

Original Article

Geoconservation Initiatives in the State of Paraná (Brazil)

Luiz Alberto Fernandes^{1*}, Fernanda Caroline Borato Xavier¹, Kimberlym Tábata Pesch Vieira¹, Liliane Maia Tcacenco-Manzano¹

¹ Postgraduate program in Geology, Federal University of Paraná, Curitiba, Brazil

Abstract

Even though geoconservation has advanced significantly in the last few decades, general awareness of its importance is limited, especially in Brazil. Here, we present an overview of geoconservation actions and initiatives in the state of Paraná. We highlight geoscientific aspects since the 20th century, the installation of interpretative panels, and key findings from the inaugural geological heritage inventory for the state, the second in the country. We also present two examples of pioneering geoconservation and scientific communication initiatives: the creation of the Curitiba Sedimentary Basin geosite (a municipal conservation unit within the urban territory) and the Paleontology Museum of Cruzeiro do Oeste's research station. Despite the concerted efforts of academic research groups, the state geological survey (Mineropar, now defunct) and the national geological survey (CPRM-SBG), current initiatives remain limited to academic research. Overall, there are not enough systematic public policies to protect the state and national geological heritage. Regrettably, geodiversity and geoconservation remain the least known components of the state's natural heritage. A long-standing concern has been the absence of geological content in the curriculum of the Brazilian basic education system. Overcoming this problem will require the incorporation of geology and geoconservation concepts into school curricula and educator training, and the effective communication of their significance to society at large.

Corresponding Author:

Luiz Alberto Fernandes
Postgraduate program in Geology,
Federal University of Paraná, Curitiba,
Brazil
ORCID: 0000-0002-0718-5154
Email: lufernandes@ufpr.br

Keywords: Geodiversity, Geoheritage, Conservation Units, communication

Article information

Received:2023-07-29

Accepted:2023-10-11

First Publish Date:2023-12-20

DOI:10.57647/j.gcr.2023.0602.19

How to cite: Fernandes LA, Xavier FCB, Vieira KTP, Tcacenco-Manzano LM (2023). Geoconservation Initiatives in the State of Paraná (Brazil). *Geoconservation Research*.6(2): 293-307. <https://doi.org/10.57647/j.gcr.2023.0602.19>

Geoconservation Research e-ISSN: 2588-7343 p-ISSN: 2645-4661

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Introduction

The state of Paraná in the southern region of Brazil covers an area of approximately 200,000 square kilometers and has a population of over 11 million inhabitants. Its geological history dates to around 2.8 billion years ago (Ga), starting with the basement of the South American platform, which outcrops in the eastern part of the state. This ancient substrate consists of high-grade metamorphic Archean to Paleoproterozoic rocks, acidic Proterozoic magmatic rocks, and vulcanosedimentary and sedimentary rocks formed in restricted basins during the Ordovician, marking the transition between the end of the Brasiliano orogenic cycle (850–500 Ma) and the cratonization of the South American platform after the orogenic activities. The Brasiliano orogeny, or Brasiliano cycle, encompasses collisional events that occurred during the Neoproterozoic, shaping the western part of the Gondwana supercontinent. This orogeny is considered the primary geological process that structured the Brazilian landscape. These rocks served as a substrate for the formation of sedimentary and volcanic rocks, exposed in the central and western parts of Paraná, that accumulated in the intracratonic sedimentary basin of Paraná, from the beginning of the Ordovician period to the Early Cretaceous. In the Upper Cretaceous, sedimentary deposits accumulated in the northwest of the state in the Bauru Basin. During the Cenozoic, unconsolidated continental and marine sediments formed, partially covering the older units.

The limited specific legislation on the conservation of abiotic heritage in Brazil mainly consists of legal tools for the preservation of areas or sites as cultural, historical, or biodiversity heritage, or as part of Conservation Units¹ (CUs).

There was no record of systematic and objective initiatives dedicated to geoconservation in Brazil until 1980 (Pereira 2010). The first Brazilian initiative to compile a national inventory occurred in 1993 when the National Department of Mineral Production (DNPM), now the National Mining Agency (ANM), collaborated with the United Nations Educational Scientific and Cultural Organization (UNESCO) to inventory sites to be included in the World Geological Heritage List. It was not until 1997 that a systematic inventory of national geological heritage began with the establishment of the Brazilian Commission on Geological and Paleobiological Sites (SIGEP) (Schobbenhaus *et al.* 2002).

The results of SIGEP's work were published in three volumes (Schobbenhaus *et al.* 2002; Winge *et al.* 2009; Winge *et al.* 2013), documenting 116 geosites, 11 of which are in the state of Paraná. However, since 2012, SIGEP's activities have been suspended because the organization lacks the authority to impose legal measures for the conservation of the selected geosites. This has led to a halt in its activities until a legal solution is reached. Another issue about SIGEP's actions, pointed out by Pereira (2010), was the lack of objective criteria for evaluating nominations and their national ranking to ensure that this set of geosites could truly represent Brazil's geological heritage.

Some state geological services have developed programs to install interpretive panels at well-known geological or tourist sites in their territory to raise awareness about geological, geomorphological, and paleontological aspects. In Rio de Janeiro, the "Geological Trails" project, developed by the Geological Service of Rio de Janeiro (DRM-RJ), was a pioneer in this type of sci-

1- Conservation Units are protected areas established to preserve natural resources and cultural heritage. They have special administrative regime, to which the adequate protection guarantees apply according to the National System of Conservation Units of Nature (Sistema Nacional de Unidades de Conservação da Natureza – SNUC). There are two types of conservation units, the Full Protection Units (Ecological Station, Biological Reserve, National Park, Natural Monument and Silvester Life Refuge) and Sustainable Use Units (Environmental Protection Units, Relevant Ecological Interest Areas, National Forests, Extractive Reserve, Fauna Reserve, Sustainable Development Reserve and Private Natural Heritage Reserve). Source: ICMBio (2023).

entific outreach. Since 2001, they have installed 103 panels in 28 municipalities across the state. In Paraná, a similar project called “Geological and Paleontological Sites of Paraná” was developed by the now-defunct Geological Service of Paraná (Mineropar). Similar projects have been developed in São Paulo, “Geological Monuments of the State of São Paulo”; Bahia, “Geological Trails of Bahia”; and Rio Grande do Norte, “Geological Monuments of Rio Grande do Norte” (Mansur *et al.* 2013). These initiatives primarily focused on communication but also aimed to raise awareness about the importance of these geological sites in terms of geoconservation goals.

The “Geoparks of Brazil” project, another notable initiative in Brazil, was established in 2006 by the Brazilian Geological Service (CPRM-SGB). It aimed to identify, describe, and assess the national geological heritage by identifying regions with the potential to create geoparks. The results were published in 2012 in the book “Geoparks of Brazil: Proposals” (CPRM 2012), which presents an inventory of 17 territories with 362 selected geosites.

CPRM-SGB developed an application called GEOSSIT (Rocha *et al.* 2016) to standardize the registration of geosites, with the goal of identifying and evaluating Brazil’s geological heritage. The application was developed based on the methods proposed by Brilha (2005, 2016) and García-Cortés & Carcavilla Urquí (2009).

São Paulo (Garcia *et al.* 2018) and Paraná (Xavier *et al.* 2023) are the only two Brazilian states that have inventories of geological heritage based on their scientific value. A significant portion of inventory work in Brazil has focused on the central-southern part of the country and some parts

of the northeast. The northern and central-western regions show the least evidence of geological heritage inventory studies in the country. The same situation was reported by Pereira (2010) regarding the registration of geological sites of interest by SIGEP.

Geoconservation initiatives in Paraná

There have been concerns about the conservation of nature in Brazil since the mid-20th century. The concluding remarks of a classical work on the Caiuá sandstones (Maack 1941) are in themselves a pioneer ecological manifest. The author affirmed:

“Having finished my considerations, I wish to mention, as a grateful admirer of the natural beauty of the State of Paraná, that the people of the state care to avoid the destruction of the breathtaking natural aspect and nature’s life in the State of Paraná, but indeed stay preserved intact there, where they do not hinder the working man. I cannot imagine a more adequate region for a park dedicated to the protection of the hunt animals of the State of Paraná than the low and not very fertile zone in the Upper São Bento – Caiuá sandstone region on both margins of the Ivaí River, which is at present the last refuge of the hunt animals. Henceforward we should awaken this sole wish in the population: more protection for the hunt and the forest!”²

Among the first nature conservation actions implemented in the state of Paraná the creation of the Environmental Defense and Education Association (Associação de Defesa e Educação Ambiental; ADEA 2023) in the 1974 stands out, idealized by the geologist João José Bigarella (1923–2016). His work paid special attention to the Atlantic Forest, which mainly occupies the Serra do Mar in Paraná. He also acted in the discussions and fight

2- Free translation by the authors. In the original: “Finalizando minhas considerações, eu desejo ainda mencionar, como grato admirador das belezas naturais do Estado do Paraná, que o povo do Estado tem o cuidado de evitar a destruição do deslumbrante aspecto natural e da vida da natureza no Estado do Paraná, mas sim fiquem conservados intatos lá, onde não estorvam o homem trabalhador. Não posso imaginar uma região mais adequada para um parque de proteção aos animais de caça no Estado do Paraná do que a zona baixa e pouco fértil na região do arenito de São Bento superior - Caiuá em ambas as margens do Rio Ivaí, a qual hoje é o último refúgio dos animais de caça. Por isto devíamos despertar na população o desejo: mais proteção à caça e à floresta!”

against regional geological erosion (Bigarella & Mazuchowski, 1985).

At the end of the 1990s, the State Geological Service (Mineropar) began to develop the project entitled “Geological and Paleontological Sites of Paraná”, where the main action was the installation of 48 panels with geological information in 21 locations of geological interest. In addition, four sites of geological interest were registered by the Secretariat of Culture of Paraná, legally integrating them as part of the state’s natural heritage (Guimarães *et al.* 2013). Mineropar also published a guide associating geology with tourism, entitled Geotourism in Curitiba, indicating the origin of the rocks found in the urban landscape (Liccardo *et al.* 2008).

In the early 2000s, the Brazilian Geological Survey (CPRM) created the Brazilian Committee of Geological and Palaeobiological Sites (Comissão Brasileira de Sítios Geológicos e Paleobiológicos – SIGEP) (Schobbenhaus *et al.* 2002). It was responsible for cataloging more than a hundred geosites throughout Brazil, 13 of which are in Paraná.

Another initiative of CPRM, Brazil’s Geoparks Project (Projeto Geoparques do Brasil), also created in the early 2000s, promoted the evaluation of the geological heritage within potential national geoparks. In the state of Paraná, there are two national geopark proposals: one in the eastern portion known as Campos Gerais, and the other in the Upper Ribeira Valley, situated along the border between the states of Paraná and São Paulo (Schobbenhaus & Silva 2012). More recently, a protected area in Prudentópolis, in the central-southern region of the state, was implemented.

There are three research groups registered in the Brazilian National Council for Scientific and Technological Development (CNPq) currently active in Paraná: the Geoconservation and geological heritage (Geoconservação e patrimônio

geológico) group, associated with the Graduate Program in Geology at the Federal University of Paraná, the ROTAGEO, research group which studies the natural and cultural heritage of Campos Gerais, the region in the center-east of Paraná and the Geotourism and geoparks (Geoturismo e geoparques) group, both associated with the Graduate Program in Geography at the State University of Ponta Grossa.

Among activities developed by the Geoconservation and Geological Heritage Group associated Federal University of Paraná (UFPR), worthy of particular attention was the creation in 2018, in association with the City Hall of Curitiba and the UFPR Natural Sciences Museum, of a Relevant Ecological Interest Area (Área de Relevante Interesse Ecológico – ARIE) based on its scientific relevance in paleontology and stratigraphy. Until then, there were only two documented findings of continental mammal fossils from the Paleogene in Brazil, at Itaboraí (Rio de Janeiro) and Taubaté (São Paulo) (Sedor *et al.* 2022). The location, named “Curitiba geosite/Guabirotuba Fm. paleontologic park” (Geossítio de Curitiba/Parque paleontológico Fm. Guabirotuba), is in the outskirts of Curitiba, the state’s capital. It is the only known fossiliferous site of the Curitiba Sedimentary Basin (Vieira & Fernandes 2020). It is rich in fossils dated approximately to 40 Ma, including invertebrates, fish, reptiles, birds, and mammals.

The first geo.day in Paraná in 2019 had the objective of communicating geodiversity and the importance of its conservation to society. The event took place at Ilha do Mel, on the coast. It was conceived by the UFPR Geoconservation and Geological Heritage Group, in partnership with undergraduate students from the Tutored Education Program (Programa de Educação Tutorial – PET) from the UFPR Geology Undergraduate Course and from the extension project Geosurf – Paraná branch. Following it, three other geo.days were

organized in the state. In 2021 the second geo.day of Paraná was part of the first Brazilian geo.day, which took place in various cities across Brazil. Social distancing implemented as part of the measures against the COVID-19 pandemic defined the format as virtual tours to the Pedreiras and Tanguá parks, former Atuba Complex migmatite quarries, which were transformed into municipal parks.

The UFPR Geoconservation and Geological Heritage Group have been taking part in activities in the Art, Culture and Literature Week (Semana de Arte, Cultura e Literatura) hosted annually by the City Hall of Curitiba, offering educational workshops for teachers from the municipal network of schools for children from ages 6 to 11. In the workshops, concepts such as geodiversity, geological heritage, geoconservation and its implementations in daily life are presented, using examples from the city of Curitiba and the school's surroundings.

Other important initiatives related to research and essentially academic actions are the regional scale inventories, methodological studies applied

to karstic terrains, interpretative track proposals, and motivation research (e.g., Moreira *et al.* 2019; Folmann 2020; Pontes *et al.* 2021; Rapanelli *et al.* 2021; Massuqueto *et al.* 2022).

Inventory of the Geological Heritage of Paraná

After São Paulo (Garcia *et al.* 2018), Paraná was the second state in Brazil to have an inventory and quantification of its geological heritage (Xavier *et al.* 2021; Xavier *et al.* 2023), following the steps proposed by Brilha (2016) for territories with hundreds of thousands of square kilometers.

Some methodological adaptations were made for the geological heritage of Paraná, by including a type species option in the criteria type location; cultural and ecological diversity in educational and touristic values; anthropogenic vulnerability and natural fragility for vulnerability assessment; and carrying capacity criteria (Xavier *et al.* 2021; Xavier 2022).

The final list of geosites amounts to 76 entries that document the geological heritage of Paraná (Fig.

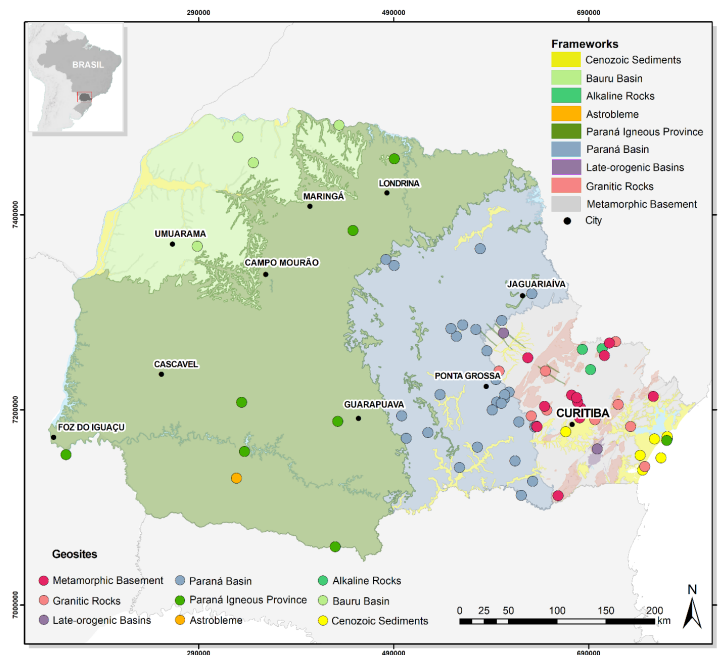


Figure 1. Geological frameworks and location of the geosites that integrate the geological heritage inventory of Paraná. Source: Xavier et al. (2023).

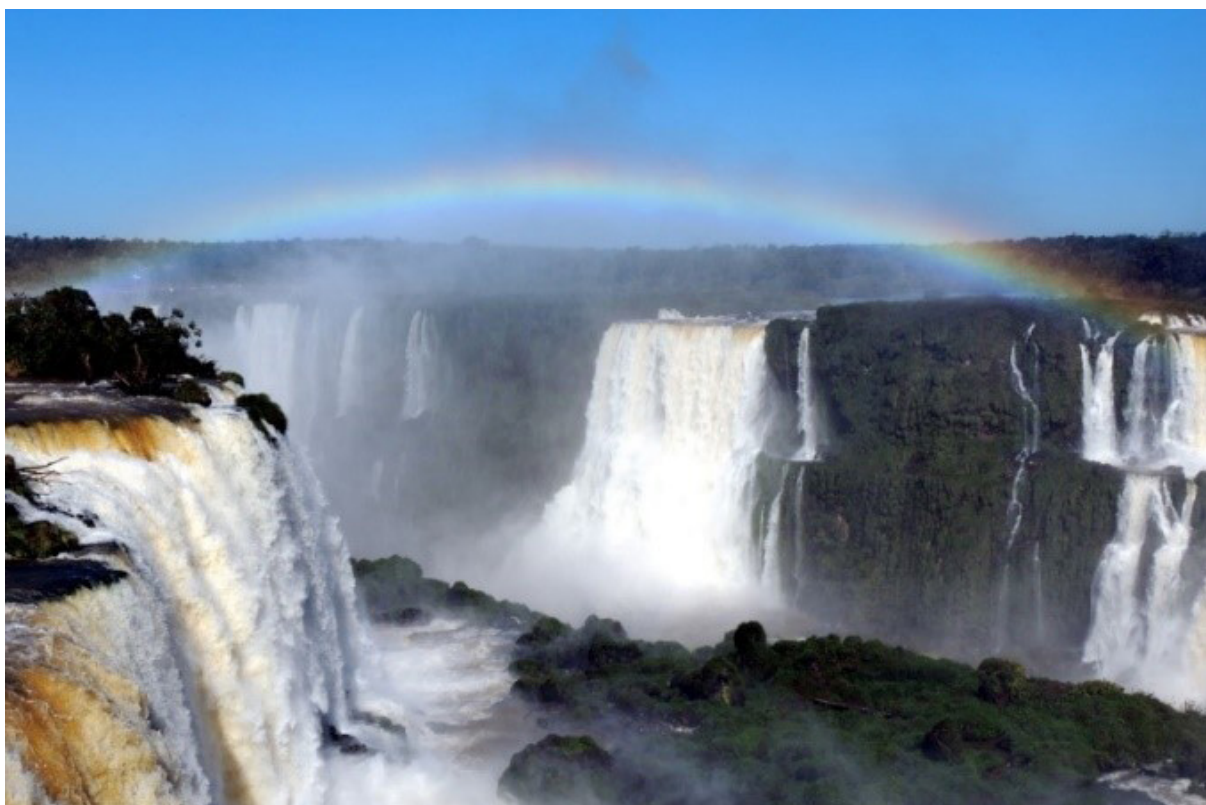


Figure 2. Iguazu Falls basalt (Lower Cretaceous), Geosite of the Paraná Geoheritage. The geosite is located inside the Iguazu National Park, a Full Protection Unit of the System of Conservation Units (SNUC) in Brazil. Location: Foz do Iguazu municipality.

1). These include previously known locations of international fame because of their exuberant scenic beauty, such as the Iguazu Falls basalt geosite (Cretaceous, Fig. 2).

In terms of the current state of preservation, most geosites (73%) have no statutory protection, as only 12% are within conservation areas where sustainable use is allowed. Approximately 5.3% of the geosites have full protection according to the Federal Law 9.985/2000, which supports the Brazilian System of Protected Areas, and 10.5% have mixed protection (both sustainable use and full protection) (Xavier 2022; Xavier *et al.* 2023).

The geosites of lowest vulnerability are inside Full Protection Conservation Units, or within National or State Parks. They are listed as protected areas or exist within Sustainable Protection Conservation Units. As there is no specific legislation

to safeguard geological heritage in Brazil, Law 9.985/2000 can be used as a serviceable alternative for conservation (Xavier *et al.* 2023).

In the following sections, we present some of the most important geoconservation initiatives taking place in the state of Paraná.

Curitiba Sedimentary Basin geosite, a Pioneer Experience

In Brazil, most places or areas of relevant geological interest are protected not due to their geological elements, but because they are within Conservation Units often created to protect local biodiversity. The Curitiba Sedimentary Basin geosite (Fernandes *et al.* 2016; Sedor *et al.* 2017) was a successful geoconservation experience, pioneering in Brazil, as it is protected by municipal decree for its paleontological and stratigraphical scientific interest.

In 2015, the UFPR Geoconservation and Geological Heritage research group initiated a dialog with the Municipal Secretary of Environment of the City Hall of Curitiba, stating the importance of protecting an area with fossils of exceptional scientific value within an urban zone. In 2018, the mayor created a 160 thousand square meter park as a Relevant Ecological Interest Area (Área de Relevante Interesse Ecológico - ARIE). The ARIE is a category of the National System of Conservation Units for units of sustainable usage. The decree considers the necessity to conserve, value and communicate the geosite as part of the geological and paleontological heritage of the city of Curitiba. Scientific research will be permitted and supported if it is authorized by the Management Board, follows the site's Management Plan, and in context of the competencies of the State and the Union.

The Management Board responsible for the administration of the ARIE can receive resources or donations of any type, national or international, with or without charge, from private or public organizations, or from individuals who wish to

collaborate with its conservation. The communication of the geosite creation decree in a public event stimulated local media, which responded enthusiastically, and this helped to embed ideas of geoconservation in the minds of public administrators and society at large.

Cruzeiro do Oeste Paleontology Museum

The “Alexandre Gustavo Dobruski” Cruzeiro do Oeste Paleontology Museum (COPM) was founded in 2019 (Municipal Law 007/2019) following the discovery of *Vespersaurus paranaensis*, the first dinosaur from Paraná (Langer *et al.* 2019). Currently, the COPM is linked to the Cruzeiro do Oeste Secretary of Economic Development, Tourism, Science and Technology. Part of this single fossiliferous site is the property of the city hall and has restricted access. After the discovery of the lizard *Gueragama sulamericana* (Simões *et al.* 2015), the city hall created the Cruzeiro do Oeste Palaeontology Laboratory, appended to the Municipal Forum of the city (Fig. 3A, B), for the development of palaeontological research.

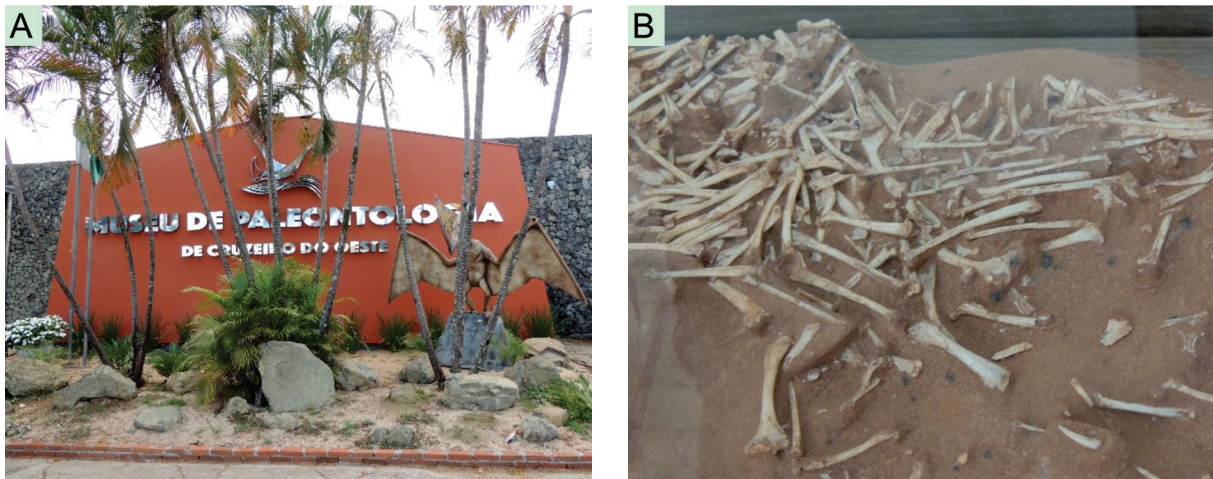


Figure 3. A) Main building facade of the Municipal Museum of Paleontology of Cruzeiro do Oeste. B) Its collection includes bones from two pterosaurs, two dinosaurs and a lizard. Pterosaur bones were found in bone beds (Geosite of the Paraná Geoheritage), which constitute one of the rare occurrences of this type of deposit in the world. Exposed bone bed from the collection. Location: Cruzeiro do Oeste municipality.

Currently, the University of São Paulo/Ribeirão Preto supports the museum through the installation of a paleontological research station. The area where the rocks are directly exposed was covered for its protection from weathering and erosion, and to provide more comfort for researchers working at the site. At present, it awaits fencing and the construction of research support facilities. The excavations will be conducted with lithofacies control, which will allow its use for training and education. Five species have been discovered so far. The museum exhibits specimens of two, the pterosaur *Caiuajara dobruski* (Manzig *et al.* 2014) and the dinosaur *Vespersaurus paranaensis*.

In terms of valorization and communication of its collection, the COPM distributes leaflets and installs interpretative panels about the fossils and the history of the municipality of Cruzeiro do Oeste. The museum promotes activities with schools, such as guided visits and training for teachers. It also maintains a social media profile on Instagram. Some city squares exhibit replicas of the species discovered at Cruzeiro do Oeste. Other communication initiatives stem from local commerce and industry, such as selling pastries in the shape of pterosaurs and the recent release of special labels for the cream cheese *Crioulo*, a large dairy industry based in the county, highlighting the discovery of the paleontological site. In 2022, the museum had an exhibition of replicas and panels as a celebration of the county's anniversary, expected to be repeated in the future.

Conservation

Geoconservation is carried out in five phases: inventory, quantitative assessment, conservation, interpretation, and promotion, and monitoring of sites (Brilha 2016). The State of Paraná has finished the first two phases (Xavier *et al.* 2021; Xavier 2022; Xavier *et al.* 2023).

Regarding conservation, the geosites are in vari-

ous states. Most of them are very vulnerable and without any form of legal protection. Only those within Conservation Units of federal or state jurisdiction have effective protection. Among them, there is a very unusual case, the Curitiba Sedimentary Basin geosite, which is protected under municipal law. Overall, locations of geological interest are protected by their location within zones of high biodiversity, considered important by Brazilian legislation, hence at a federal level.

The vulnerability assessment of currently unprotected sites is a priority geoconservation measure for the management and monitoring of the geological heritage of Paraná. The use of listing as a legal resource, as allowed by Brazilian legislation, has been used a few times in the state. The following places are listed: 1) Serra do Mar, in the eastern region of the state (Coast: Antonina, Guaraqueçaba, Guaratuba, Matinhos, Morretes and Paranaguá; Curitiba Metropolitan Area: Campina Grande do Sul, Piraquara, Quator Barras, São José dos Pinhás and Tijucas do Sul); 2) São Luiz do Purunã ichnofossils (Devonian), in Balsa Nova; 3) Vista Alegre astrobleme, in Coronel Vivida; 4) Witmarsum glacial striations (Permian-Carboniferous, Fig. 4A, B); 5) Ilha do Mel, where the Ilha do Mel Isthmus (Holocene, Fig. 5A), Ilha do Mel incipient dunes (Holocene), Ilha do Mel dune (Pleistocene) and Gruta das Encantadas dyke (Lower Cretaceous, Fig. 5B) geosites are found, in the county of Paranaguá; 6) State Park of Vila Velha, where the Vila Velha ruiniform sandstone (Carboniferous, Fig. 6) and the Lagoa Dourada Senile Cave rocks (Silurian-Devonian) geosites are found, in Ponta Grossa; 7) the Pinheiro de Pedra fossiliferous geosite (Permian, Fig. 7), in Prudentópolis; and 8) Gruta da Lancinha, in Rio Branco do Sul (PARANÁ, 2023, Fig. 8). Listing as a legal instrument for protection is deemed effective, primarily because it can restrict access to and utilization of the designated area. Any instances of damage to heritage are promptly addressed through protec-

tive measures instituted by the Public Ministry. Nevertheless, the potential impediment that listing may occasionally pose to geoconservation efforts remains a subject of ongoing debate within the

scientific community, given that the primary aim of listing is preservation rather than active conservation.

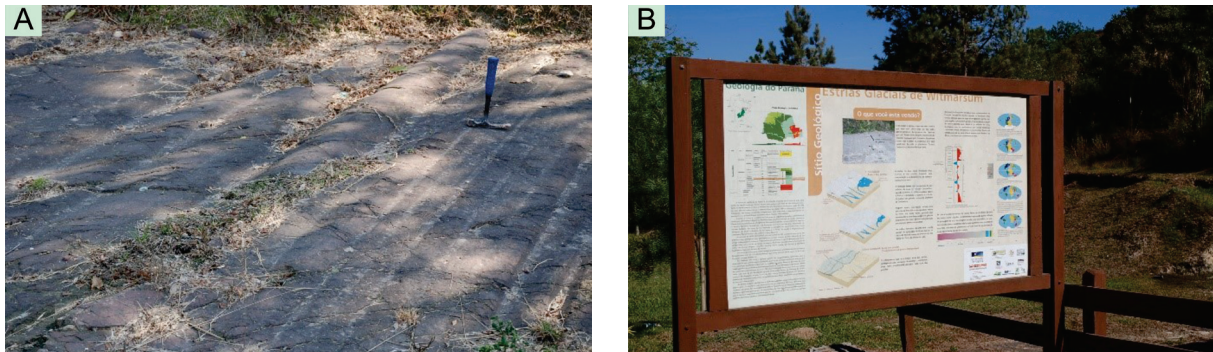


Figure 4. Witmarsum glacial striations on sandstones (Permian-Carboniferous), A) Geosite of the Paraná Geoheritage. B) Interpretive geology panel, installed by the project Geological and Paleontological Sites of Paraná, of Mineropar now-defunct Geological Service of Paraná. The geosite is protected as a geological site by the Paraná State Department of Culture. Location: Palmeira municipality.

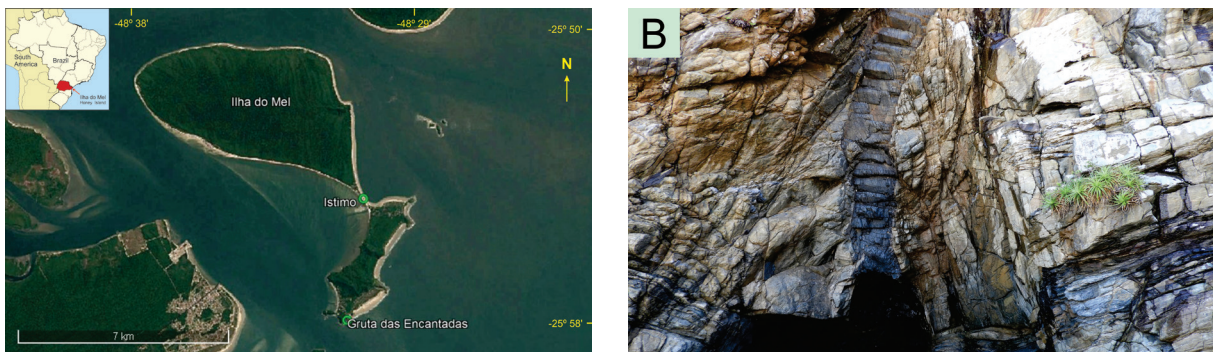


Figure 5. Ilha do Mel (Holocene), Geosite of the Paraná Geoheritage). A) Aerial view of the island, where the Holocene isthmus can be seen. Google image obtained on September 29, 2020. B) Gruta (cave) das Encantadas, showing a Cretaceous diabase dike intruded into the pre-Cambrian basement. The isthmus and the cave are protected as a geological site by the Paraná State Department of Culture. Paranaguá municipality.



Figure 6. Vila Velha ruiniform sandstones (Carboniferous), Geosite of the Paraná Geoheritage. State Park of Vila Velha, full conservation unit created by the Department of Historical and Artistic Heritage of the State of Paraná in 1966. A) iconic feature of the park, known as “cup”, B) general view of the plateau formed by the set of ruin-like features. Ponta Grossa municipality.



Figure 7. Pinheiro de Pedra petrified trunks (Permian), Geosite of the Paraná Geoheritage. Fossil trunks of coniferous trees from the Glossopteris Flora, typical of the Permian period, of the Teresina Formation. The geosite is protected as a geological site by the Paraná State Department of Culture. Location: Prudentópolis municipality.



Figure 8. Gruta da Lancinha, Geosite of the Paraná Geoheritage. Cave developed in Neoproterozoic metadolomites/ stromatolitic marbles, interbedded with quartzites and rhythmic phyllites, from the Capiuru Formation. The geosite is protected as a geological site by the Paraná State Department of Culture. Location: Rio Branco do Sul municipality.

At present, the Curitiba Sedimentary Basin geosite ARIE (Fig. 9) is awaiting the creation and naming of its management council by the City Hall of Curitiba. After this phase, the next geoconservation actions to be implemented are 1) definition of guidelines and legal protocols for managing the geosite; 2) definition of techniques for the physical conservation of the area; 3) forming of partnerships with institutions involved with its future management; and 4) installation of the minimum infrastructure required to support research. In addition, the following geoconservation actions should be implemented in the future: 1) promotion of interactions with the neighboring community; 2) production and publication of scientific and educational materials; and 3) promotion of educational, science communication and teaching activities. The Curitiba Sedimentary Basin geosite ARIE should also be integrated as a small “satellite museum” of the yet-to-be-made Natural History Museum of Curitiba, whose construction was approved in 2021.

The research station under implementation by the Paleontology Museum of Cruzeiro do Oeste is another pioneer experience in Brazil. The station will include systematic scientific research and scientific communication efforts focused on raising the awareness about the importance of geoconservation. Understanding and appreciating geodiversity can serve as a catalyst to foster a sense of connection among residents and visitors, accentuating the significance of the paleontological and paleoenvironmental archives of Cruzeiro do Oeste. This underscores the vital importance of conserving sites with remarkable geological significance that document the evolutionary history of the region. The museum has an important flux of visitors, especially from schools from the public network. At present, it is also concerned with identifying the interests and geoscience knowledge of visitors with surveys directed to the improvement of the shape and content of the information offered during the visits.



Figure 9. Curitiba Basin (Paleogene), Geosite of the Paraná Geoheritage. Immature sands with cross-stratification, with carbonate cementation horizons (calcretes), interspersed with muddy facies. It is an important paleontological site (urban conservation unit, protected by law), one of the few places where Paleogene vertebrate fossils occur in Brazil. Location: Curitiba City.

Basic Education and Conservation

Even though the topic is not within the main objective of this work, we believe it is important to discuss the near absence of geological content in the guidelines and curriculums of the primary and secondary schools, both in Paraná and in Brazil as a whole. This directly contributes to low awareness in Brazilian society of the need to conserve natural heritage and, especially, geological heritage.

There is no guideline or even an explanatory note specifically on geology in the curriculum guidelines for primary education from the Basic Education Department of the State Secretary of Educa-

tion of Paraná (PARANÁ 2008). In the geography guidelines, there is a vague reference to geology in the structuring content “socio-environmental dimension of the geographic space”, which includes, among other topics, the relationships between societies and nature, the environmental crisis, and the physical aspect of the geographic space. In the module expectations notebook, there is a mention of “areas of environmental protection for the preservation of natural resources”, what could be related to notions of geoconservation. In the science curriculum guidelines, the theme of “matter” includes the study of Earth’s formation and matter transformation by natural phenomena, among others. Another relevant theme is biodiver-

sity, which could be used as a basis for teaching about geodiversity. Besides that, there is an also a brief mention of the study of the evolution of living beings, which is linked to paleontology. In the expectations notebook, knowledge of the geological eras and biogeochemical cycles is expected from the students.

As for primary education, there are no specific guidelines about geology for secondary education in the curriculum guidelines of the Basic Education Department of the State Secretary of Education of Paraná (PARANÁ 2008). In the Biology curriculum guidelines, concepts from geology are mentioned when discussing evidence of changes in Earth's crust and the extinction of species. Biodiversity is considered as a structuring content in the Science guidelines, in which there are references to the geological eras. In the chemistry guidelines, geology is discussed in the structuring content "biogeochemistry and geochemistry". The latter refers only to the influence of living beings on the chemical composition of the Earth, the interactions between the hydrosphere, lithosphere and atmosphere, and the exploration of biogeochemical cycles. The term "biogeochemistry" is used to refer to the complex set of relationships between living beings and inanimate matter within the biosphere. Besides that, changes in Earth's properties through time are mentioned to approximate or connect topics from biology, geology, and chemistry.

In the most recent version of the National Common Curricular Basis (Base Nacional Comum Curricular – BRASIL 2018), of the Education Ministry of Brazil, geology is vaguely alluded to as one of the many processes that affects life on Earth:

Similarly, the comprehension of what is sustain-

ability assumes that the students, in addition to understanding the importance of biodiversity for the maintenance of ecosystems and the dynamic socio-environmental balance, can evaluate consumption habits that involve natural and artificial resources, and identify the relationships between atmospheric, geologic, astronomic, and social processes with the necessary conditions to sustain life on the planet³.

In the National Common Curricular Basis document, geology is restricted to brief mentions of abilities included in the science curriculum of the 6th grade. It considers Earth and the Universe as a "thematic unit", and the shape, structure, and movements of Earth as a "knowledge objective". Lastly, it considers the identification of the different layers that structure the planet Earth (from the internal structure to the atmosphere) and their main characteristics, the different types of rocks, associating the formation of fossils to sedimentary rocks in different geological epochs as "abilities".

It is beyond doubt that the almost complete absence of geological knowledge in the guidelines of Brazilian basic education is an old problem. Its solution requires the inclusion of concepts of geology and geoconservation in the curriculum guidelines, as well as the training of educators and the communication of its importance to society.

Conclusions

The Paraná geological inventory and quantification of geosite values provide support for establishing conservation strategies regarding the territory's geological heritage. It also supports the implementation of practical and efficient actions so that the geological heritage will not be lost irretrievably following the lack of responsibility from

3- Free translation by the authors. Inorigin: "De forma similar, a compreensão do que seja sustentabilidade pressupõe que os alunos, além de entenderem a importância da biodiversidade para a manutenção dos ecossistemas e do equilíbrio dinâmico socioambiental, sejam capazes de avaliar hábitos de consumo que envolvam recursos naturais e artificiais e identifiquem relações dos processos atmosféricos, geológicos, celestes e sociais com as condições necessárias para a manutenção da vida no planeta."

the State and civil society.

For the state of Paraná, the next geoconservation phases are conservation, interpretation and promotion, and monitoring. To achieve that, public managers must be well-informed and convinced of the necessity of including conservation in the scope of governmental actions. The actions of the Federal University of Paraná in partnership with the City Hall of Curitiba – which culminated in the creation of a conservation unit solely for geology – is an example to follow.

The increasing number of publications in scientific journals, research outputs, communications in conferences, and the increase in the world network of geoparks, including exposure in the media, shows that there is a movement for convincing and action by society.

These initiatives, however, remain confined to academic research and extension activities by research groups affiliated with the university, the Brazilian Geological Survey, and their geoconservation concepts and activities in recent years. It is our responsibility, as heirs of Earth's heritage, academic researchers, public managers, civil society organizations, and environmental council members, to urge discussion of the importance and necessity of conservation of geological heritage. We must act in a way that promotes the effective implementation of concrete actions.

Lastly, it is crucial to highlight the near absence of geological content in the curriculum guidelines for primary and secondary education, not only in Paraná but also across Brazil. This deficiency directly correlates with a lack of awareness of the imperative need to conserve our natural heritage. Therefore, incorporating geology and geoconservation into school curricula, providing training for educators, and fostering communication with society, are all indispensable strategies to enhance the appreciation and preservation of our natural heritage.

Acknowledgments

The authors extend their heartfelt gratitude to the Geology undergraduates of UFPR and the undergraduate research assistants, Luana Tiemi Moletta, Maiara Fabri Maneia, and Liza Mohana Cavalheiro, for their invaluable contributions to this research. Special thanks also go to the tourism expert MSc Raquel V. Rapanelli for her thoughtful readings and engaging discussions on the manuscript. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) – Finance Code 001. The first author's work is supported by a productivity fellowship from the Brazilian National Council for Scientific and Technological Development (CNPq/Brazil).

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