences, and importance of travel per group in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

Dimension	Metrics	Group 1	Group 2	Group 3	Group 4
General attitudes about leisure travel	Mean	4.52	4.48	4.83	4.10
	Median	4.57	4.57	4.86	4.14
	Std. Dev.	0.30	0.29	0.16	0.56
Environmental and cultural attitudes	Mean	4.48	4.68	4.63	3.98
	Median	4.60	4.80	4.60	4.00
	Std. Dev.	0.29	0.23	0.25	0.39
Cultural behavior	Mean	3.71	3.58	4.26	3.26
	Median	3.67	3.67	4.33	3.33
	Std. Dev.	0.62	0.63	0.54	1.13
Travel and destination preferences among travelers	Mean	3.88	3.75	4.22	3.42
	Median	3.88	3.75	4.25	3.25
	Std. Dev.	0.48	0.53	0.35	0.48
Importance of travel aspects	Mean	4.67	4.11	4.83	4.22
	Median	5.00	4.00	5.00	4.00
	Std. Dev.	0.48	0.92	0.45	0.67

geological aspects" and "Destinations that have authentic historic or archaeological buildings and sites." Therefore, a geotourist would be someone with an interest in learning that the construction and transformation of the geographic space were due to the human being actions in the natural object geodiversity, modified by the technique throughout history (Santos 2011), both during the diamond mining cycle (Nolasco 2002, Iphan 2014a, b, c) and during tourism (Brito 2005, Santos 2006). The Senhor dos Passos Festivity can be a bridge between Religious Tourism and geodiversity (Guimarães et al. 2009), as Senhor dos Passos is the patron saint of miners.

The preference for the destination to maintain its identity and uniqueness was pointed out in "My travel experience is better when I am seeing or doing something unique." In addition, travel should provide social and cultural experiences, as found in "Experimenting people, lifestyles, and cultures very different from mine." However, still considering the "travel and destination preferences," there is disagreement regarding the statement "Very/extremely important that the trip offers the opportunity to be in luxury and be pampered (i.e., luxury hotels and good restaurants)", corroborating with Božić and Tomić (2015), who stated that pure geotourists demand basic infrastructure at the destination, giving more importance to geosites without major touristic and protected infrastructures. Among the geotourists defined by Stokes et al. (2003), the means of accommodation vary from small-scale accommodation, managed by the local community, to high-quality accommodation, options available in Lençóis.

Although geotourism must be the engine for sustainable development in geoparks, it is necessary to emphasize that it is not yet a touristic segment (MTUR 2010, UNWTO 2019), just as it is not a "new" product of ecotourism (Robinson 2008), as it does not depend on seasonality (Hose 1995). Moreover, geotourism is broader than geological tourism, which favors rock formations in its activity (Dowling and Newsome 2018), as it can happen in urban, natural (Newsome and Dowling 2006), and cultural environments (Mantesso-Neto et al. 2012), while ecotourism is only performed in natural environments (Ceballos-Lascuráin 1998). Ecotourism is the second most popular tourist activity in Lençóis (Figure 3) and advocates that the community should be benefited socioeconomically (Ceballos-Lascuráin 1998), but it is necessary to review the reasons why the community of Lençóis has not been benefited over the years, as the social gap increased in the municipality from 1999 to 2010 while per capita income more than doubled (Eschiletti and Lanzer 2019).

Part of the tourists mentioned that they know what a geological heritage is (58.3%) and part of them have heard about it (27.8%), which corroborates with Fonseca Filho and Moreira (2017). All tourists with a "strong affinity for the practice of geotourism" would like to know more about the geological heritage of Chapada Diamantina. It is a great opportunity to qualify the type of tourism practiced for leisure, as pointed out by Hose (2012), as most tourists affirmed their interest in obtaining and expanding knowledge. About 44.4% of the tourists mentioned to know what a geopark is, but they are unaware that geoparks are in the territory of the Serra do Sincorá Geopark Project (77.8%), indicating the need for disclosure in the media and actions in the municipalities of Lençóis, Andaraí, Mucugê, and Palmeiras.

Although geotourism is not an activity widely practiced among the tourists who exhibit attitudes, behaviors, preferences, and importance of travel consistent with the desired profile for geotourism, most of them (83.3%) mentioned they have heard or known what geotourism is, a result that meets the geotourist found by Fonseca Filho and Moreira (2017). Most respondents (91.4%) believe that the creation of the Serra do Sincorá Geopark will contribute to local conservation. Moreover, according to Fonseca Filho and Moreira (2017, p. 18), geotourists at Itacolomi State Park "believe that the geopark brings benefits to the community, especially for teaching and research purposes" (Table 4).

Considering the perspective of Stueve et al. (2002) and the understanding of Braghirolli et al. (2011) that a set of attitudes, behaviors, and preferences of travel is necessary for the action of visiting, we can agree with the statement of Allan et al. (2015) that the experience in geotourism consists of geotourists going to a place with geological or geomorphological

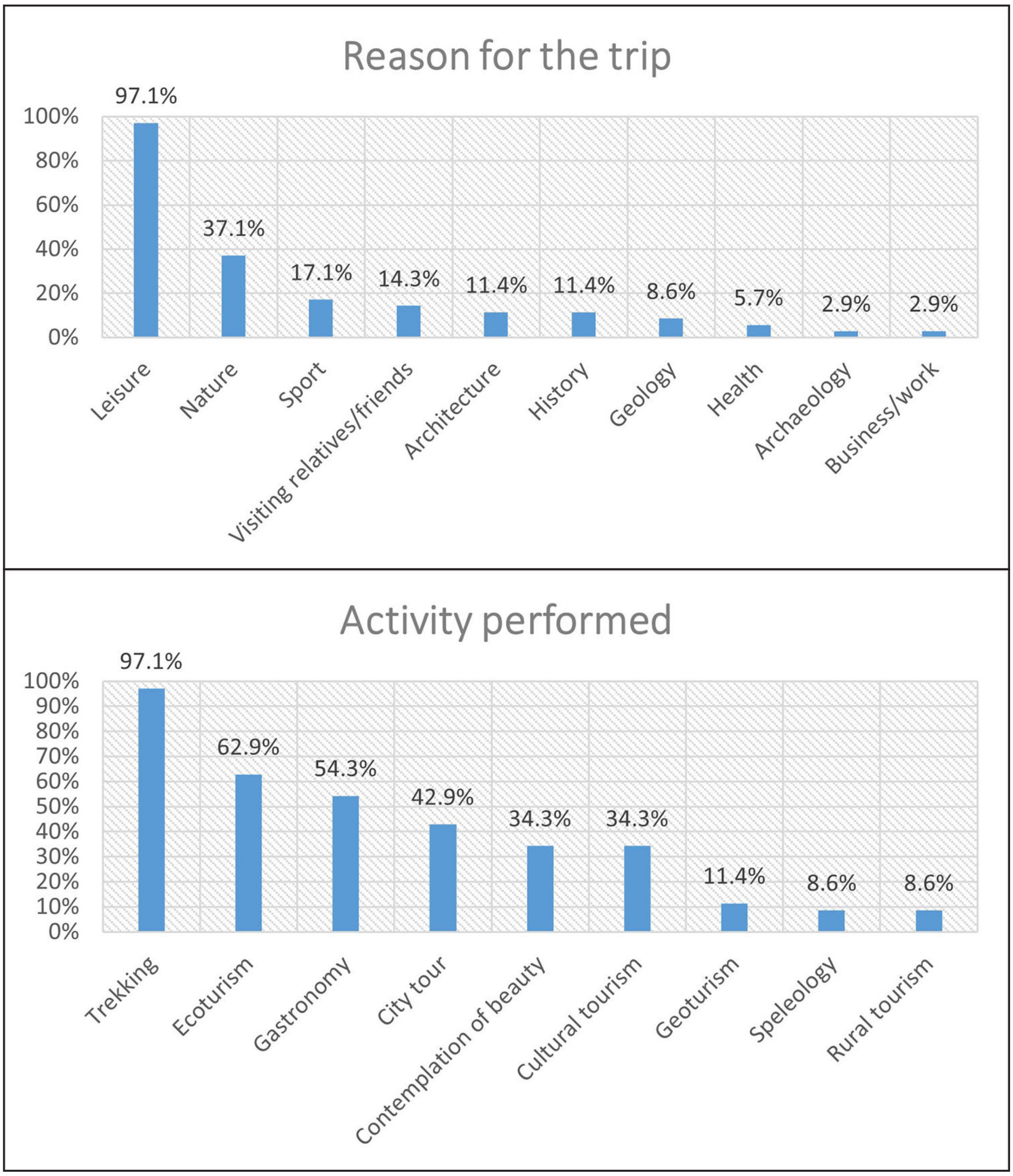

FIGURE 3. Reason for travel and activities carried out by tourists with a strong affinity for the practice of geotourism in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

FIGURE 4. Most visited attractions. A – Morro do Pai Inácio, B – Mucugezinho River balneario, C – Serrano. Photos by the author (A and C) and Açony Santos (B).

TABLE 4. Affinity with 3G (geological heritage, geotourism, and geopark) of tourists considered to have a strong affinity for the practice of geotourism in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

AFFINITY WITH GEO'S (GEOLOGICAL HERITAGE, GEOTURISM, AND GEOPARK) (n=36)					
Variable	**Category**	**%**	**Variable**	**Category**	**%**
Visited natural attractions	Luís Santos neighborhood	2.8	Visited cultural attractions	Cemetery	23.1
	Donana waterfall	2.8		Historical center	46.2
	Fumaça waterfall	30.6		Fair	38.5
	Andorinhas waterfall	2.8		Museum	19.2
	Riachinho waterfall	16.7		None	19.2
	Tiburtino waterfall	8.3	What is a geological heritage?	Yes	58.3
	Poço Encantado cave	16.7		No	13.9
	Torras cave	2.8		I have heard	27.8
	Diamictites of the Bebedouro formation	2.8	Learn more about the geological heritage of Chapada Diamantina	Yes	100
	Paixão cave	5.6	Do you know what a Geopark is?	Yes	44.4
	Marimbus	2.8		No	19.4
	Monte Tabor – Morrão do Capão	2.8		I have heard	36.1
	Morro do Cruzeiro	2.8	Proposed area for Serra Sincorá Geopark	Yes	22.2
	Morro do Pai Inácio	100		No	77.8
	Mucugezinho	63.9	What is geotourism?	Yes	38.9
	Poço Azul	55.6		No	16.7
	Paraguaçu River – Mucugê Balneario	5.6		I have heard	44.4
	Serrano	33.3	Creation of Serra Sincorá Geopark for conservation	Yes	91.4
				No	8.6

TABLE 5. Sociodemographic profile of tourists considered to have a strong affinity for the practice of geotourism in the territory of the Serra do Sincorá Geopark Project, Lençóis, Bahia.

SOCIO-ECONOMIC PROFILE (n=36)					
Variable	**Category**	**%**	**Variable**	**Category**	**%**
Gender	Female	58.3	Occupation	Administrator	5.6
	Male	30.6		Lawyer	2.8
	I prefer not to say	11.1		Systems Analyst	5.6
Age range	20 to 24 years	11.1		Software Test Analyst	2.8
	25 to 29 years	30.6		IT Analyst	2.8
	30 to 34 years	22.2		Administrative Assistant	2.8
	35 to 39 years	8.3		Designer	2.8
	40 to 44 years	13.9		Entrepreneur	5.6
	45 to 49 years	2.8		Nurse	2.8
	50 to 54 years	8.3		Engineer	8.3
	Above 60 years	2.8		Beautician	2.8
Marital status	Single	66.7		Student	8.3
	Married/common-law marriage	16.7		Government Employee	5.6
	Separated/divorced	13.9		Physician	2.8
	Other	2.8		Pedagogue	2.8
Income in Minimum Wages (MW)	1 MW and under	5.6		Teacher/Professor	13.9
	More than 1 MW to 2 MW	2.8		Cultural Programmer	2.8
	More than 2 MW to 3 MW	19.4		Psychologist	8.3
	More than 3 MW to 5 MW	41.7		Industrial Chemist	2.8
	More than 5 MW	30.6		Technician	2.8
Education	High school	2.8		Occupational Therapist	2.8
	Incomplete higher education	19.4		Tourism specialist	2.8
	Complete higher education	25	Region of Brazil	South	8.6
	Postgraduate studies	52.8		Southeast	31.4
				Midwest	2.9
				Northeast	57.1

characteristics to observe and gain knowledge. However, also considering a more comprehensive perspective of geotourism, in which geological tourism is another component added to the environment, culture, and aesthetics (Martini et al. 2012), the mean value showed that tourists in Lençóis have a positive agreement for “cultural behaviors” and “learning as much as possible about the landscape, geology, customs, geography, and culture of the destination”, showing that geography, geology, and history are inextricably linked in the territory proposed for the Serra do Sincorá Geopark. It places geotourism in a broader approach, as mining shaped (and shapes) in this territory over time, culture, and society, as well as the landscape currently visited by tourists.

4.3. Sociodemographic profile

The sociodemographic profile (Table 5) of the group with “strong affinity for the practice of geotourism” regarding gender, education, and marital status is similar to the profile found by Stueve et al. (2002) and Hurtado et al. (2014). The average age of these tourists (between 25 and 34 years old) is lower than the age found in studies that portray the geotourist profile (Stueve et al. 2002, Robinson 2008, Mao et al. 2009) and the age range from 31 to 55 years old found by the Brazilian Micro and Small Business Support Service of Bahia – Sebrae (2018) in Lençóis. The results of this research corroborate with Sebrae (2018) regarding gender, income, and regional origin (Table 5). The most frequent professions refer to tourists without geoscientific training (Hose 1995), but some individuals have a possible affinity to geosciences (teachers and engineers), as observed by Mao et al. (2009).

Finally, geotourism in the territory of the Serra do Sincorá Geopark Project tends to be an excellent tool for sustainable development if well planned, with the possibility of making fundamental contributions to the economic resumption of the touristic activity in the post-pandemic of the new coronavirus (SARS-CoV-2), because the UNWTO (2020) guidelines include domestic tourism, promotion of experiences to tourists, focus on nature, and sustainable products, that is, some of the main characteristics found as preferences of geotourists.

5. Final considerations

Knowing the demand is essential to plan the geotourism offer in Lençóis, Andaraí, Mucugê, and Palmeiras. The study allowed identifying, from the perspective of social psychology and based on the dimensions “general attitudes of leisure travel,” “environmental and cultural attitudes,” “cultural behavior,” “travel and destination preference,” and “importance of travel aspects,” a potential demand of 29% of tourists corresponding to the criteria used to distinguish geotourists. These tourists present significant values for each of the mentioned dimensions and, therefore, for the practice of geotourism.

About three geotourists out of 10 tourists know what geological heritage is, showing interest in knowing more about the geological heritage of Chapada Diamantina and demonstrating knowledge about the meaning of geotourism and geopark. However, these tourists did not know they were in the territory of the Serra do Sincorá Geopark Project, but they believe that the Project will contribute to the conservation of the area. Motivation made them visit the geosites, showing an interest in learning about the geological, geographic, and cultural characteristics of the destination, with attitudes and behaviors repeated at home and when they travel. They are motivated by geology/geodiversity, but they do not know it and the activities carried out are related to geotourism. The dominance of the female gender was identified, which points to a differentiated demand that better meets the expectations of not seeking luxury or elite environments, but rather unique and authentic places, with a protected environment, good touristic service at a fair price, and basic infrastructure in attractions, being geotourists without professional affinity with geosciences.

The demand for geotourists tends to increase although still incipient, as the territory must present well-defined geotouristic characteristics related to the offer of touristic products to attract this type of tourist to receive the seal of the United Nations Educational, Scientific and Cultural Organization – UNESCO. The articulated and integrated planning for geotourism associates natural and cultural heritage, strengthening culture without mischaracterizing the place, aiming to provide tourists with an enriching, educational, and unique experience in the territory of the Serra do Sincorá Geopark Project. Geotourism emerges as another touristic activity because it takes place in both natural and urban environments, necessarily involving the community. However, geotourism is not yet a recognized touristic segment and the characterization of demand, in addition to contributing strategically to the consolidation of the activity at the destination, also serves to segment the offer of geotourism.

Moreover, the pandemic of the new coronavirus (SARS-CoV-2) caused a decrease in the search for the tourism practice. Therefore, the results of this research also contribute to the planning of the resumption of the touristic activity, as the research showed that the tourist of Lençóis is domestic, regional, motivated by nature, and seeks experiences and education, which are trends pointed out by UNWTO as guidelines for the resumption of tourism. The Serra do Sincorá Geopark Project could be an excellent tool for territorial development in the municipalities of Lençóis, Andaraí, Mucugê, and Palmeiras in the medium and long term, as it can specialize and integrate the tourism offer that already exists and insert geotourism.

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Geologic Highway Map of Rio de Janeiro State: a product to stimulate geotourism and broadcast Rio de Janeiro's geodiversity

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Abstract

Geologic Highway Maps are used in several countries to, inform and entertain travelers who drive along main highways. They bring, in a language style accessible to the general public, information about the observable nature along roads, showing local and regional geodiversity on a map, in geological sections and at specially chosen stops. The remarkable geodiversity of the Rio de Janeiro state is considered to be the result of a complex geological and geomorphological evolutionary history, resulting in several geotouristic attractions. Although there are many important initiatives for dissemination of Rio de Janeiro's geodiversity, such as the Caminhos Geológicos Project, the Rio de Janeiro state still remains with a wide geotouristic potential yet to be explored. In this sense, this work presents the Geologic Highway Map of the Rio de Janeiro State (GHMRJ), in its final stage of design, as a product to propagate geodiversity and encourage geotourism. GHMRJ is an unprecedented initiative in Brazil, and a new way of publicizing geotourism bringing geoconservation of Rio de Janeiro's geodiversity into the spotlight.

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1. Introduction

Geologic Highway Maps are used in several countries to disseminate, inform and entertain travelers who drive along main highways (Kamilli and Richard 1998, Colorado Geological Survey 2003, Wilks 2005, Matthews 2009). They bring, in a language style accessible to the general public, information about the observable nature along roads, showing local and regional geodiversity on a map, in geological sections and at specially chosen stops.

Diverse concepts of geodiversity, from the most classic to the most current, address the variety of the abiotic environment that constitutes the natural diversity of terrestrial landscapes (Mansur 2018, Gray 2004, Gray 2013), considering the geological characteristics together with the hydrological, geomorphological and pedological ones in the set that makes up geodiversity.

The richness and exuberance of nature in Rio de Janeiro State, and the recent publication of the Geological and Mineral Resources Map on a 1: 400,000 scale by the Geological Survey of Brazil (Heilbron et al. 2016), motivated the team of the Tectonic Studies Laboratory of the Research Group in Geotectonic (LET-TEKTOS) of the Rio de Janeiro State University to prepare a Geologic Highway Map of the state. This map fills a gap in this type of scientific diffusion in the country and takes advantage of the tourism potential of Rio de Janeiro.

The difficult choice of highways, many of them traverse spectacular scenic landscapes, as well as stopping points, which demand places for secure and safe parking for travelers, was based on criteria of geological and geomorphological diversity and the extension of the roads, prioritizing those that cross a large part of the state. The Map was designed to be easy to use, with information on the front and back, and with a list of geosites and geological stations of interest, as well as the delimitation of the Costões and Lagunas Geopark Project and State Conservation Units.

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We hope that the Geologic Highway Map of the of Rio de Janeiro State will be a means of disseminating geosciences and stimulating environmental preservation.

2. General Aspects on the Design of Rio de Janeiro State's Geologic Highway Map

In the final stage of design, GHMRJ aims to stimulate geotourism and publicize Rio de Janeiro's geodiversity, highlighting the relevant aspects of such geodiversity around the state's highways.

GHMRJ is the result of the vast database acquired by the Geotectonic Research Group - TEKTOS, from UERJ, for design of the Geological and Mineral Resources Map of the Rio de Janeiro State (Heilbron et al. 2016). Its target audience is composed of tourists, students and other people interested in geosciences who wish to broaden their knowledge of Rio de Janeiro's geodiversity. In this sense, the use of simple and accessible language for different audiences was one of the major aspects taken into account when designing the map.

In addition to the TEKTOS Group database, data from other institutions were used; for example, Brazil's Ministry of the Environment (MMA), Brazil's National Department of Transport Infrastructure (DNIT) and the Mineral Resources Department of Rio de Janeiro State (DRM-RJ). The final publication foresees a Front and Back layout (60 cm x 120 cm) divided into thematic sections; this way, when folded, the GHMRJ is 15 cm x 15 cm in size, which is compatible with pocket publications. It is noteworthy that all maps presented in the publication used the geodesic reference SIRGAS 2000.

3. Front Face: Geology of the Rio de Janeiro State

The front face of GHMRJ has six thematic sections (Figure 2): (1) geological map and geological road profiles; (2) geotectonic evolution; (3) publication cover; (4) tectonic map; (5) mineral resources map; and (6) credits and general information about the publication.

The geological map presented in GHMRJ (Figure 3) is a simplification on a 1:600,000 scale of the Geological and Mineral Resources Map of the Rio de Janeiro State (Heilbron et al. 2016). In terms of simplification, some lithostratigraphic units were grouped, resulting in 21 classes of complexes and groups. The structures were simplified and grouped according to the main characteristics; they were represented on the map only as shear zones, faults, fracture zones and mylonitic zones.

The geological map also presents road vector data (DNIT 2013) with recent updates in the road network, and the geological sections of the main highways in the state: (a) BR-101 (Rodovia Rio-Santos), (b) BR-040 (Washington Luís Highway), (c) BR-116 (Via Dutra), (d) RJ-116 (Presidente João Goulart Highway), (e) RJ-124 (Via Lagos), (f) RJ-106 (Amaral Peixoto Highway) and (g) BR-356.

The tectonic map (Figure 4), represented on a scale of 1: 3,500,000, is also a simplification and update from the Geological and Mineral Resources Map of the Rio de Janeiro

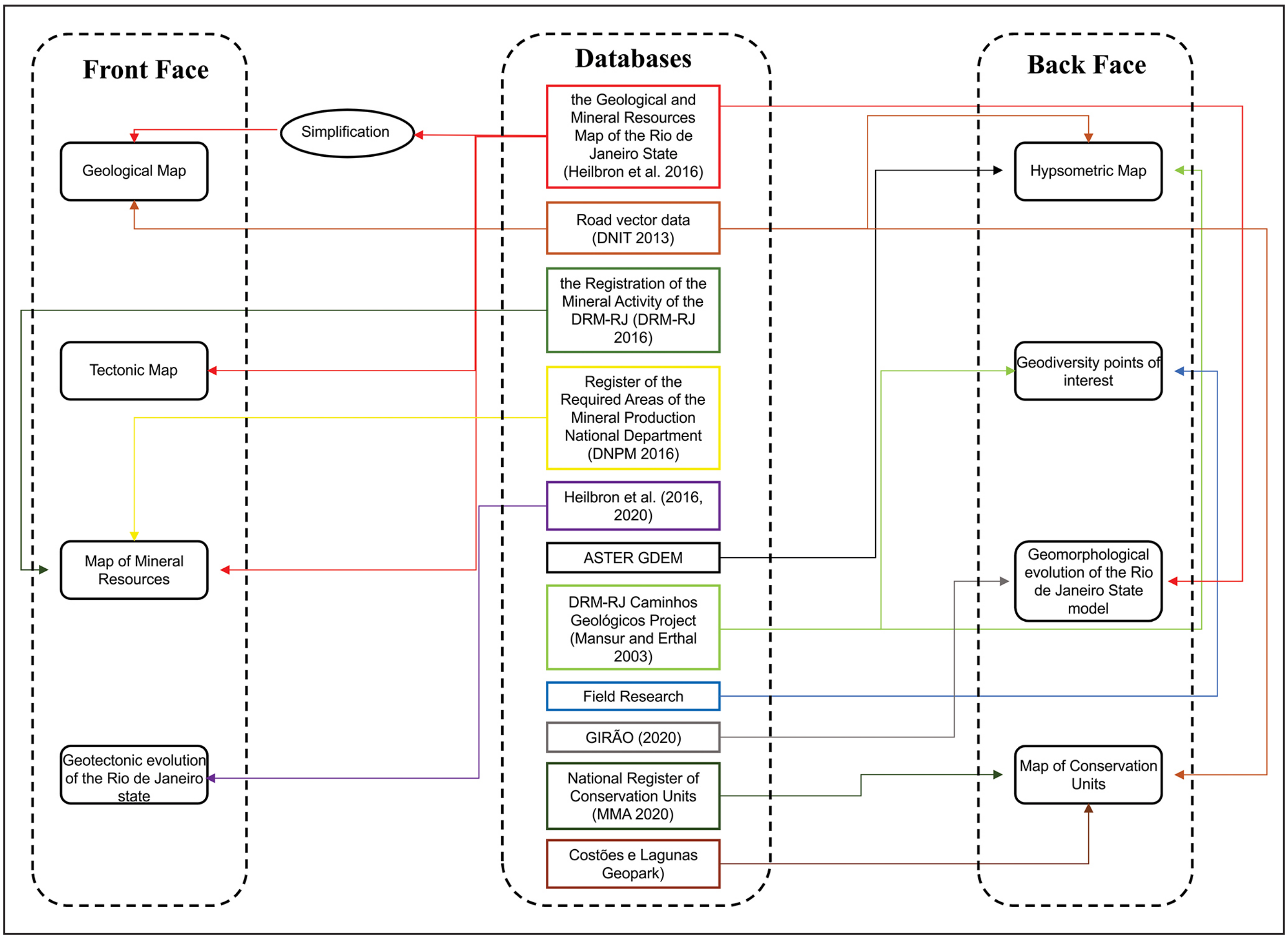

FIGURE 1. Flowchart with the database and products developed for the Geological highway map of the Rio de Janeiro State.

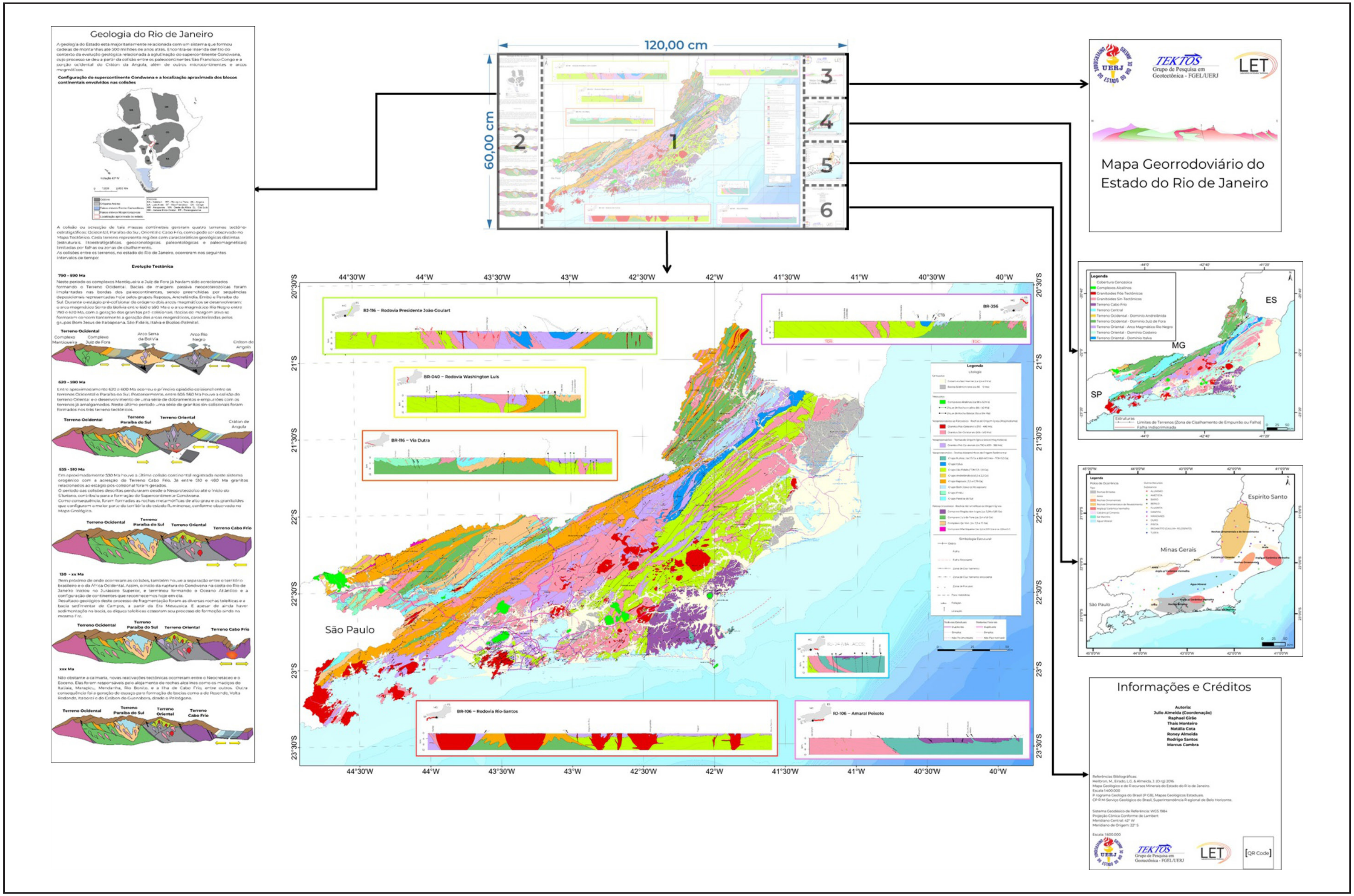

FIGURE 2. Front face of the Geologic Highway Map of Rio de Janeiro State.

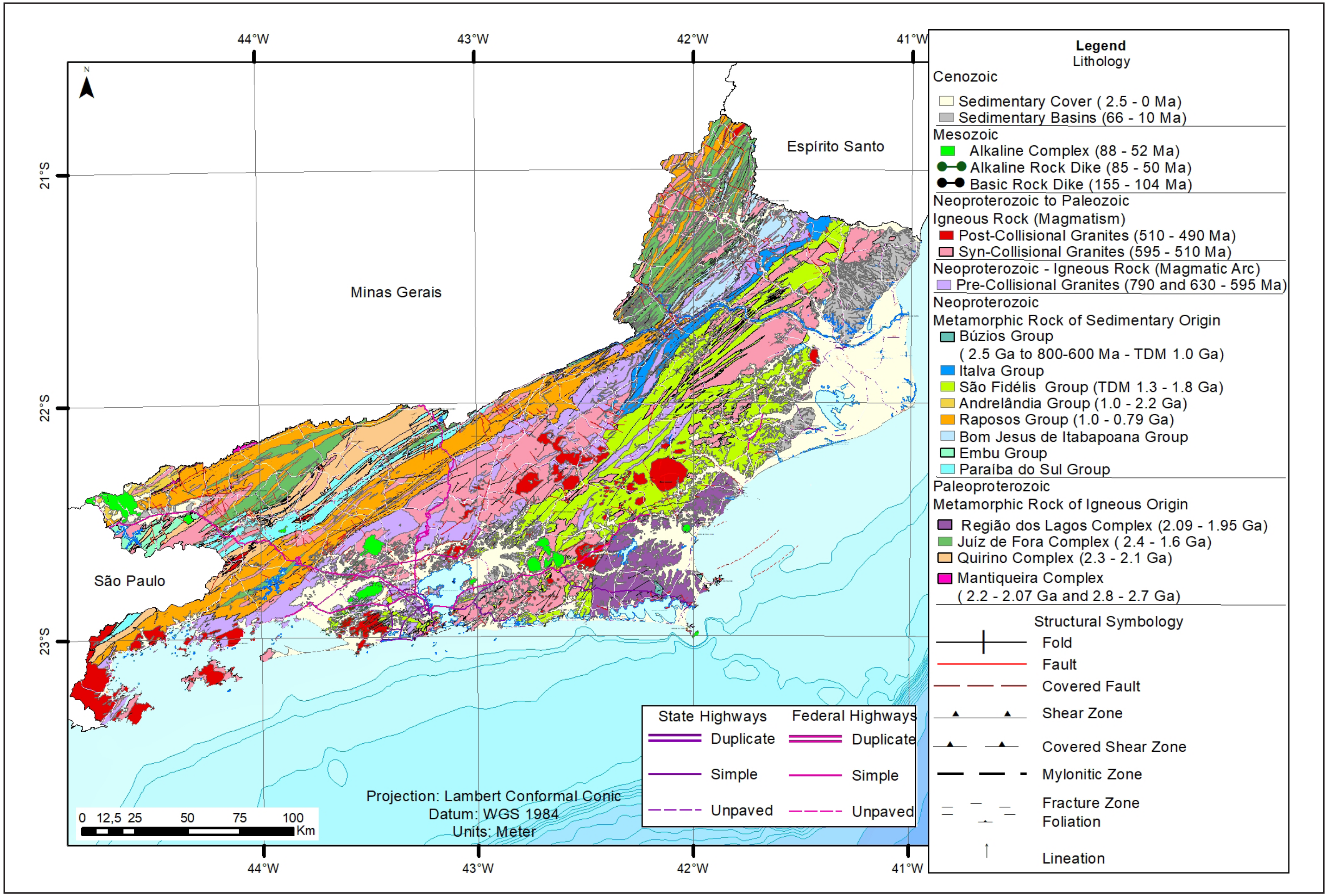

FIGURE 3. Geological Map of Rio de Janeiro.

State (Heilbron et al. 2016). This map shows the tectono-stratigraphic terranes that make up the Ribeira Orogenic Belt, the granites of the sin and post tectonic magmatic events, the intrusive alkaline rocks, and the Cenozoic sedimentary cover.

The map of mineral resources was prepared on a scale of 1: 3,500,000 (Figure 5) from the compilation of three data sources: the Geological and Mineral Resources Map of the Rio de Janeiro State (Heilbron et al. 2016), the Registration of the Mineral Activity of the DRM-RJ (DRM-RJ 2016) and the Register of the Required Areas of the Mineral Production National Department (DNPM 2016). Based on these data, areas were identified where the main mineral resources are exploited, such as mineral water, ornamental rocks, sand and clay. The map also shows the most significant mineral occurrences for the state of Rio de Janeiro.

The geotectonic evolution of the Rio de Janeiro State is presented in stages over geological time accompanied by schematic models (Figure 6), based on Heilbron et al. (2016, 2020), which integrates data collected from geological surveys for more than thirty years.

4. Back Face: Geomorphology, Geodiversity points of interest; Conservation Units

The back face of GHMRJ has four thematic sections (Figure 7): (1) hypsometric map; (2) geodiversity points of interest; (3) geomorphological evolution; and (4) map of conservation units.

The hypsometric map was created on a 1:800,000 scale using the digital elevation model (DEM) ASTER GDEM, which has a spatial resolution of 1 arc-second and is associated with the geoid model EGM96. Road vector data (DNIT 2013) were also used, updated with the recent changes in the road network and the stations of geological interest of the DRM-RJ Caminhos Geológicos Project (Mansur and Erthal 2003).

By showing the different colors of the altimetric classes, the map offers the perception of the geomorphological compartmentation of the state that is criss-crossed by the state and federal highways, representative of the relief units of mountains, hills and plains. Figure 8 shows a simplified version of the hypsometric map present in GHMRJ.

Field research was carried out to select the points of interest for geodiversity on the major highways in the state: BR-101, BR-040, BR-116, RJ-116, RJ-124, RJ-106 and BR-356. The stations of geological interest of the DRM-RJ Caminhos Geológicos Project (Mansur and Erthal 2003) were used as an initial basis and, in field research, the points of interest were selected considering the following criteria: scientific value, educational value, touristic value, access facilities for visitors and minimum structure for visitors to stay in the place safely. Some points of interest not belonging to the DRM-RJ Caminhos Geológicos Project (Mansur and Erthal 2003) were also included because, during field research, they were found to be of great relevance.

Figure 9 shows an example of one of these points. In addition to the photo and a description of aspects of its geodiversity, there is also information about its location and how to stop at such location.

The geomorphological evolution of the Rio de Janeiro State deals with the geological and geomorphological events that gave rise to the current Rio de Janeiro relief (Figure 10). Three-dimensional models illustrate four

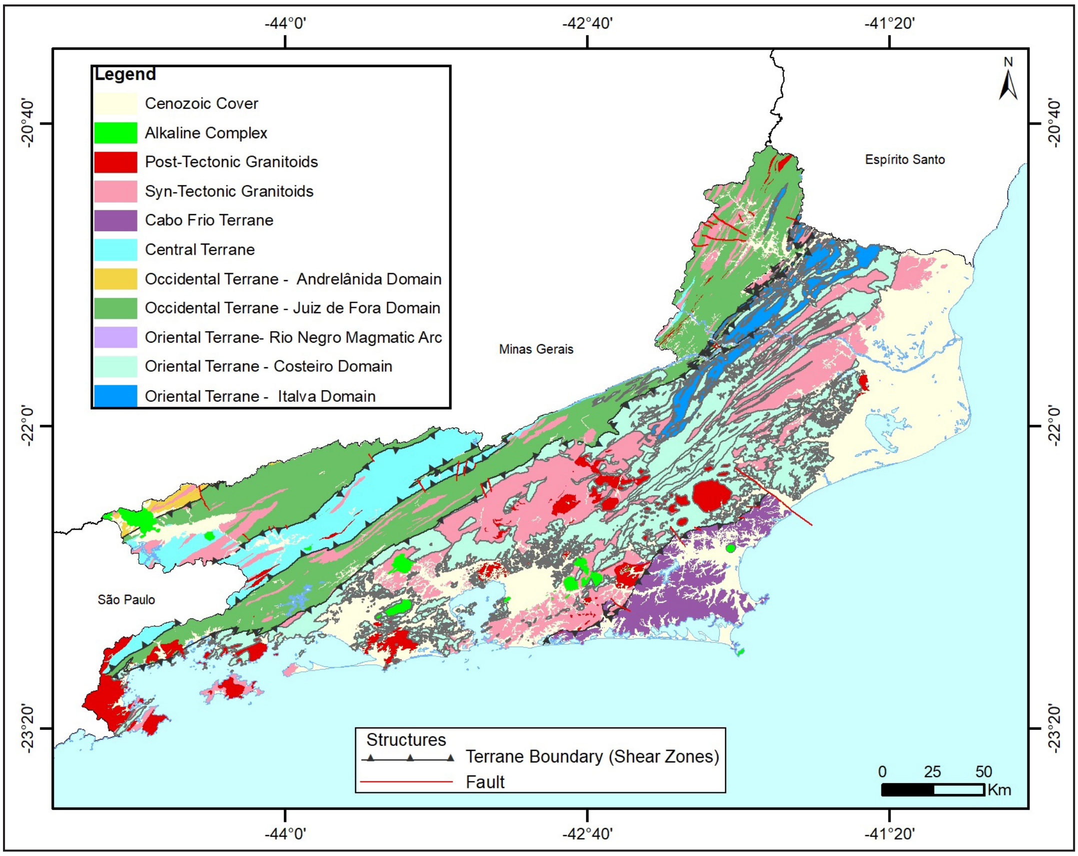

FIGURE 4. Tectonic map of Rio de Janeiro.

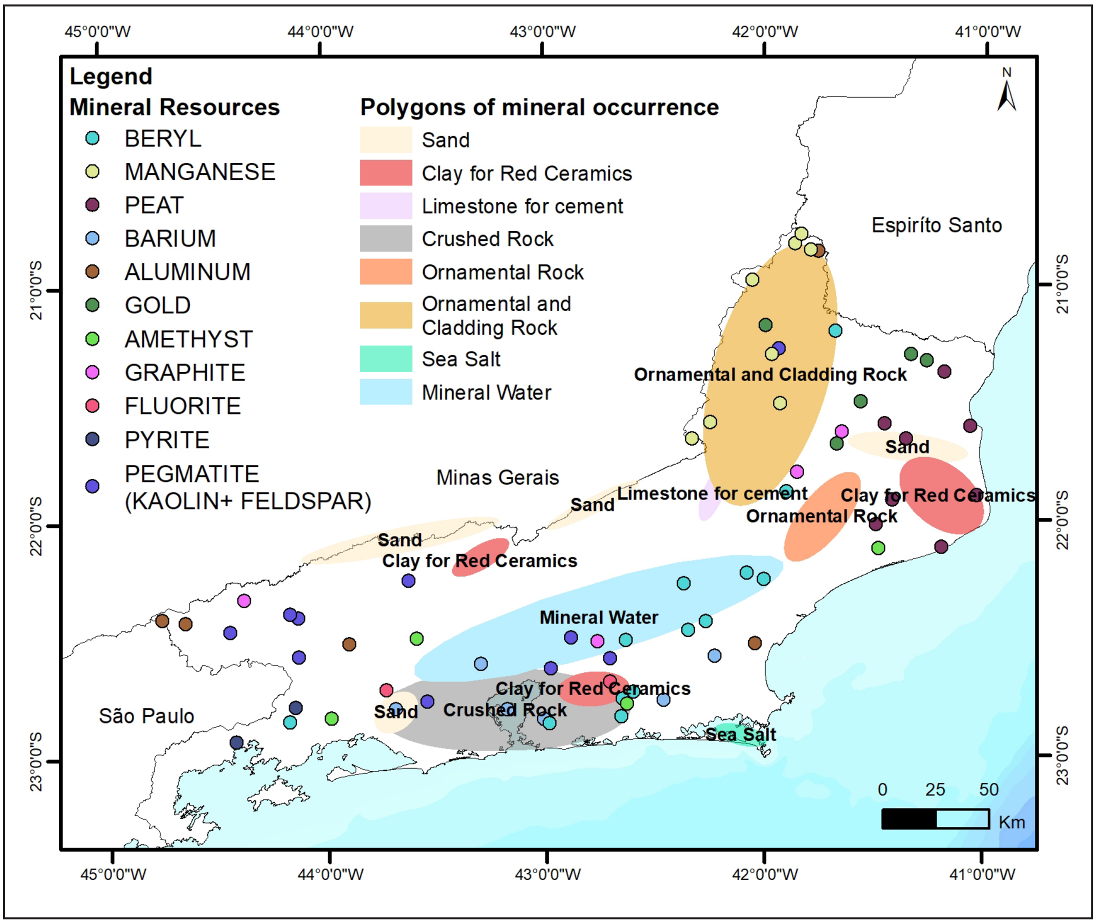

FIGURE 5. Map of Mineral Resources of the State of Rio de Janeiro.

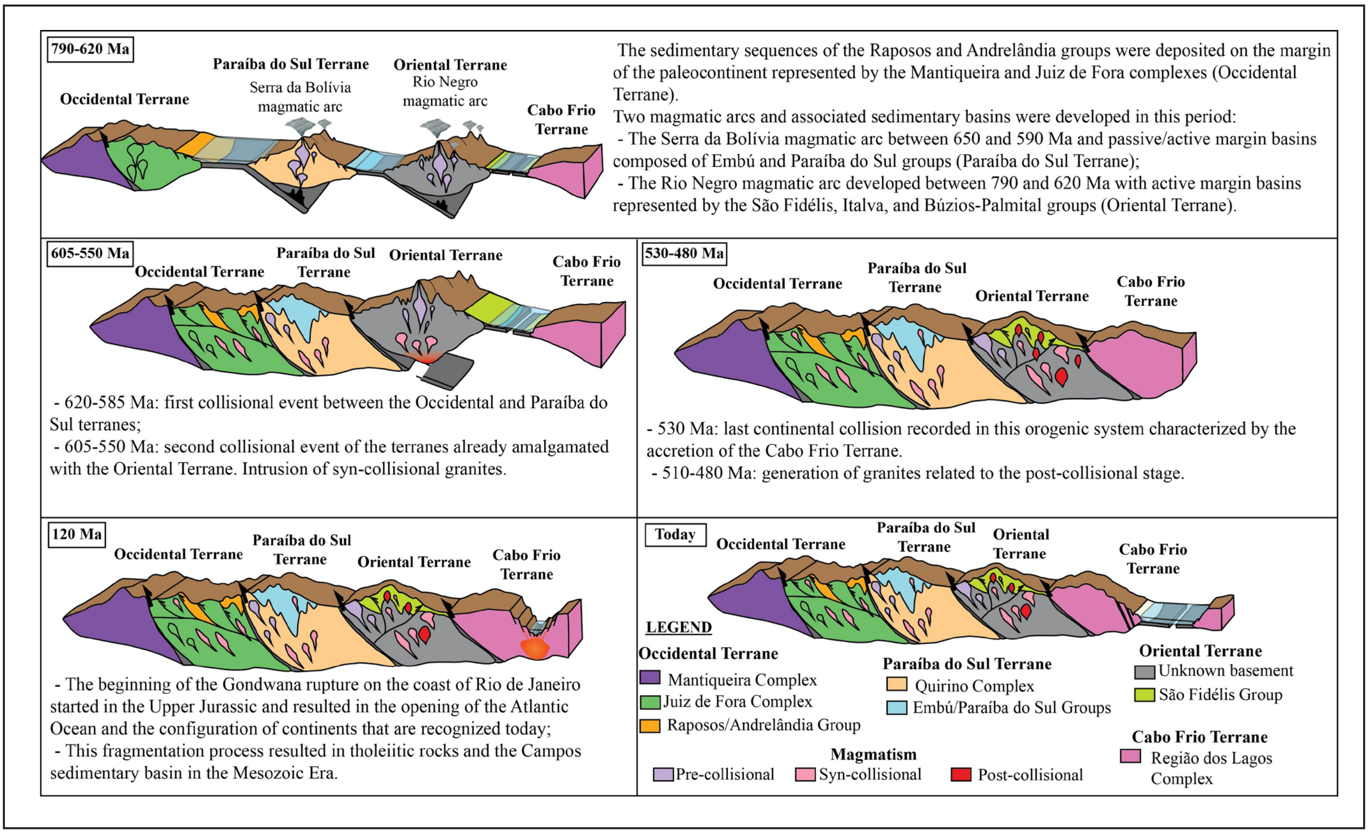

FIGURE 6. Geotectonic evolution of the Rio de Janeiro state..

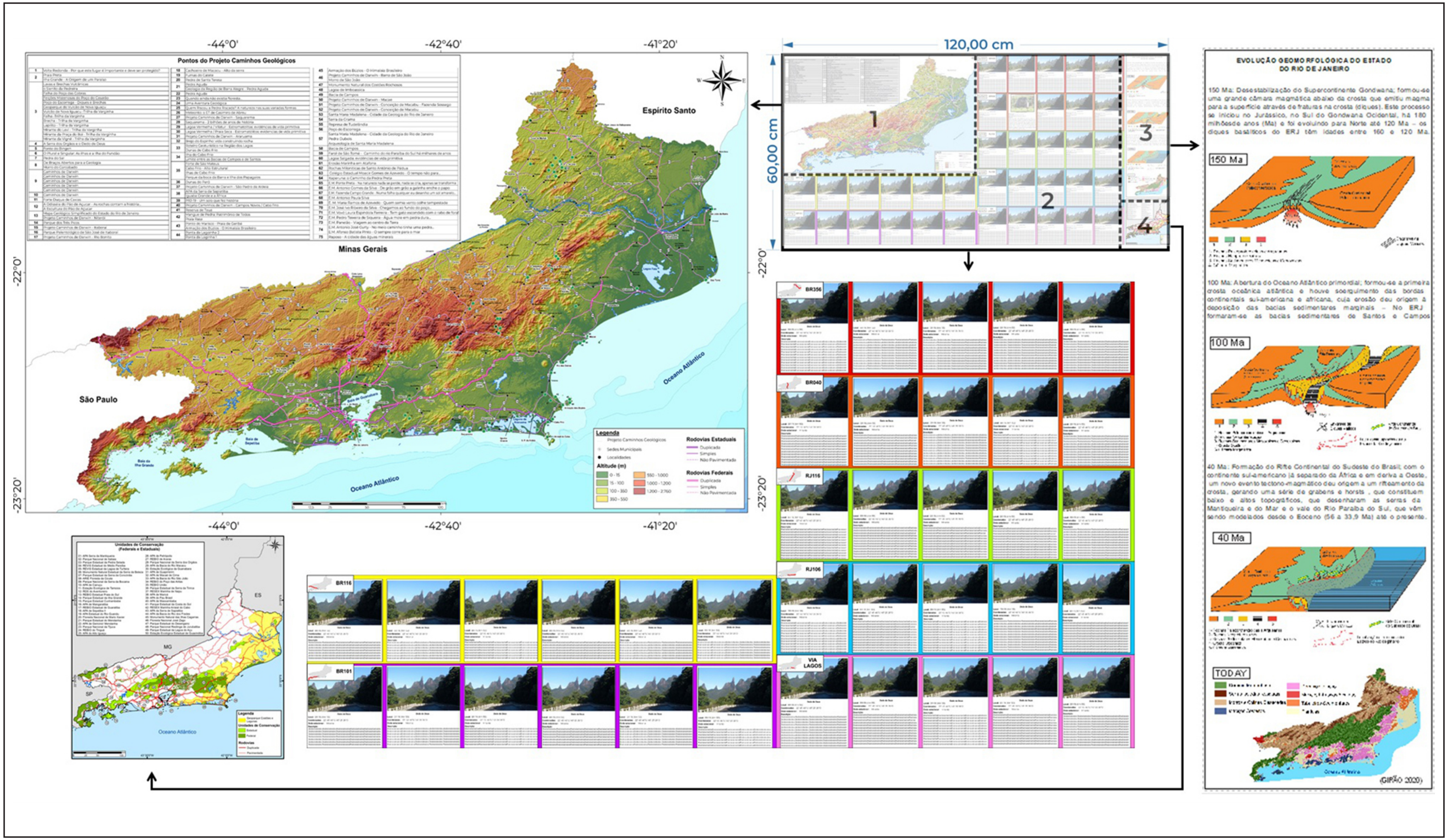

FIGURE 7. Back face of Geologic Highway Map of Rio de Janeiro State.

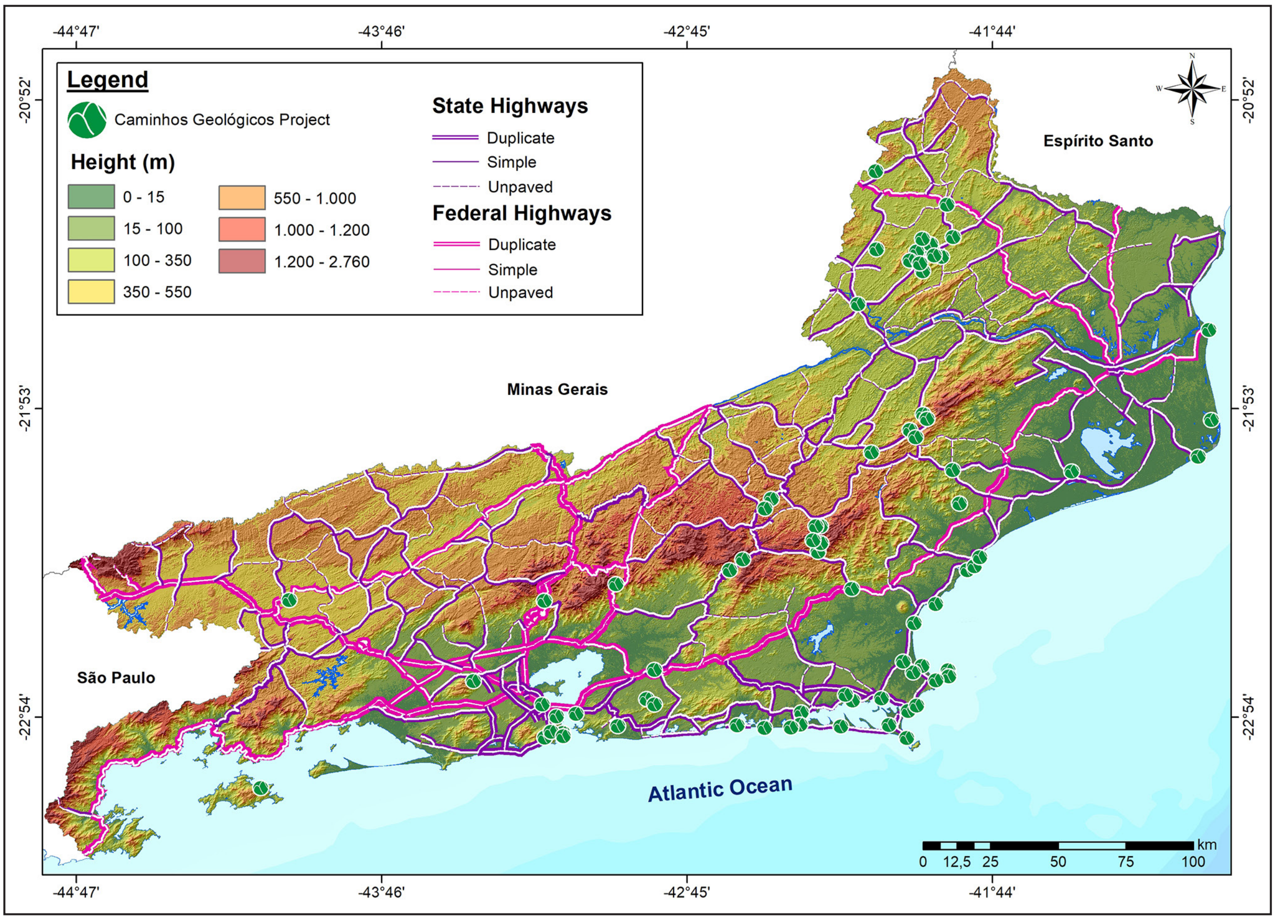

FIGURE 8. Hypsometric Map of Rio de Janeiro.

FIGURE 9. Example of geodiversity points of interest.
Caieira São Joaquim.
Site: BR-356 highway. Coordinates: 21°24'09"S; 41°41'24"W.
Where to park: Highway shoulder.
Description: "Caieiras" are ovens for the production of lime (lime kiln). In 1940, A.R. Lamego mentioned the existence of fourteen of these ovens in the Muriaé River valley, close to Fazenda São Joaquim (São Joaquim farm), where thick layers of marble emerge. The furnace shown in the photo was dug into the side of the hill and its walls were raised with blocks of local gneiss. Filled with crushed limestone ($CaCO_3$), the burning took five days and eight more days for cooling (Lamego 1940). The product removed was lime (CaO), used in the local construction and in the sugar mills of the Baixada Campista region. Currently, limestone is no longer calcined, being ground and used in the cement industry.

stages of the relief evolution of the region, where the state of Rio de Janeiro is located today, and which also configured the Brazilian southeastern continental margin, the contours of the current Brazilian coast, as well as marginal sedimentary basins, rich in mineral and energy resources and the Atlantic Ocean itself. The models also show how the drainage network has evolved, especially the Paraíba do Sul River and its tributaries, in addition to the contours of the highlands of the Mar and Mantiqueira ridges and coastal plains and lagoons.

The map of conservation units (Figure 11) was designed on a 1: 3,500,000 scale using vector data from state and federal conservation units, collected from the National Register of Conservation Units (Brasil 2020), and from state and federal highways. (DNIT 2013). It has been updated with the recent changes in the road network. In addition, the limits of the proposal of the Costões and Lagunas Geopark were included (Mansur et al. 2012).

5. Final Remarks

In its proposition, GHMRJ presents updated information on the geology of Rio de Janeiro offered for optimal use of the enormous geotouristic potential of the state. Users of the GHMRJ, when traveling along the main highways in the state of Rio de Janeiro, will be able to take advantage of knowledge of the geodiversity of Rio de Janeiro. In places with greater geotouristic potential, carefully selected points of interest contain information about their geological, geomorphological, hydrological, and mineral resource aspects.

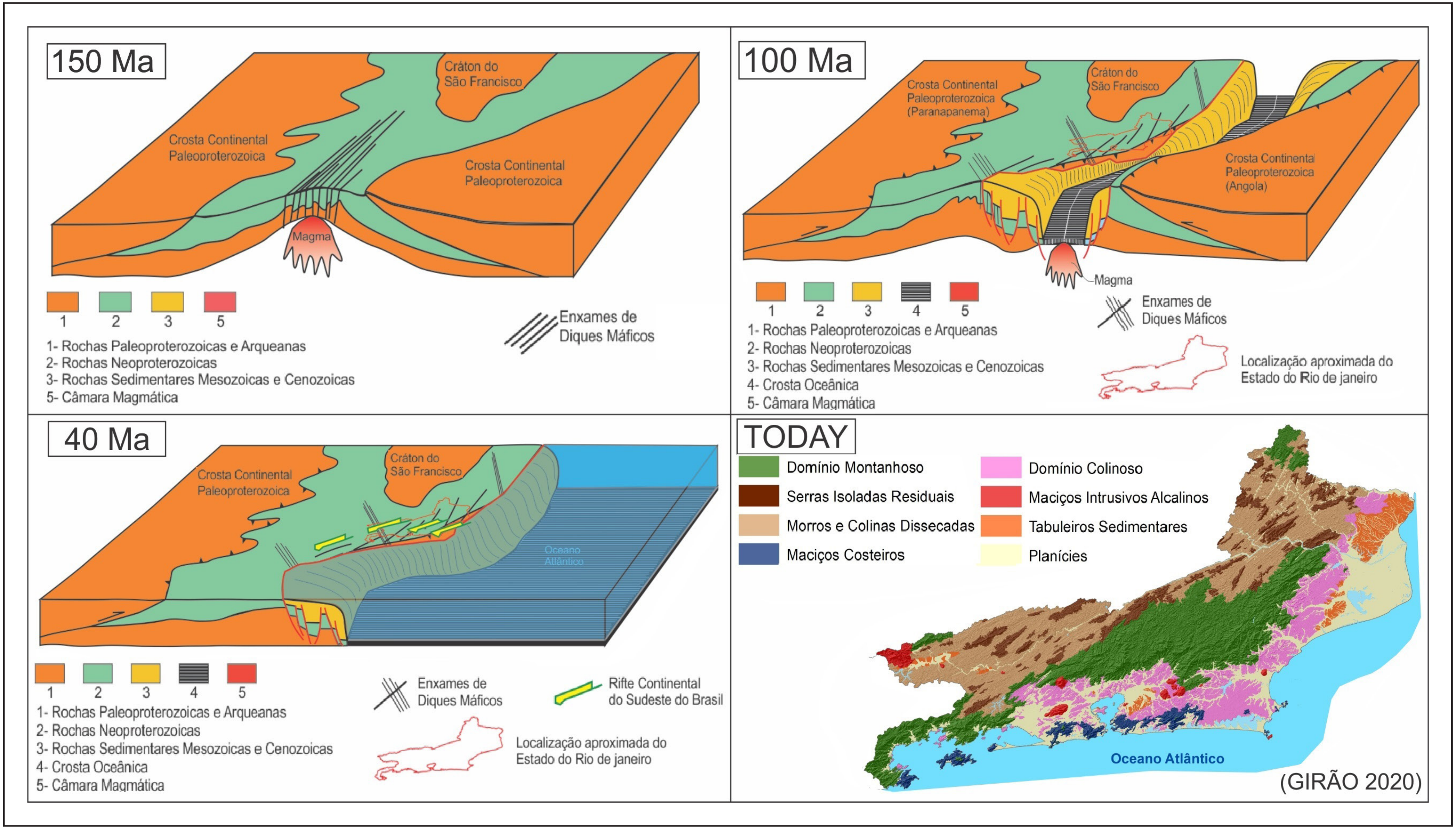

FIGURE 10. Geomorphological evolution of the Rio de Janeiro State model.

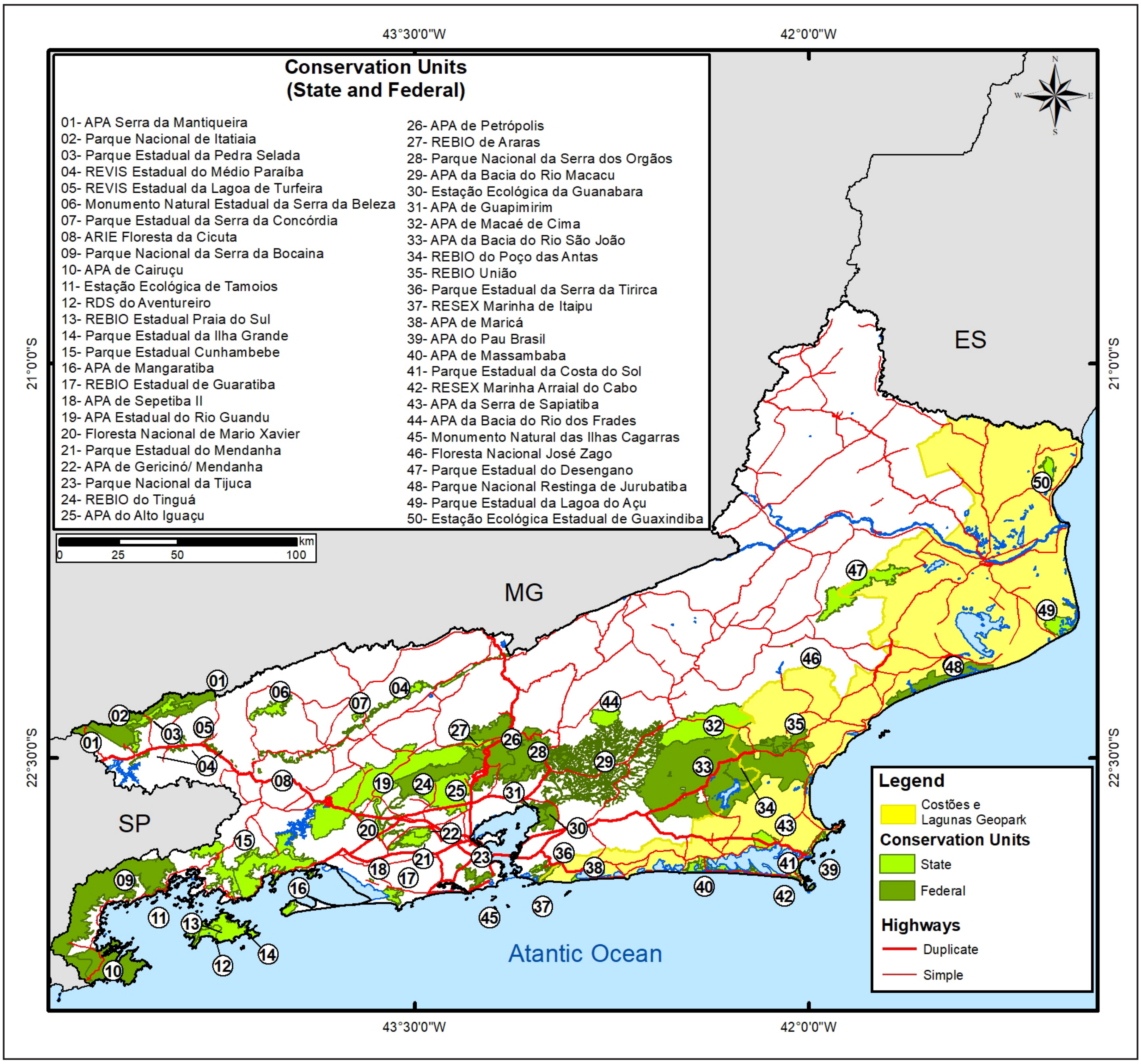

FIGURE 11. Map of Conservation Units of Rio de Janeiro

GHMRJ is an unprecedented initiative in Brazil. It can be adopted as a means of propagating geodiversity and encouraging geo tourism. It can be considered as new way of publicizing geotourism, bringing geoconservation of Rio de Janeiro's geodiversity into the spotlight. Moreover, it can be adopted in conservation and environmental preservation projects.

Acknowledgements

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The opinion of divers on the interpretation of marine geology in the archipelago of Fernando de Noronha, Brazil

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Abstract

Environmental interpretation seeks to reveal meanings to provoke personal connections between the public and the protected heritage. In the specific case of geological heritage, it determines and communicates the meaning of a geological and geomorphological phenomenon, event or location. There is a range of nature tourism activities that can promote interpretation of this heritage. The practice of properly organized scuba diving can bring benefits both to conservation of the environment and to local communities. Fernando de Noronha is one of the best dive sites in Brazil and actions focused on aspects of marine geology add even more value to the activity. In this sense, we sought to investigate the opinion of divers about environmental interpretation and aspects of marine geology in the archipelago by applying a questionnaire. The questionnaire was applied online between April 2018 and May 2019, with 100 individuals who had practiced scuba diving in the archipelago at least once. Different data collection techniques were applied (convenience, purposive sampling, quota and snowball). The main results indicate that information on marine geology is relevant for the scuba diving activity, and this type of action can contribute to a more conscious attitude towards island sustainability.

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1. Introduction

The Fernando de Noronha archipelago is located in the South Atlantic Ocean, 345 km off the Brazilian coast. With a unique geological heritage, this territory highlights part of the geological history of oceanic islands of volcanic origin. Studies and actions are being carried out to recognize the area as a UNESCO Global Geopark (Wildner and Ferreira 2012, Moreira 2008, Vale 2017). In 2013, the Geopark Project Working Group was formed. Wildner and Ferreira (2012) identified 26 geosites in an inventory of the archipelago's geological heritage. This study, however, did not consider marine geosites, which were later suggested by Moreira and Silva Jr. (2016).

Moreira and Silva Jr. (2013) also collected information on the marine geology and geomorphology of diving sites, in a study on underwater trails aimed at interpretation. There is still little interpretation of aspects of marine geodiversity. In Brazil, this type of study is virtually non-existent, which shows the lack of initiatives in the field of teaching and dissemination of geoscientific information.

Environmental interpretation can be understood as "the set of communication strategies aimed at revealing the meanings of environmental, historical and cultural resources in order to provoke personal connections between the public and the protected heritage" (Caetano et al. 2018). Hose (2012, p.17) defined geo-interpretation as "the art or science of determining and then communicating the meaning or significance of a geological or geomorphological phenomenon, event or location." When considering environmental interpretation as a fundamental aspect for understanding the landscape, the objective of this research was to identify the perceptions of the visitors who scuba-dived in Fernando de Noronha, of aspects of interpretation of geodiversity.

2. Materials and methods

Data were collected using a structured questionnaire containing 13 closed-ended and multiple-choice questions. The first part of the questionnaire consists of questions about the profile of the visitors while the second part focuses on interpretation of aspects of geodiversity.

The survey was applied through the Google Forms online platform between April 2018 and May 2019. A total of 100 valid questionnaires were collected. Sampling was non-

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probabilistic and data collection techniques were based on quota, convenience, purposive sampling, and snowball. Thus, three steps were followed:

1. The first stage was the adoption of the quota technique, which, according to Mason (2002), defines categories and the minimum number of cases required for each category. Thus, people who had scuba-dived in Fernando de Noronha at least once were selected and distributed equally into groups of men and women.

2. In the second stage, techniques for convenience and judgment were adopted, with respondents who were accessible and willing to participate in the study, based on their qualities (Etikan et al. 2016). The form was targeted towards divers, according to previous knowledge on the activity in the archipelago, and sent online to diving groups.

3. In the final stage, the snowball technique was adopted. “A sampling procedure may be defined as snowball sampling when the researcher accesses informants through contact information that is provided by other informants” (Noy 2013, p. 330). It was more likely that interviewees knew other members who had visited volcanic areas; therefore, this technique made it possible to expand the sample.

This study used a mixed method of analysis in order to “answer research questions that address the relationships between variables” (Sandelowski et al. 2009). A descriptive statistical analysis was carried out to quantify the qualitative questions of the study.

3. Geodiversity

Geodiversity can be understood as the abiotic part of nature. It was conceptualized by Gray (2013) as the abiotic equivalent of biodiversity, which includes rocks, minerals, fossils, landscapes, topography, and physical processes.

3.1 Geodiversity in Fernando de Noronha

The origin of the Fernando de Noronha archipelago is related to successive volcanic eruptions resulting from the separation of the African and South American continents, which originated the Atlantic Ocean. The passage of the South American plate through a hotspot may have been the reason for the emergence of the archipelago (Wildner and Ferreira 2012). The volcanic events that gave rise to the islands began about 12 million years ago. The base of the volcanic mountain that houses the archipelago is 74 km in diameter and 4,000 m in depth, and it is located in the fracture zone of Fernando de Noronha (Almeida 1958, 2006).

According to Almeida (1958), the archipelago has volcanic and sub-volcanic subsaturated rocks, especially sodium-alkaline ones. The geological structure has rocks dating from the Quaternary, Upper and Lower Pliocene and Upper Miocene periods. Almeida (1958) identified distinct rock formations, e.g., Remédios, Quixaba, São José and Caracas. There are controversies about the São José Formation, as recent studies indicate that the rocks found in this formation are part of the Remédios Formation (Perlingeiro et al. 2013, Lopes and Ulbrich 2015).

The topography is related to the nature and geological history of the rocks. The main island has an irregular outline with recesses and protrusions and wavy surfaces. At 323 meters, Morro do Pico is the highest point of the archipelago (Teixeira et al. 2003).

The morphological composition is divided into eight units: hills, plateaus, low plateaus, slopes, beaches, dune fields, mangroves, and rocks (Wildner and Ferreira 2012).

The sand on the beaches is different from that of the continent, as it does not have quartz-rich rocks; rather, it is formed by bioclastic materials such as shells, remains of marine animals, and rock fragments (Teixeira et al. 2003).

Most of the soils are young and shallow, and were influenced by the generalized phosphatization of birds that led to the formation of a Latosol. This unusual soil is sandy, and is composed of bioclastic and carbonate material in dunes and emerged marine platforms (Schaefer et al. 2017, Silveira et al. 2020).

The Geological Survey of Brazil – CPRM carried out a technical study that supports the creation of the Fernando de Noronha Geopark, recognizing its importance for geoconservation. A total of 26 geosites of scientific, educational and tourist importance have been identified, 8 of which are of international relevance (Wildner and Ferreira 2012).

It can be said that Fernando de Noronha's international relevance is due to the fact that the islands represent a unique example of volcanic oceanic islands west of the Mesoatlantic Dorsal Volcanic Mountain Range, associated with tectonic structures (e.g., transforming faults) of the MAR (Middle Atlantic Region) itself (Vale 2017).

Fernando de Noronha is the top of an underwater volcano and represents the last volcanic events that occurred in Brazil. Wildner and Ferreira (2012) pointed out that one can directly observe rocks from the Earth’s mantle with xenoliths.

4. Scuba diving

Diving is a practice that has occurred since the dawn of humanity as a strategy for obtaining food (Cousteau 1979). Since the 1930s, equipment has improved to enable longer submersion time (Cunha 2018). With this technological advance, the practice of diving tourism began to occur more frequently as of the 1950s (Musa and Dimmock 2013).

According to the Professional Association of Diving Instructors (PADI, 2020), there are three types of diving:

- Discover scuba diving: known in Brazil as ‘baptism’, this modality introduces people to scuba diving under supervision. Participants learn the basic concepts of safety and the correct use of equipment to swim underwater under the supervision of a professional.
- Accredited diving: in this modality, the person who has already completed the course and has a diving certification contacts a diving operator who takes them to the place to be visited. Before starting the dive, information is passed on (briefing) by a local diving guide and, during the activity, this professional draws a route to be followed in order to ensure the safety of divers. For the Open Water Diver certification, maximum depth is 18 meters, while for Advanced Open Water Diver, it is 40 meters.
- Course: courses are based on progressive training that includes diving skills, equipment handling, safety procedures and knowledge of the underwater environment.

The tourist dive is performed on a trip away from the diver's place of residence. This trip can be planned specifically for scuba diving, or the activity can be done at the destination (Musa and Dimmock 2013). With the growing demand of practitioners of the activity, regulations are required for conservation of the marine environment and diver safety. Discussions on the impact on biodiversity are common; however, when it comes to marine geodiversity, the topic remains little debated.

Burek et al. (2013) and Gordon et al. (2016) highlighted the work on marine geoconservation being done in the United Kingdom. Regarding geoparks, there are few initiatives that mention marine geosites, and two examples are the Azores Geopark (Portugal) (Lima et al. 2018) and the Lanzarote and Chinijo Islands UNESCO Global Geopark, in the Canary Islands (Spain) (Galindo et al. 2019).

Diving in Conservation Units must follow ICMBio guidelines. The Normative Instruction of April 24, 2020 states the procedures for carrying out the activity. According to article 4, scuba diving, free diving or floating can be considered as an activity for educational purposes, and the operator can develop informative and interpretive activities on the natural and cultural environment being visited (Brasil 2020). For Moreira and Silva Jr. (2013), the training of operators who conduct underwater trails should include elements of geodiversity.

Human activities have the potential to impact both geomorphological and geological features on the seabed. (Gordon and Barron 2012). In scuba diving, divers try to minimize the impact of the activity; however, inexperienced people may negatively affect geodiversity owing to the lack of buoyancy control, and may touch and damage rock formations.

4.1 Scuba diving in Fernando de Noronha

Fernando de Noronha has 25 diving sites, four in the Environmental Protection Area of Fernando de Noronha - São Pedro and São Paulo (APA) and twenty-one in the Fernando de Noronha National Marine Park (PARNAMAR) (Figure 1).

The following sites are located in the Park area: Ilha do Meio (Figure 2A), Ressurreta, Cagarras Rasa, Cagarras Fundas, Buraco do Inferno, Cordilheira, Cordas, Pontal do Norte, Macaxeira, Buraco das Cabras, Cabritos, Caieiras (Figure 2B), Pedras Secas, (Figures 2C and 2D), Frade, Trinta Réis, Cabeço Submarino, Iuias, Navio do Leão, Capim Açu, Cabeço da Sapata (Figure 2E) and Caverna da Sapata (Figure 2E). In the APA area are Corveta Ipiranga - V 17 (Figure 2F), Laje Dois Irmãos, Cabeço Dois Irmãos and Naufrágio do Porto. The modalities offered by four companies are baptism, accredited diving and courses.

For Teixeira et al. (2003), what makes Fernando de Noronha one of the best diving sites in Brazil are the convenience and the ease of observing biodiversity, whether waist deep in water or at a depth of a hundred meters. The underwater landscape, with

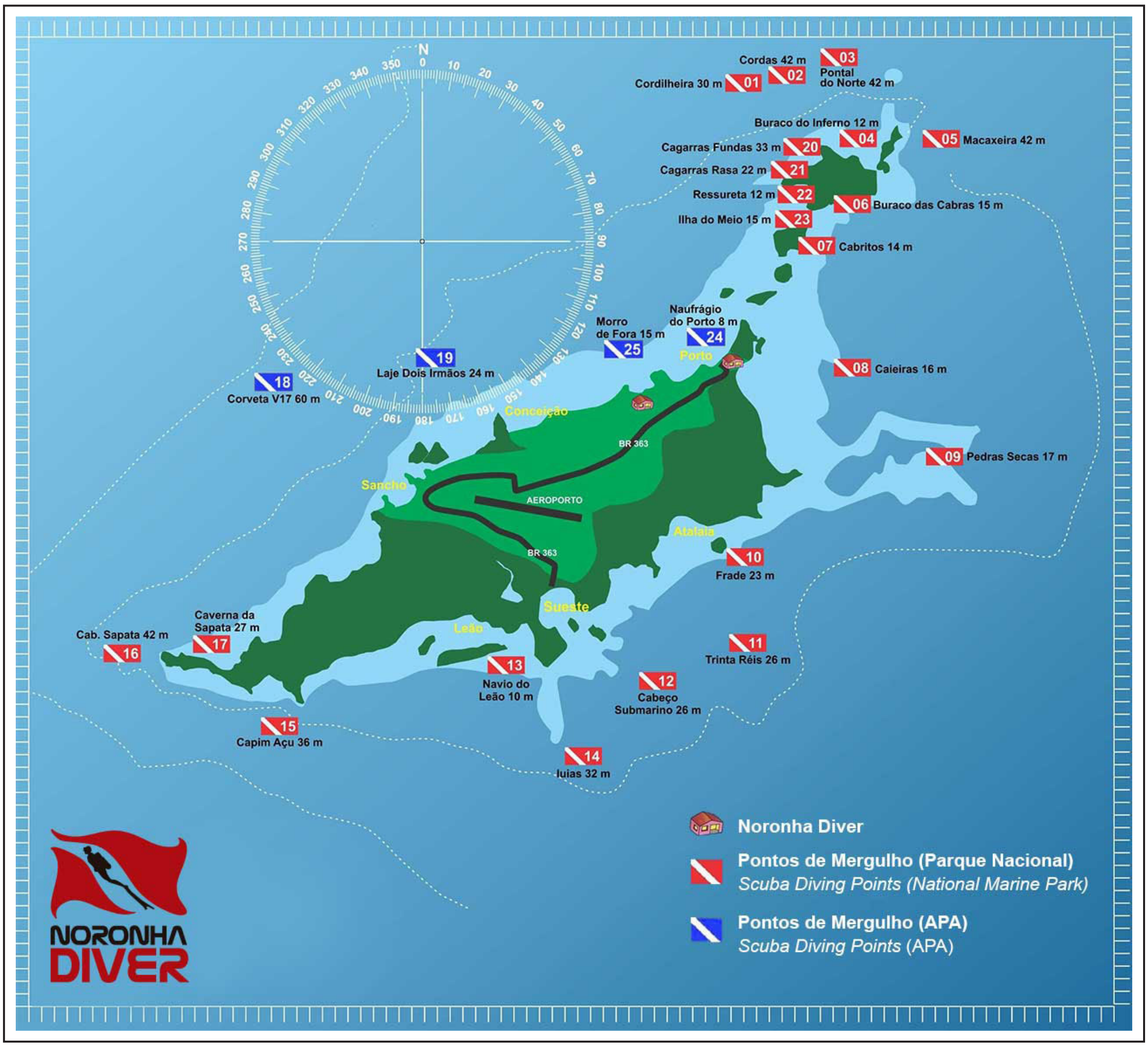

FIGURE 1. Diving sites in the Fernando de Noronha National Marine Park (PARNAMAR), and Environmental Protection Area of Fernando de Noronha - São Pedro and São Paulo (APA) (Source: http://www.noronhadiver.com.br/).

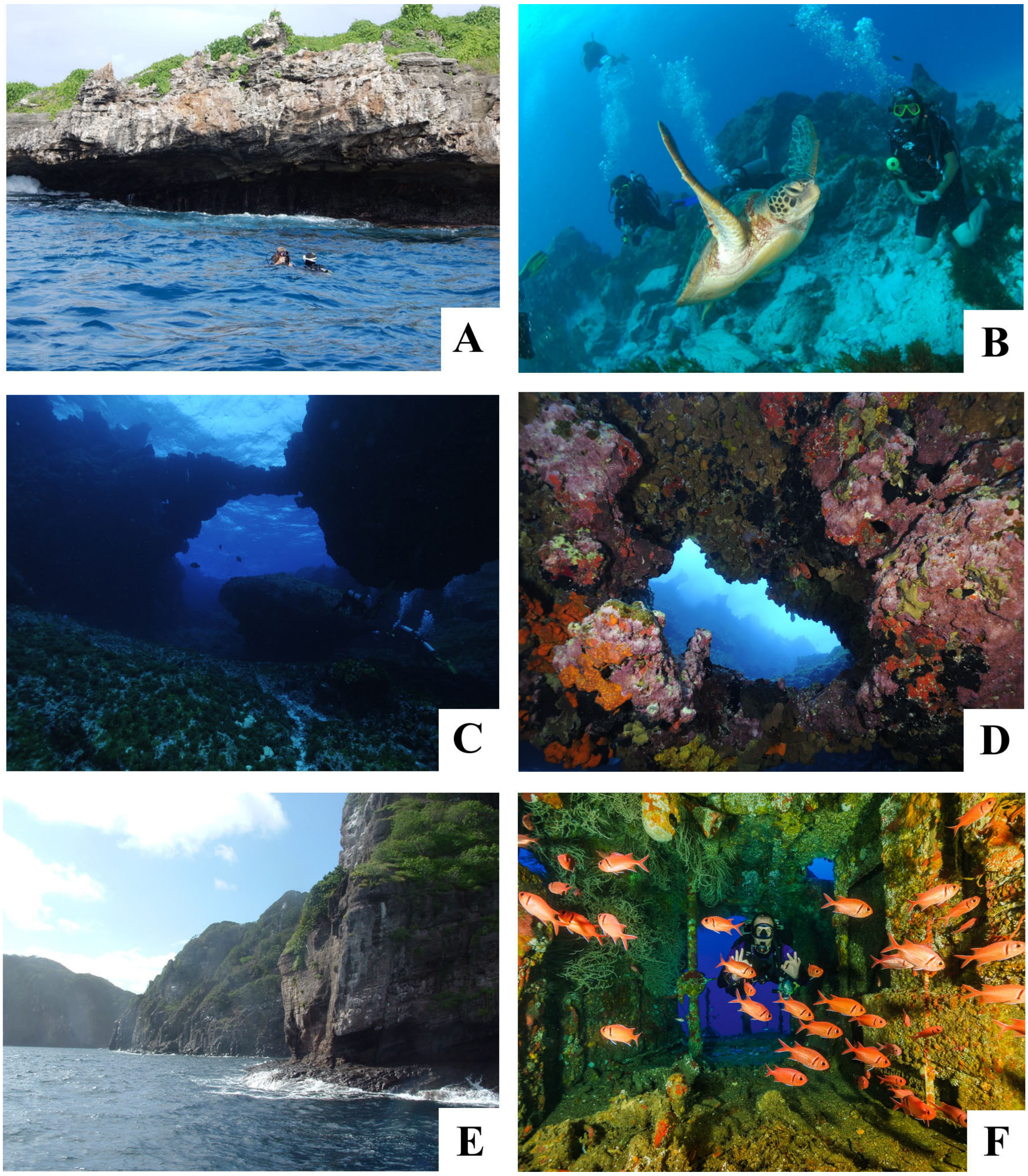

FIGURE 2. Diving sites in the Fernando de Noronha archipelago. (A) The Caracas sandstone, near Ilha do Meio. (B) Caieiras is composed of pyroclastic rocks. (C and D) Pedras Secas is considered as one of the best diving sites in Fernando de Noronha. (E) Caverna da Sapata area, where the diving boats stay anchored. (F) Corveta Ipiranga – V 17 is a shipwreck and has rich marine life. Sources: 2A, Tatiane Ferrari do Vale (2016); 2B, Jasmine Cardozo Moreira (2010); 2C and 2D, Marcos Tanner de Abreu (2019); 2E, Jasmine Cardozo Moreira (2007); 2F, Augusto Mano (2019).

emphasis on the geological formations, can be as attractive as the aspects of biodiversity if it is properly interpreted.

The APA Management Plan presents the necessary procedures for performing scuba diving activities. There is no specific mention of marine geology, however, as the document intends “to disseminate scientific knowledge about fauna, flora and geology, among other topics researched, with the valorization of local knowledge.” (ICMBIO 2017).

The Study of Carrying Capacity and Operationalization of Nautical Tourism Activities of the National Marine Park of Fernando de Noronha, carried out by Luiz Jr. (2009), analyzed how the activity can cause damage to the marine environment. The author considers that “the intervention of the diving guide is one of the most effective strategies for reducing the physical impact of divers with reefs”. In other words, it is essential to train these guides, who can explain the importance of these places, as they are the ones who monitor and provide instruction on the activity.

Teixeira et al. (2003) reported data on dive sites in the archipelago; however, they do not characterize the geology and geomorphology of these sites. Moreira and Silva Jr. (2013) collected geological and geomorphological information at 21 dive sites in Fernando de Noronha to assist in the environmental interpretation of these aspects, as it had been found that the operators only passed on information about the local biodiversity.

These dive sites were considered to be geosites by Moreira and Silva Jr. (2013) and their characteristics are shown in Table 1, with their Geological Formation (Quixaba, Remédios or Caracas) and the type of the dive that can be done (baptism or advanced).

Sea turtles, spinner dolphins, sharks, rays and fish can be seen in the sea. In addition to rich biodiversity, visitors who do scuba diving get to know a unique environment, with shipwrecks, caves, and marine canyons.

During night dives, animals sighted during the day are resting, and the marine fauna is different. In this type of diving, aspects of geodiversity can be hardly observed, since light is limited and divers only have the range of the light beams from the lanterns.

The Fernando de Noronha archipelago has ample potential to attract divers for the reasons listed by Davis and Tisdell (1995): interest in marine ecology or other characteristics of the submerged environment, such as geology and archeology; the search for experiences close to nature; or for the feeling of adventure and excitement.

An alternative that can help people gain knowledge of Fernando de Noronha's geodiversity and marine geosites is Google Street View, which has mapped the archipelago. Through 360º images, it allows anyone with internet access to get to know it. In addition to the images, there is also some information about each location.

5. Results

In this study, 100 people who had performed the dive in Fernando de Noronha at least once were interviewed. Of the 100 respondents, 50% were female and 50% were male. Regarding age groups, most of them were aged between 26 and 35 years old (51%), followed by 36-45 years old (22%), 18-25 years old (17%), and 46-55 years old (10%). As for level of education, they have postgraduate studies (46%), complete higher education (27%), incomplete higher education (13%), and a high school diploma (5%).

Regarding origin, 98% are Brazilian, from Pernambuco (22%), Paraná (21%), São Paulo (14%), Rio de Janeiro (11%), Minas Gerais (6%), Rio Grande do Norte (5 %), Santa Catarina (5%), and Bahia (4%), with the others add up to 9%. The origin of one of the respondents could not be detected. The foreign participants accounted for 2% and came from the countries of El Salvador and Portugal.

Of the visitors who did scuba diving, 44% practiced it more than 8 times, while 23% from 1 to 4 times, 23% only once (baptism) and 10%, 5 to 8 times. (Figure 3A). As for the year of the first dive, most were done in 2018, 2016, 2015 and 2013.

The main motivation for carrying out the activity was recreation, tourism and/or adventure (73%), followed by science, study and/or research (17%), work (7%) and other activities (3%) (Figure 3B).

Of the respondents, 83% said they had received information about marine flora and fauna, 30% about marine geology, 11% had not received any information and 5% could not remember if they had (Figure 3C). Regarding this issue, 85,7% of those who said they had received some type of information indicated that this was easily identified during the activity, while 14,3% said it was not (n = 91) (Figure 3D).

Divers were asked if they felt any information was lacking, and 26% indicated marine fauna and flora, 60% marine geology, while 11% reported not having missed any specific information (Figure 3E). Regarding the information made available, 87.1% (n = 91) said it had been provided by briefing before the dive; 34.1%, in conversation after the dive, and other responses corresponded to 11% (Figure 3F).

The last question asked about the opinion of divers on environmental interpretation and aspects of marine geology, and 98% believe that this subject is a relevant aspect for carrying out the activity.

TABLE 1. Geological characteristics of dive sites in Fernando de Noronha (After Moreira and Silva Jr. 2013).

Geosite	Geological Formation	Characteristics	Diving modalities
Pontal do Norte	Quixaba	Ankaratrite flow	Advanced
Buraco do Inferno	Quixaba	Ankaratrite flow	Basic / Baptism
Buraco das Cabras	Quixaba	Organogenic Phosphates	Basic
Cagarras Rasa e Funda	Quixaba	Ankaratrite flow	Basic / Baptism
Laje Dois Irmãos	Quixaba	Ankaratrite flow	Basic / Advanced
Caverna da Sapata	Quixaba	Ankaratrite flow / Underwater Cave	Advanced
Cabeço da Sapata	Quixaba	Ankaratrite flow	Advanced
Iuias	Quixaba	Ankaratrite flow	Advanced
Cordilheira	Quixaba	Modern Sediments / conglomerates	Basic / Advanced
Cabeço das Cordas	Quixaba	Ankaratrite flow	Advanced
Ponta da Macaxeira	Quixaba	Ankaratrite flow	Advanced
Caieiras	Remédios	Pyroclastic Material	Basic
Cabeço Submarino	Remédios	Pyroclastic Material	Advanced
Ilha do Frade	Remédios	Phonolite Rocks Island	Basic / Advanced
Trinta Reis	Remédios	Phonolite Rocks island / Underwater “canyon”	Advanced
Ilha do Meio	Caracas	Modern Sediments / conglomerates	Basic / Baptism
Ressurreta	Caracas	Modern Sediments / conglomerates	Basic /Baptism
Pedras Secas	Caracas	Calcarenite / Underwater Cave	Advanced

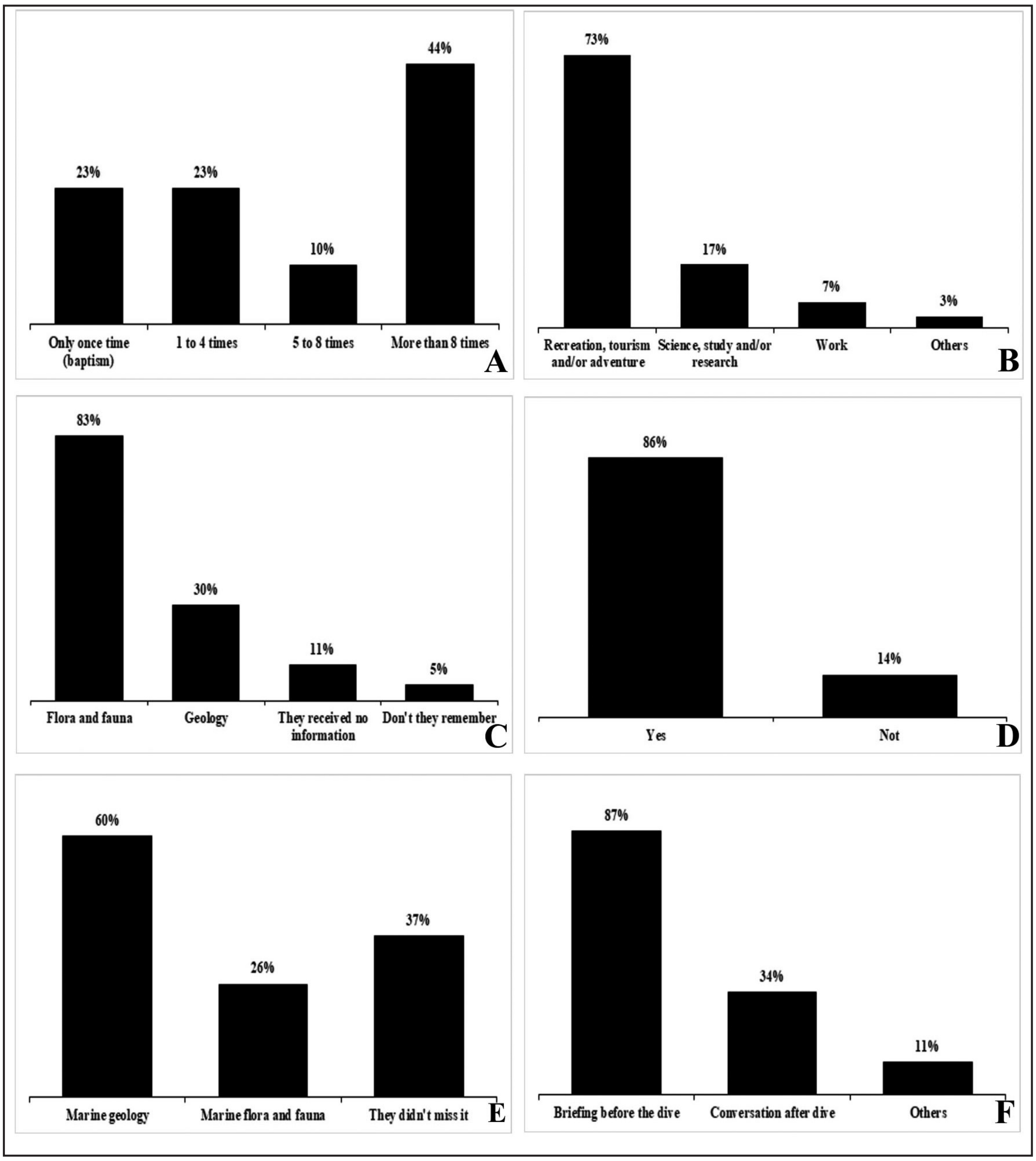

FIGURE 3. Histograms showing the frequency of answers from interviewed persons who did scuba diving in Fernando de Noronha. (A) Number of times they performed the dive (n=100). (B) Divers' main motivation (n=100). (C) Themes that received information (n=100). (D) Ease of observation of the information provided during the activity (n=91). (E) Need for information about marine geology or marine flora and fauna (n=100). (F) Time when information was provided (n=91).

6. Discussions

As indicated by previous studies, the interpretation of marine geodiversity can be important for scuba diving. It is common for practitioners of this activity, especially those less familiar with the marine environment, to identify biodiversity more easily, as dolphins and sea turtles are more commonly sighted than an underwater ankaratrite flow. Raising the awareness of visitors to biodiversity conservation is still a challenge, but such theme has the advantage of having been widely debated for much longer than geodiversity.

Importantly, despite the benefits provided by this practice to environmental conservation and to communities, it must occur in a controlled manner, as studies have shown that the excess number of vessels in the archipelago has threatened spinner dolphins (Stenella longirostris) (Silva et al. 2018).

Most respondents made the dive more than 8 times, which means that for this portion of visitors, the activity is interesting. The divers indicated that they felt they lacked information about marine geology, which means there is room for the development of actions in this regard. Almost three quarters of the respondents dove for the purposes of recreation, tourism and/or adventure, which demonstrates the attractiveness of the archipelago for this type of tourism.

The divers showed that the information had been provided before the dive. A more in-depth study of the effectiveness of these communicative strategies before and after the activity should be carried out. Virtually everyone responded that they believed marine geology to be a relevant subject for carrying out the activity.

Interpretative means are resources that can be used by guides to facilitate the recognition of elements of marine geodiversity. During the briefing, explanations about the geological context and the rocks that can be observed at the dive site may be accompanied by illustrated panels and mini-guides, or more advanced resources such as 3D models and simulations.

It is worth highlighting the importance of the operators for the success of interpretation, as they are the main channels of communication capable of revealing the meanings of the geological marine landscape. Establishing relationships between aspects of biodiversity and geodiversity would make the divers' experience more satisfying, as they would shift from being mere lovers of the landscape to agents of change, more committed to the sustainability of Fernando de Noronha and the oceans.

In Fernando de Noronha, a preliminary study was carried out to identify marine geosites; however, a methodology for assessing geological heritage should be applied to quantify and appreciate the relevance of these sites. As highlighted by Galindo et al. (2019), identifying and valuing shallow underwater geological heritage is crucial for the development of underwater and diving geotourism. The diving areas are already protected by the Conservation Units; however, when taking the necessary steps to value each site, monitoring actions can be better targeted, with the aim of reducing the impact of the activity in areas which are relevant for conservation.

7. Conclusions

This study showed that given the geological relevance of Fernando de Noronha, approaches that involve the interpretation of geodiversity could improve the visitor experience, since they believe that information about marine geology is relevant for the practice of scuba diving.

Fernando de Noronha is one of the tourist destinations most sought after by Brazilians, and the protection of this unique territory is essential. The implementation of an underwater trail and approaches to marine geology can reveal the meaning of the landscape and create connections between visitors and the geological heritage. This type of action helps to raise awareness of the importance of geoconservation and contributes to a more conscious attitude towards island sustainability.

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Strategic diagnosis of geocommunication using SWOT analysis in the Varvite Geological Park, São Paulo, Brazil

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Abstract

The central concern for geodiversity conservation is the low perception of its importance and appreciation by society, as the individual rarely values what he does not know. Thus, communication is essential to promote a better perception and comprehension by the public and, consequently, the conservation of geodiversity. Geosites are exceptional places to promote the communication of Geosciences because they allow public engagement through the enchantment provided, for example, by the story that can be told there. The Varvite Geological Park is a geosite of São Paulo state and is frequently used in formal education field activities pointing out its importance to geoscience knowledge dissemination. This municipal park brings important geodiversity elements that represent the late Paleozoic glaciation in southeastern Brazil, such as sedimentary structures, dropstones and ichnofossils. The development of a communication strategy requires an understanding of the Park's current situation. To this end, a SWOT (strengths, weaknesses, opportunities and threats) analysis of the Varvite Geological Park was carried out involving several stakeholders whose professional performance is related to the Park. This analysis resulted in a situational matrix with data organized in four quadrants that considered strengths, weaknesses, opportunities and threats. The results of the SWOT analysis pointed out a discontinuity in the existing communication actions and that an integrated and strategic approach is missing. Thus, the current communication gives to the visitor a fragmented view of Park's geological, historical and cultural context. Consequently, the potential to disseminate important geological concepts for public understanding and preservation is not fully explored.

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1. Introduction

Geodiversity, as a set of abiotic elements of nature and their natural processes, is indispensable for the existence of life on our planet. Despite this, its importance is not adequately perceived by society (Cañizares et. al. 2019). This perception deficiency impairs the individual's ability to exercise citizenship through behaviors aimed at the conservation and demanding priority public policies and protective measures. Therefore, the gap in the perception of geodiversity and the basic concepts of geosciences impacts its conservation. In this sense, geocommunication and the dissemination of geosciences to the lay public is fundamental for improving this perception. Geocommunication goes beyond making the content available to the public and search for its engagement instead. One way to do it is by sharing scientific knowledge through entertainment, for example.

Geosites are excellent scenarios for this purpose for two reasons. First, the search for deeper experience with nature is increasing as well as the interest in knowing more about the place visited. Second, the geosites can provide enchantment through their geological history. Thus, narrating this story in a fantastic way facilitates the absorption of complex concepts and promotes public engagement (Somerville and Hassol 2011).

The Varvite Geological Park is a geosite of São Paulo State's Geological Heritage Inventory (2018), very suitable for the study and development of communication strategies. It is a place that arouses public interest and is widely explored as a tourist attraction receiving visitors from Brazil and around the world. In addition, it has an established vocation for teaching figuring in field activities for students from elementary to graduate school, as well as in scientific research (Guimarães et al. 2018).

The hypothesis claimed is that strategic principles combined with the most current methodologies of geocommunication can

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improve the public's perception of the geodiversity in this Park. As a first approach, we conducted a situational diagnosis of this geosite focusing the current geocommunication practices using a SWOT (strengths, weaknesses, opportunities and threats) analysis. This methodology allows the identification and systematic organization of the positive and negative aspects, both internal and external Park´s environments. This data rationalization facilitates aspects crossing and prioritization for decision making on the communication strategy to be used in further studies.

2. Area of interest

The Varvite Geological Park is located at Rua Parque do Varvito, 400, in Itu, São Paulo (Figure 1). Currently, it is a municipal park managed by the Environment City Secretary, with an area of 44,346 m^2 and attended by an annual audience of over 60 thousand visitors. It is also a geosite included in São Paulo State's Geological Heritage Inventory due to its outstanding scientific value identified in its geological aspects (paleoenvironmental, paleontological, sedimentological, stratigraphic) in addition to its tourist, historical and educational importance (Garcia et al. 2018).

Before becoming a Park, the site was a quarry and the rock was extracted for building. In Itu city's historic center some varvite rock floors, jambs, streets and sidewalks remain preserved and can be appreciated nowadays. The scientists' interest combined with the site historical character sensitized public management to its importance and need for conservation and protecting measures. In 1974, the Condephaat (Council for the Defense of the State's Archaeological Artistic and Tourist Heritage) recognized this heritage and preserved part of the quarry area. In 1993, the Municipality of Itu expropriated the entire quarry area, including the previous partially preserved one, totalizing a protected area of 44,346 m^2. In 1995, the place was transformed into a municipal park (Rocha-Campos 2002).

In 2011, the Varvite Geological Park was recognized as one of the 11 Geological Monuments of São Paulo State by the Geological Monuments Centre, which is a research centre of the Geological Institute, related to the São Paulo's Environment State Secretary. Geological Monuments have a special character as a protected area and are included in the State's Information and Management System for Protected Areas and Environmental Interest (Sigap) (Moura 2017). The Park is now included in São Paulo State's Geological Heritage Inventory (Garcia et al. 2018) which further demonstrates its patrimonial character.

Its relevance is related to its geological context since the sedimentary rocks in the Park register the Itararé Subgroup of the Paraná Basin, and its formation occurred during the Permo-Carboniferous period. The outcrop consists of rhythmites with alternating deposition of light-colored and thicker layers of fine sandstone and siltstone, and dark-coloured and thinner layers of claystone and siltstone. Ichnofossils are present mainly as trails left by invertebrate animals, in addition to dropstones and glaciogenic debris released by icebergs (Rocha-Campos 2002). Varvite is a type of sedimentary rock probably deposited in a glacio-lacustrine environment, in a lake in contact with the margin of an ancient glacier. The characteristically annual seasonality is evidenced by light layers deposited by turbidity currents action during the summer, alternated by dark layers (greater presence of organic matter) decanted during the winter while the body of water was frozen (Rocha-Campos 2002). The outcrop in the Varvite Geological Park brings together elements of high scientific value, as it is one of the few sites in the country where researches can be performed to decipher the geological history of glaciation in southeastern Brazil during the Permo-Carboniferous period. These researches are also important for understanding the climate changes that society currently faces. In addition, it is also the most extensive and well-preserved varvite example of the Paraná Sedimentary Basin (Guimarães et al. 2018).

In this way, the Park offers a unique opportunity to put the public in touch with its geodiversity at the same time the Earth history contained in the countless elements found there is told, besides connecting them to the entire historical, economic, cultural and tourist context of the region.

3. SWOT analysis and strategic communication

According to Mintzberg et al. (2006), strategy can be considered a set of actions rationally designed, with a predefined purpose, aiming to solve a problem in a systematic way. With a well-formulated strategy, any institution can organize and manage its resources (financial ones or others)

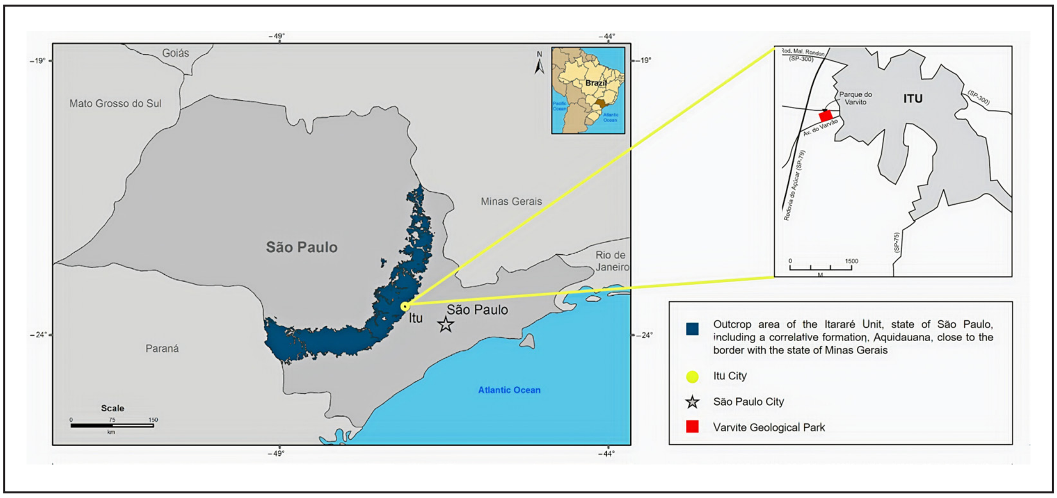

FIGURE 1. Varvite Geological Park's location (adapted from Guimarães et al. 2018 and Rocha-Campos 2002).

in order to make itself viable, singular and efficient. This level of excellence is reached when the institution's competences are properly explored and any environment changes are anticipated (Mintzberg and Quinn 2001).

A strategy formulation is an interactive process that depends on constantly evolving factors and their in-depth knowledge is essential for the development of this plan. SWOT analysis is one of the most used tools in strategic diagnosis. This methodology seeks to understand the boundary conditions through methodical and in-depth evaluation of the universe in which the institution is inserted. In other words, this diagnosis maps the strengths (S) and weaknesses (W) present in the institution's internal environment, and the opportunities (O) and threats (T) present in its external environment. Internal factors, positive or negative, are those that the institution can control. The external ones take into account the stakeholders, the competitors and social, technological, economic, political and other aspects over which the institution has little interference. The result is a matrix where these boundary conditions are mapped and organized into four quadrants (Figure 2) (Kotler and Keller 2012). Thus, it is a methodology that can be applied in a traditional proposal or using additional methodologies, depending on the complexity of the decision-making process, and already aiming at building the action plan such as the TOWS Matrix, GUT method, the Balanced Score Card, among others (Lurati and Zamparini 2018).

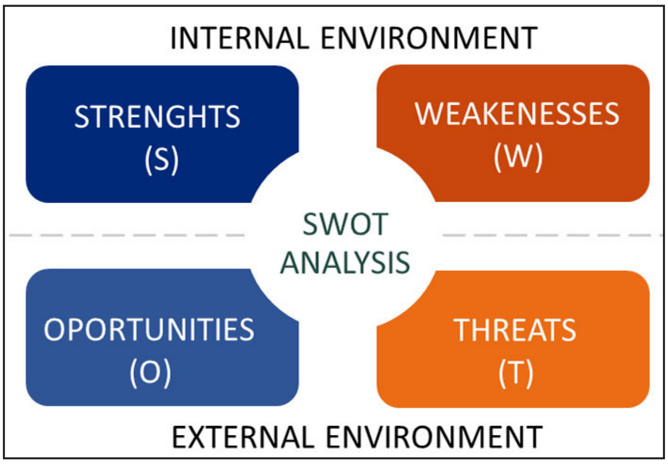

FIGURE 2. SWOT analysis Matrix

The use of SWOT analysis for the development of strategic communication considers specific factors that impact both its implementation and its result. The internal analysis considers the following aspects: communication execution (efficiency and effectiveness), the institution's relationship with its stakeholders, the organization's identity and its reputation. The external analysis is based on the communication strengths and weaknesses of the institution's competitors, the external environment (social, technological, economic, political aspects) and the stakeholders' environment factors that influence communication (Lurati and Zamparini 2018).

The SWOT analysis has being applied in conservation units such as Parque Estadual Restinga de Bertioga, Brazil (Banzato et al. 2012), in national park tourism evaluation in Penang National Park, China (Hong and Chan, 2010), in assessment of the educational potential of mining morphology in Červený kopec, Czech Republic (Kubalíková 2017), in the Seridó geopark, Brazil for geotourism evaluation (Medeiros et al. 2017), or in the formulation of geoconservation strategies in geomorphosite in Mama Bhagne Pahar, India (Datta 2020), among others.

4. Analytical procedures

As this diagnosis will support a future communication strategy formulation, the data used in this study covered aspects of communication and accessibility such as infrastructure, communication elements (existing types, conservation conditions, content, location, etc.); physical aspects of geodiversity such as its elements conservation conditions and vulnerability resulting from the anthropic visitors actions; and the perception of visitors, employees, different institutions partners and public managers.

The data were collected through:

a) bibliographic research on the geoscientific aspects of the Park and the historical use and scientific approach evolution;

b) online and offline Park's current communication content and means research;

c) field observation of visitor behaviour, as well as existing communication elements;

d) face-to-face interviews to investigate Park's visiting public perception;

e) online questionnaires to investigate the perception of Park's stakeholders.

Two perception surveys were carried out since the investigated groups expectations and interactions have different natures and purposes. The questionnaire applied to stakeholders addressed issues related to geodiversity, geoconservation, geological heritage and the connection of Park's context (geoscientific, historical and cultural aspects) to the visitors' daily lives. In this case, the objective was to investigate what issues stakeholders consider relevant to be disseminated in the Park. Brief explanations on these topics were included throughout the questionnaire to assess whether stakeholders would change their prioritization as they became more familiar with them. Issues related to the Park's current communication were also addressed to assess how their expectations were pleased. The visitors' interviews addressed issues listed by stakeholders as priorities for the exercise of citizenship in order to assess how the information in the Park's communication is retained. Additionally, the time dedicated to the appreciation of the panels was also observed in the field to assess the interest aroused by them.

An online solution was taken in place in order to facilitate the stakeholders' data collection considering schedules incompatibility and individuals' locomotion difficulty. A presentation with a Park's panel location map and its respective pictures was sent to the stakeholders in the way they could enjoy its contents as if they were conducting a face-to-face visit. After appreciating the presentation, participants answered an online form with subjective and objective questions.

Starting from the data collected, a traditional SWOT analysis was carried out and the strengths, weaknesses, opportunities and threats were identified using adapted guidelines from the propositions of Lurati and Zamparini (2018) summarized in Table 1.

TABLE 1. SWOT analysis structure applied to the Varvite Geological Park's communication.

Environment	Aspects analyzed	Guiding questions
Internal	Identity	Does the institution have a clear purpose?
		Does that purpose motivate people?
		Are the institution's values inspiring?
		Is there a brand (logo, slogan, colors, etc.) developed?
	Reputation	Are the products and services adequate?
		Does the institution have the ability to innovate?
		How does the institution play its role in society?
External	Competitors	What are the strengths and weaknesses of the competitors' communication?
	External environment (social, technological, economic, political)	
	Communication with stakeholders	How diverse are the interests and opinions among stakeholders?
		Is the exchange of information with the Park adequate?

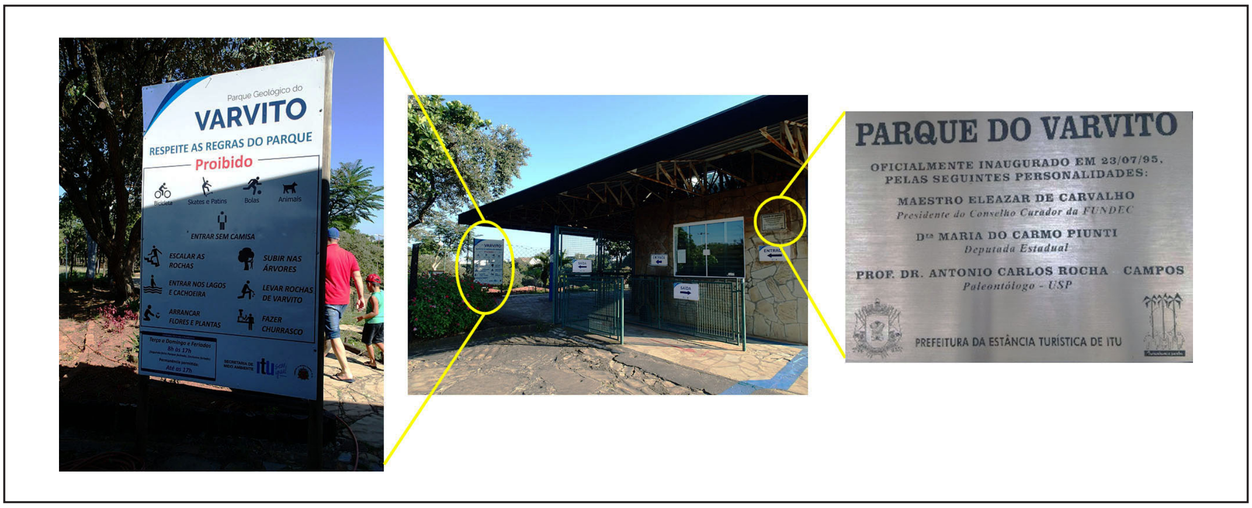

FIGURE 3. Communication elements available at the Park's entrance (Photos: Andrea Duarte Cañizares, 03/13/2020).

5. Results

5.1 Communication in use

Visitors access a single entrance (Figure 3) where there are no communication elements indicating a visitation route, the attractions location or other Park's and its stakeholders' institutions' informative and promotional material such as flyers. At this point the visitors find visitation rules and the Park's inauguration board.

The current elements of communication found in the Park are: nine explanatory panels installed at different locations (Figure 4A), a totem pole (Figure 4B), a notice board (Figure 4C) with a posted leaflet (Figure 4D), a website (Figure 5A) and a page on Facebook social network, which is temporarily disabled due to the proximity of municipal elections, according to the Park administration (Figure 5B). There is no formal communication plan for the Park. The communication currently installed on the site is the result of a partnership with the Universidade Estadual Paulista – UNESP that also resulted in a commemorative edition of the magazine "Revista do Parque do Varvito" due to the Park's 20 years' anniversary in 2015 (Figure 6) (Furlan et al. 2015).

Some attractions, such as the Iceberg Viewpoint (Figure 7) do not have neither interpretive elements nor an attraction's name board or a rules signal. Others have attraction's name board but no explanation about its meaning.

5.2 Stakeholders' perception

The online questionnaire applied to stakeholders was available for 60 days. Sixteen stakeholders (44% men, 56% women), between 40 and 66 years old (62.5%) answered it. Most of them have an education level in higher education (25%) or postgraduate education (62.5%) and they are working as managers (environment, tourism, education, historical heritage and culture), teachers in public and private schools, scientists, environmental monitors, museum curators and administrators/caretakers.

Table 2 synthetized what content stakeholders expect to be addressed in the Park's communication before introducing them the concepts of geodiversity, geoconservation and

FIGURE 4. A) Panel on the Benthic Trail, B) Totem, C) Notice board and D) Leaflet in the Civic Square (Photos: Andrea Duarte Cañizares, 03/13/2020).

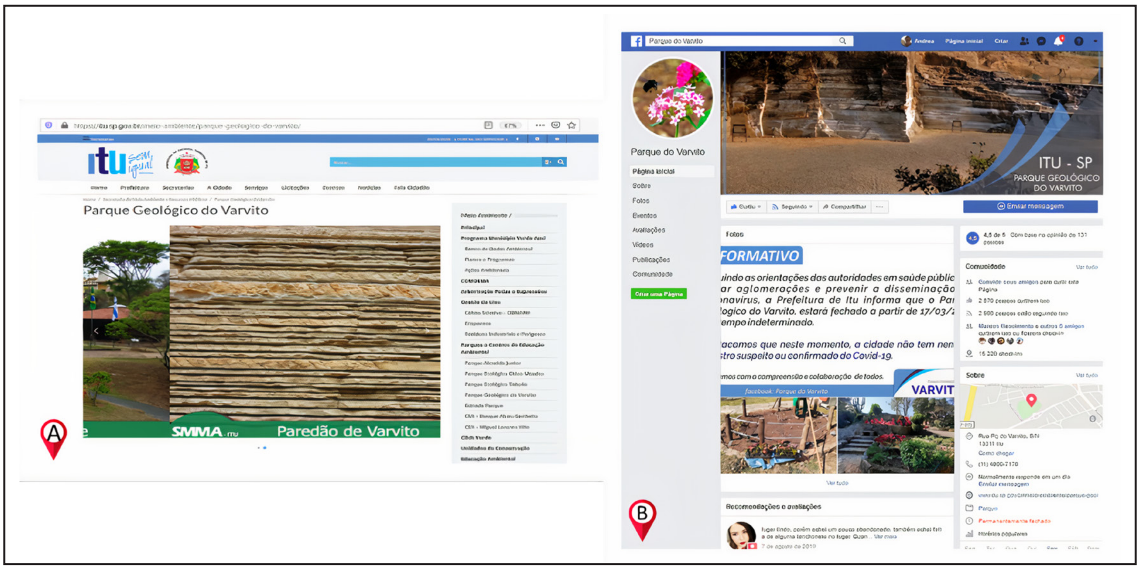

FIGURE 5. A) website (Website: https://itu.sp.gov.br/meio-ambiente/parque-geologico-do-varvito/); B)Facebook page (https://www.facebook.com/Parque-do-Varvito-145485018972603/).

FIGURE 6. Summary of the commemorative edition of 20 years of the Park (2015) of Parque do Varvito Magazine (Itu 2015).

FIGURE 7. Different views from the Iceberg Viewpoint (Photos: Andrea Duarte Cañizares, 03/13/2020).

TABLE 2. Stakeholders' expectation and authors' analysis about their approach in the different Parks' communication channels (not observed: gray; partially observed/explained: blue; detailed explanation: green).

Within the context in which you relate to the Park, describe what geoscientific knowledge you think the public should obtain during the visit.	Mentions	Panels	Totem	Flyer	Magazine	Site
glaciations and climatic variations	6	blue	gray	gray	blue	gray
sedimentary processes as a whole	5	gray	gray	gray	green	gray
geological time	5	gray	gray	gray	green	gray
varvite formation process	4	green	gray	blue	green	blue
fossilization processes (fossils and ichnofossils)	4	blue	gray	blue	blue	gray
paleoenvironment of varvite	4	blue	gray	blue	blue	blue
types of rocks and their formation processes (rock cycle)	3	gray	gray	gray	gray	gray
importance of the Park as a geological heritage	3	gray	blue	gray	blue	blue
geodiversity: concept, valorization and protection / conservation	2	gray	gray	gray	gray	gray
sedimentary structures	2	blue	gray	blue	green	gray
supercontinents (especially connection to Africa)	2	blue	gray	gray	blue	gray
Earth's internal and external dynamics	2	gray	gray	gray	blue	gray
Earth's history and formation process	1	gray	gray	gray	blue	gray
Park's foundation history	1	gray	gray	gray	green	gray
São Paulo State's geology	1	gray	gray	gray	gray	gray
biodiversity, urbanization and environmental impacts	1	gray	gray	gray	gray	gray
soil formation process	1	gray	gray	gray	gray	gray
varvite use in regional architecture and its importance (economic, cultural, etc).	1	gray	gray	gray	green	gray
Atlantic Forest and Brazilian Cerrado's current ecosystems	1	gray	gray	gray	gray	gray
naturalists' expeditions during the 19th century	1	gray	gray	gray	gray	gray
connection with Tietê river	1	gray	gray	gray	gray	gray
local anthropology, topography and geography	1	gray	gray	gray	gray	gray
sense of belonging	1	gray	gray	gray	gray	gray
information on geology subject	1	gray	gray	gray	blue	gray

geological heritage. This table also shows an authors' analysis about how is the approach of these concepts in the different Park's communication channels. The Facebook content was not evaluated because the official page is not available. Table 3 synthetized what knowledge stakeholders judge to be essential, after being introduced to the concepts mentioned above, to prepare the visitors to exercise their citizenship.

Asked about how much the Park's communication makes clear the meaning of the names of its attractions (such as Permian Lake, Benthic Trail, Boulder Grove, etc.), 56.25% of stakeholders understand that their meaning is not clear for the visitor. When asked about the identification of these attractions, 56.25% understand that the Park's communication makes clear the location of its attractions. In general, the stakeholders showed themselves to be knowledgeable about the Park's context, although one of them voluntarily stated that he had never accessed the Park's website. The perceptions about the use of the Park's structure can be seen in figure 8.

Regarding the challenges and suggestions to improve the Park's communication, the stakeholders' answers were compiled in Tables 4 and 5.

5.3 Visitors´ perception

Face-to-face interviews were held on a Saturday, during the park's opening period (8 am to 5 pm). Thirty visitors were interviewed (47% men, 53% women), between 25 and 34 years old (33%) with training mostly in higher education (46.7%) or postgraduate (23.3%). The objectives of the visit declared by the visitors were: curiosity and knowledge (43.3%), contact

TABLE 3. Geoscientific knowledge deemed necessary by stakeholders for citizens' formation.

Geoscientific knowledge deemed necessary by stakeholders for citizens' formation	Answers Frequency
concept and importance of geoconservation (balance between exploration and conservation), like mining in the quarry and its transformation into a park	9
perception of the concept, value and need for conservation of the geological heritage	4
types of rocks and their formation processes (rock cycle)	2
geological time	2
rocks use and the importance of mineral resources to society	2
geodiversity concept	2
tourist possibilities	2
geosciences importance and individual responsibility on geoscientific issues	2
geological characteristics association with forming processes and environments.	1
sense of belonging	1
natural and urban environment perception	1
tectonics plate	1
pebbles concept	1
supercontinents (Pangea)	1
varvite formation process	1
connecting rock use with urban perimeter and transposing it to the daily lives of individuals	1
reflections on new attitudes about the environmental resources' management and its exploration impacts	1
recognition of the geological trajectory of the territory on a world scale	1
climatic variations	1
comparison of geological ages and climate change in Brazil	1
individual's relationship with the environment	1
paleontological site	1
scope of sciences (Geology, Paleontology, Geography, History and Economics)	1
legislation	1
natural history of the individual's city, region and country	1
science relevance to social development	1

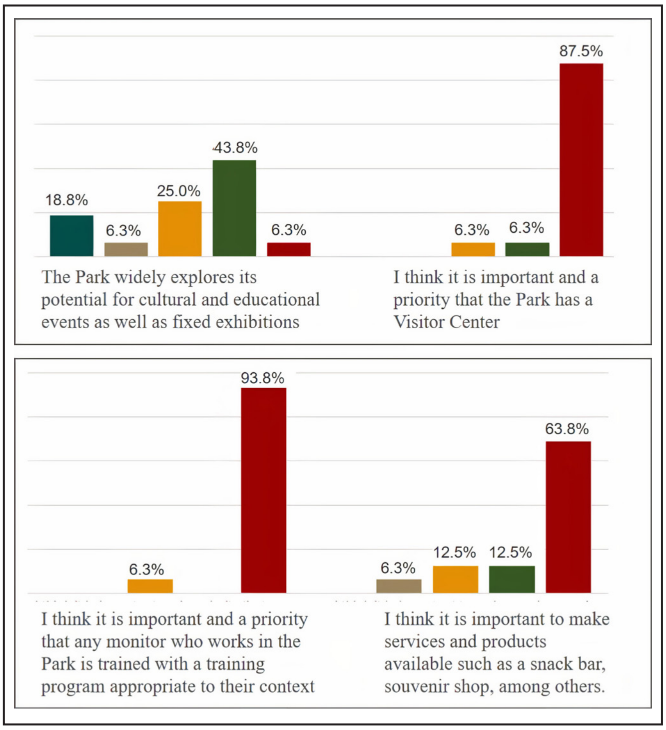

FIGURE 8. Perceptions of stakeholders on the use of structure holding events, providing products and services, visitor centre and monitors training.

with nature (36.7%) and other reasons (20%). Many visitors declared not seeking information about the Park previously the visit (43.3%) and those who sought it, did so mainly using the internet (82.4%) followed by books and scientific articles (11.8%) and consultation with family and friends (11.8%).

To measure understanding about the meaning of geodiversity, visitors were asked to mention words that came to their mind when they heard that term. The words rock / stone / rock formation was most frequently cited (11 mentions), followed by diversity / variety (10 mentions), soil (3 mentions) and study (3 mentions). The term geological was mentioned only twice and mineral, trace, past and Earth only once. When asked to give examples of geological heritage, 47% replied that they did not know how to exemplify, 10% provided incorrect examples and 43% mentioned the Park itself. When asked about the actions that could be taken to better preserve the Park, respondent mentioned investment in security and inspection such as installing cameras, focusing on maintaining the facilities regardless of elected public management, implementing communication aimed at preserving nature, creation of digital content, elaboration of specific legislation, incentive to visitation, involvement of the local community in activities, programs with schools, population education, public-private partnerships, dissemination of the Park´s importance and place information.

To assess the panels attractiveness, visitors were asked about the time dedicated to each one of them (Figure 9). In

TABLE 4. Stakeholders suggestions to improve communication and the visitor experience.

Suggestions	Answers Frequency
Park placed training courses for different audiences including environmental monitors	3
clearer connection with citizen daily life, the importance of geodiversity for the economy	2
specialized team to attend visitors	2
partnerships with educational institutions in the region, including universities in São Paulo	2
partnerships with other attractions in the region promoting exchanges of knowledge and integration with other tourist spots where the varvite extracted from the Park is used	2
Park's historical and economic importance contextualization and its link with the city at the beginning of the visit	2
implementation of didactic activities associated with student visits	1
bus or train that takes people city centre - park and park - city centre	1
improving explanatory signs and signage	1
implementation of a script that tells a story	1
tailored communication to each type of audience	1
place to receive and guide the public at the beginning of the visit (explanatory video or lecture)	1
more suitable space for visitors stay and socialize, since currently stay is very short	1
future study centre with forty seats	1
better implement of existing ideas	1
transforming the park into a museum	1
interpretation centre	1
creative economy and tourism as a source of income	1
entrance charge to generate funds to be invested to improve visitors experience	1
electronic interactions	1
real-time interactions, like geoscientists showing how they study rocks and fossils	1
update the geological information on the panels	1
implementation of physical accessibility in compliance with NBR 9050	1
public-private partnerships	1
educational and cultural public policy for the park	1
better park conservation	1
use simple and didactic ways to divulge complex and difficult to understand concepts	1
promote sense of belonging	1
use the current research for revitalizing the park and helping the city and the population to maintain and enhance this important geological heritage	1
taking into account that the heritage list process was aggressive	1
create a work plan with the local team	1

TABLE 5. Challenges of the external environment listed by the stakeholders regarding communication.

Challenges	Answers Frequency
financial resources	6
need of specialized people to develop communication (geologists, educators, designers, communicators, administrators, etc.)	4
awareness of public bodies about the importance of the Park, political will	3
dialogue with the Park management	1
park management interest	1
training people working in the Park	1
coordination of the Park's activities by a specialist	1
continuity of communication actions	1
projects to bring the academy (researchers, students and teachers) close to population	1

parallel, the authors observed visitors' behaviour and noticed that the time spent did not exceed 15 seconds, with the exception of two individuals.

In order to ascertain the degree of information retention, the interviewees were asked to mention examples of rocks found in the Park. Only 20% of them mentioned the varvite itself and the rest did not answer, did not know or mentioned unsatisfactory or very generic examples such as "stratified rocks" or "metamorphic rocks". When asked about the varvite time magnitude order, 54% answered millions, 29% thousands, 11% billions and 7% hundreds of years.

5.4 SWOT Analysis

The results obtained were organized in a four quadrants matrix and presented in Tables 6, 7, 8 and 9.

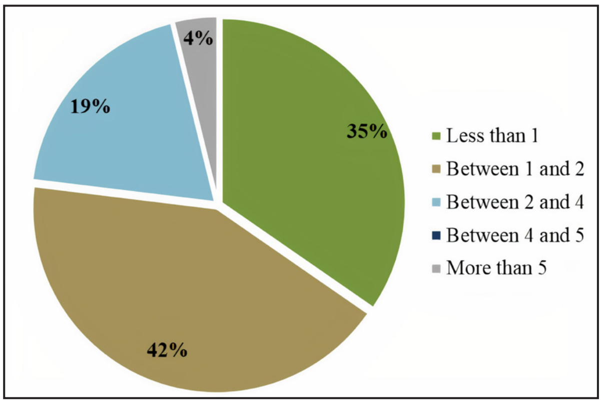

FIGURE 9. Declared reading time of each panel by the interviewees.

6. Discussions

The Park's communication currently in use is already well developed which provides a more favorable starting point for future actions and planning (S1). It makes the Park a reference for other institutions (S2). Its panels are well maintained and located which facilitates their viewing. Some panels are close to the geodiversity element they refer to. This location allows the content association with what is being observed which provide a better understanding (S3). The panels' content is in line with the scientific literature but lacks update in order to comply more actual interpretations (W1). Other important Park' strengths are the geodiversity preservation state, the Earth system representative elements and its geological history (S4, S5 and S6). However, there is no pre-defined

TABLE 6. SWOT Matrix Quadrant 1: Strengths.

	STRENGHTS
S1	current communication is already well developed (more favourable starting point for future developments)
S2	one of the only facilities like this in the state (reference for other institutions)
S3	conservation status of panels, easy localization and association of content with the element of geodiversity
S4	reasonably preserved geodiversity
S5	representative elements of the Earth System
S6	unique features (paleoenvironment glacial lake)
S7	the panels follow standards in terms of number of words and format
S8	strong historical, cultural and emotional connection with the region
S9	structure for holding events: Amphitheatre, Civic Square, etc.
S10	responsive management to partnerships with the academic environment
S11	dissemination of other tourist and cultural attractions in the region on the totem of Civic Square
S12	future study centre
S13	high scientific value (geological heritage)

TABLE 7. SWOT Matrix Quadrant 2: Weaknesses.

	WEAKNESSES
W1	panel content needs updating according to the most current scientific interpretations (periodic review)
W2	there is no pre-established target audience
W3	previous communication objectives not identified
W4	take away communication material not available
W5	non-integrated communication (website, social networks, email, applications, etc.)
W6	low accessibility for handicapped people
W7	current trends in geocommunication not observed (storytelling and panels layout order, simple language, interactivity, etc.)
W8	partial or unobserved approach to various topics expected by stakeholders (connections with the region's history, culture and economy and use of geodiversity in visitors' daily life)
W9	low impact on visitors
W10	low integration with stakeholders to establish and achieve common goals
W11	Park's promotional materials not available in its stakeholders' institutions
W12	lack of materials in the Park to promote other regional attractions, besides the Totem
W13	there is no Park's brand (logo, colors, fonts, etc.)
W14	there is no Visitor Centre
W15	lack of training actions for internal employees and stakeholders in addition to adequate training for monitors
W16	there is no products and services offer (snack bar, souvenirs, etc.)
W17	Park's map not available at the visit beginning
W18	attractions without a board indicating their name
W19	low involvement of the local community in activities, programs with schools and education of the population

TABLE 8. SWOT Matrix Quadrant 3: Opportunities.

	OPPORTUNITIES
O1	create a strategic differential with innovative attractions offering
O2	explore digital media to create a geoconservation based culture around the Park
O3	use Park's context and vocation to reach new official curricula
O4	use numerous research and scientific publications available for content development
O5	explore stakeholders' awareness of Park's role and their openness to partnerships
O6	make place for integrative practices as a permanent working group to develop projects with stakeholders
O7	develop public-private partnerships, creative economy initiatives and other actions in order to generate financial resources

TABLE 9. SWOT Matrix Quadrant 4: Threats.

	THREATS
T1	other parks in the region offer products and services that Varvite Geological Park doesn´t
T2	information are widely available on the web but it is not always reliable
T3	Park's communication management is directed by political issues (for example: deactivation of Facebook page)
T4	the dialogue with the Park's management is not frequent
T5	individuals have different cognition mechanisms
T6	Parks haven´t a dedicated communication management that involve specialized professionals in a systematic way
T7	financial resources depend on municipal budget

target audience. A technical approach language is observed in most of the panels, which suggests that the target audience is a specialized one (W2).

There is no communication plan based on previously defined objectives (W3). According to the field observation and perception results, the main objective is to provide information on the Park's paleoenvironmental interpretation. Although it is not possible to ensure that this objective has been intentionally and previously planned. The objectives are a vital point for the communication development as they guide the direction to be followed. They describe the expected results both in terms of audience's knowledge and behaviour and also the expectations of the stakeholders (Lurati and Zamparini 2018).

The panels installed in the Park are almost the only communication tool on site. There is no take away communication materials available for visitors (W4). The offer of this kind of material is important to guide the visit and for knowledge consolidation. They are even important to Park's promotion as the visitors could share these materials within their relationship network.

It is relevant to observe the role of integrated communication. The expected result of integrated communication is the public being able to identify and dialogue with the institution and its community, to perceive its purpose and values in all its interfaces in a congruent and consistent way (Duncan and Mulhern 2004). However, this proposal is not observed in the Park's different communication channels. What is generally observed is an informative and unidirectional content. The channels do not seem to have been developed to promote a single image perception neither the existence of a general message previously planned (W5). The website is not an exclusive page. It is part of Municipality's website which has a very summarized content about the Park. It does not indicate links to other relevant content such as an agenda of events or more details about its geological and historical context, for example.

The panels follow guidelines from Gross (2006) regarding the number of words (less than 200) (S7). In structural terms, the Park's panels follow the (rectangular) formats most used by the members of the Unesco Global Geoparks Network, but do not follow the (horizontal) orientation or material most used (wood) (Von Ahn and Simon 2019). Moreira (2014) indicates that rectangular and horizontal panels are more visible and facilitate access. In fact, the issue of accessibility requires greater care, since adequate handicapped adaptations are not observed both in the route that takes visitors to the panels and in the panels themselves (W6). Some current trends in geocommunication such as storytelling narrative are not clearly identified in the panels (W7). The panels order is not aligned according to the geological time, the language is not always accessible to the lay public. The use of metaphors, images, illustrations and interactivity to stimulate imagination, reflection and understanding is also little explored (Stewart and Nield 2013).

Many of stakeholders' expectations about the knowledge dissemination are not being met (W8) (Table 2). For the stakeholders, it is also relevant to tell the Park's foundation history showing its connection with the city's history, its economic and cultural importance and the presence of rock in the historic centre architecture, for example. Some of these issues are covered in the Magazine (Figure 7) available on the Park's website, but none of them are addressed in the communication in use at the geosite. Addressing this issue on the site is essential because 43.3% of visitors do not search for Park's information before the visit. In the same way, other themes identified by the stakeholders (Table 2), for example, glaciations and climate variations on the past and present time, are not fully addressed on the geosite.

The fact that the Park was once a quarry is an aspect that can also be explored as it enables a strong historical, cultural and emotional connection with the region (S8). The promotion of this bond contributes to the sense of belonging development, which is also one of the stakeholder's expectations. Sense of belonging leads to the individual's awareness of nature conservation importance (Sorrentino 2010). This sense of belonging leads to the individual's awareness of geological heritage, geodiversity importance to sustain life and need for its conservation and rational consumption. The Park's history can also be used to promote understanding that a mining area can be transformed into benefits for nature and for society (W8). The Park's flower boxes and drinking fountains are made of varvite extracted from this quarry. The communication approach could lead the visitors to perceive this use and make connections with geodiversity elements presence in their daily lives (W8).

The expected public impact analysis is related to the changes in the visitor's knowledge and behaviour promoted by the Park's communication (W9). When asked about what knowledge is needed to enable the individual to fully exercise their citizenship (Table 3), the stakeholders mentioned geoscientific themes already indicated with regard to their involvement with the Park (Table 2) and other ones such as the relevance of geoscience to social development. However, stakeholders consider themes related to geoconservation and geological heritage a priority for the full exercise of citizenship, as shown in Table 3. This priority change was expected since clarifications on these themes were provided during the survey and consequently promoted a change in their understanding regarding the impact of such knowledge on the citizenship exercise (W8). This change was not observed in visitors' interviews. Visitors were asked to provide words that came to mind when the term geodiversity was mentioned. According to the results, we can assume that the interviewees were able to deduce the meaning of geodiversity through connections that the word itself raises since this concept is not clearly present in the Park's communication. There was no mention of sustaining life or conserving geodiversity. It is inferred, therefore, that the communication did not sensitize the visitor about the role of geodiversity, the importance of its conservation and the impacts caused by the individual's actions. In other words, communication does not seem to demonstrate to the individual his responsibility for geoconservation or to influence his future behaviour (W9).

As pointed out by Stewart and Nield (2013) and Cañizares et al. (2019), there were many gaps regarding the geoscientific knowledge held by the public. These authors related this to the fact that formal education does not deal with geosciences in a specific subject. Thus, geosciences are addressed in a fragmented and non-systemic way in several courses like geography and biology, for example. This is one of the reasons why the effectiveness of communication in non-formal education environments such as the Varvite Geological Park becomes so relevant. Concepts such as rock types and geological time were not absorbed by the visitors since only 20% of them mentioned the varvite itself as an example of rock present in the Park and almost half of them (46%) do not answer a correct order of time magnitude (W9). These results indicate low information retention of Park's communication contents, which may be explained by a low attractiveness of the panels (visitor dedicated less than 15 seconds to read panel information) or the need for greater alignment with the most current trends in geocommunication. Besides of it, the fact that much of the knowledge listed by the stakeholders (Tables 2 and 3) is not addressed or is partially addressed in the Park´s communication suggests that the communication impact on the public is not satisfactory (W9).

The relationship with stakeholders is a very relevant factor to be considered in the communication development because the institution reputation and identity are built through it (McPhee and Zaug 2000). In general, the stakeholders showed a great openness and willingness to collaborate, as well as a feeling of belonging with the Park. It suggests that there is commitment between all parties involved. The proactive and receptive posture of the Park's management stands out, especially for partnerships with the academic environment which has been frequently observed (S10). This attitude and partnerships are opportunities that can be explored, for example, to implement a scheme for periodic review of the Park's communication and eliminate this weakness (W1). On the other hand, the results do not show a mutual influence on decisions as a usual practice. The practice of meetings to discuss common objectives or any other systematic form of dialogue and integration to increase synergy was not observed, for example (W10). There are no Park's promotional materials availability in the stakeholders' institution facilities such as the tourist information office in Matriz Square, for example (W11). Also, there are stakeholders who declared they had never visited the Park website. The Park, in turn, discloses tourist and cultural attractions of the region in the Totem located at Civic Square (S11) but could provide other materials such as leaflets to highlighting the city's relationship with the Park (W12). For example, the Republican Museum exhibits works by Miguelzinho Dutra and samples of varvite and the Museum of Energy exhibits an archaeological excavation in its garden in which the use of varvite is also observed as it does in many other places in the city historical centre.

The Park's identity is not evident in the communication in use (panels, website, social networks, email, etc.) as it regards to tangible elements (brand, slogan, logo, colours, fonts, etc.) and intangible elements (purpose, values, offered experience) (W13). The institution's identity is important because the individuals recognize in it their world perceptions, their beliefs and values. That is why it is such a relevant influence in the individuals' behaviour (Stewart and Nield 2013). When identity permeates communication in a coherent and integrated way, the public recognizes these values and objectives on all the fronts it gets in touch with the Park and creates consistent bonds. These ties, that mean the sense of belonging, lead to conservation-oriented behaviour. For this reason, identity must guide strategic communication (Jankovic et al. 2019).

According to the stakeholders, the Park has a ready and satisfactorily explored structure for holding cultural events such as concerts, exhibitions, fairs, etc. (S9). However, it does not meet their expectations when it comes to the Visitors Centre (W14), monitors training (W15), services and products offer (cafeteria, souvenir shop, etc.) (W16). The Park's offered experience is one of the intangible aspects of identity and these weaknesses affect its perception by both stakeholders and visitors.

Considering the experience aspect, one of the first needs of the individual when arriving at Park is to be able to locate and identify the available attractions. A map or other form of visual representation of the place availability at the beginning of the visit is important because it provides information that allows the visitor to rationally enjoy the Park. This communication element helps in the prior creation of an image and design of the place, which, depending on how it is prepared, arouses visitors' interest in obtaining more information about its history, importance of preservation, culture, among other aspects (Morandi and Gil 2002).

Although Civic Square has a leaflet containing a map of the attractions fixed on its notice board, it is barely visible and is only available after the visitor has already covered a great part of the route (W17). Besides of it, many of the attractions do not have boards with their names and, when they do, they do not explain their meaning or relationship with the context of the Park (W18). The name of the attractions would be a good motto to contextualize geoscientific concepts, such as the Permian Lake, which is related to the geological time and the Park's paleoenvironment.

The offered products and services quality, or the absence of offers, for example, interfere with the visitors' experience. This experience impacts directly the public's formed opinion about the Park's, that is, impacts its reputation. Many respondents mentioned the involvement of the local community in activities and programs with schools and education of the population as suggestions for preserving the Park, in addition to the need for improvements in safety and inspection and maintenance of facilities (W19). In this sense, the Park management informed that it is investing in the installation of a study centre, which will certainly integrate its set of forces (S12). Eventually, a tourist itinerary could be developed to unite the tourist attractions of the region, may be with a circular transport linking the Park to the city historic centre, as suggested by one of the stakeholders.

Angelkova et al. (2012) considers the ability to increase tourist consumption and attract visitors by offering a memorable and wellness-promoting experience, a strategy that generates competitive advantage over other places that compete for public attention. The Moutonnée Rock Park, for example, has a souvenir shop, snack bar, video projection room, monitors present on the site and a panel with a Park map for prior visit guidance (T1). It also has dinosaurs' replicas that stimulate fantasy and entertain, especially children, although this attraction is geologically out of context with main attraction of the Park and, consequently, conveys incorrect concepts to the public (O1). These facilities can be seen as an opportunity to be taken advantage of by the Varvite Geological Park. For example, it could be installed Park's paleoenvironmental animals and plants replicas and even a glacier model as they are elements that can bring fantastic and disseminate correct concepts.

In addition, a large amount of information is available on the internet and may have a little trustworthy nature. Consequently, relevant and accurate content do not reach the public properly (T2). Despite this challenge, internet communication brings the institution and the public closer together (Amirkhanpour et al. 2014). The internet expanses the public reached by communication, both in number and individuals' diversity, requires relatively low financial investment and enhances interactivity and engagement. In addition, the internet communication dynamics stimulates cognitive processes and empirical and emotional associations, as well as interest and connection with the institution (De Valck et al. 2009). Thus, internet communication is an indispensable means to be used to involve the public in the community creation that identifies itself with the Park and a culture around it (O2). However, the political scenario is a limiting factor in the Park's communication. For example, the Park's Facebook page was temporarily disabled due to the proximity of the municipal elections (T3). This action not only reduces the public reached, but also leads to a discontinuity perception that can compromise the Institution's reputation. In addition, in the current scenario in which face-to-face visits were interrupted due to the coronavirus pandemic, social networks play an essential role in disseminating information to the public, including on the Park's reopening dates and procedures.

Another opportunity is the new teaching approaches (O3) that have been proposed in the country for elementary and secondary education, which stimulate a transdisciplinary, integrative, creative and practical training (Brasil 2017; Brasil 2018 and São Paulo 2020). These new approaches are other opportunities to be explored to expand education focused on geosciences, including basic, higher, and non-formal education.

The academic community interest in the Park attests to its high scientific value (S13). There are numerous researches and scientific publications about the place. The research addresses topics such as education, geotourism and geological heritage, among other more traditional areas of geosciences such as paleontology, sedimentology, stratigraphy, among others (Garcia et al 2018). The framework of knowledge generated by the academic community allows the development of a dissemination sustained in a reliable and updated theoretical foundation (O4). For this, it is necessary to incorporate periodic review of the contents in the Park's communication practices.

The stakeholder's external environment is very similar to that of the Park and for this reason they have many common goals and challenges. They are aware of the context, connections and importance of the Park. They are open to partnerships (O5) but feel the need for greater dialogue with the Park's management (T4). Thus, the formation of a permanent working group that meets regularly to discuss common objectives can be a great opportunity for successful projects to disseminate geodiversity (O6).

On the other hand, stakeholders and visitors have different mechanisms of understanding as well as different levels of cognition (T5) (Ahmad et al. 2014). A communication focused only on panels restricts the scope of geocommunication. In this sense, the inclusion of expert team to develop Park's communication (geologists, educators, designers, communicators, administrators, among others) is another challenge (T6) to be overcome, which can improve and also promote continuity, dialogue and common projects.

The main challenge of the common external environment indicated by the stakeholders (Table 5) is to obtain financial resources (T7), mainly because it is a public institution. It is true that financial resources are scarce and affect the development of communication, but it is not a totally insurmountable obstacle. It is possible to implement low-cost changes such as the reordering of panels and the permanent reactivation of social networks. Stakeholders also indicated some opportunities for generating resources (Table 4) such as public-private partnerships, initiatives aimed at the creative economy with the community (handicrafts, local products, etc.) and the offer of products and services (O7). It is therefore necessary to rethink the objectives of communication and make it meaningful for the citizen, adding social and symbolic values to its already academic and scientific nature (Martín-Cáceres and Cuenca-López 2016).

7. Conclusions

The present work offers a situational diagnosis based on the traditional SWOT analysis. In other words, the proposal is to provide an overview of the situation of geocommunication in the Park with brief discussions of possible paths to be followed from the crossing of some observed factors. The analysis already pointed out a discontinuity in the currently communication actions and a lack of an integrated and strategic approach. This discontinuity and also the lack of connection with the city itself result in specific actions that lose part of their potential because they are not strategically related.

Based on this diagnosis, crosschecking and prioritization methodologies can be used in the future to formulate a more detailed communication strategy. The definition of the communication objectives that will guide the direction to be followed to promote the desired positioning of the Park is, without a doubt, the necessary starting point for the development of action plans derived from the chosen strategy, or strategies.

A more detailed case study on the panels can support the elaboration of specific objectives that better guide the development of the strategic communication plan through the analysis of both its standards and its impact on the public. An example of an objective would be to capture public interest through the epic narrative of the separation of the supercontinent Gondwana and the existence of glaciers in Brazil, engaging public with the fascination of these themes. In addition, initiatives such as new tourist routes, souvenirs and geoproducts, cafeteria, visitor centre or study centre, training of monitors, exhibitions, better exploration of digital and online communication channels, etc., can positively contribute to the visitor's experience and consequently, for the Park's identity and reputation.

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