



OF NATURE, COMPRISED OF A VARIETY OF ENVIRONMENTS, GEOLOGICAL PHENOMENA, AND PROCESSES THAT RESULT IN LANDSCAPES, ROCKS, MINERAL, WATERS, SOILS, FOSSILS, AND VARIOUS SURFACE DEPOSITS. THIS GEODIVERSITY PLAYS A FUNDAMENTAL ROLE IN THE DEVELOPMENT OF LIFE ON EARTH, AND ITS INTRINSIC VALUES ENCOMPASS CULTURAL, AESTHETIC, ECONOMIC, SCIENTIFIC, EDUCATIONAL, AND TOURISTIC ASPECTS (CPRM, 2006).

Through the understanding of geodiversity, it is possible to identify the suitability, potential, and limitations of the physical environment of a given area, considering the various types of land use. Furthermore, through the analysis of the characteristics of rocks, topography, and weathering processes, it provides a more comprehensive understanding of the specific natural landscapes of a region.

This assessment aims to apply geological knowledge to issues related to urban occupation, agriculture, water planning, and management, promoting sustainable development, environmental preservation, and the well-being of society.

The primary beneficiaries are governmental agencies responsible for urban planning and decision-making, regulatory bodies, public and private companies, society, and the overall geoscientific community.

ABOUT THE PROJECT

IT IS WITH GREAT SATISFACTION THAT THE GEOLOGICAL SURVEY OF BRAZIL (SGB-CPRM), in its institutional role of supporting States and Municipalities in the formulation of public policies for sustainable development, continues its series of publications that have been disseminating geodiversity as a tool for territorial planning since 2006.

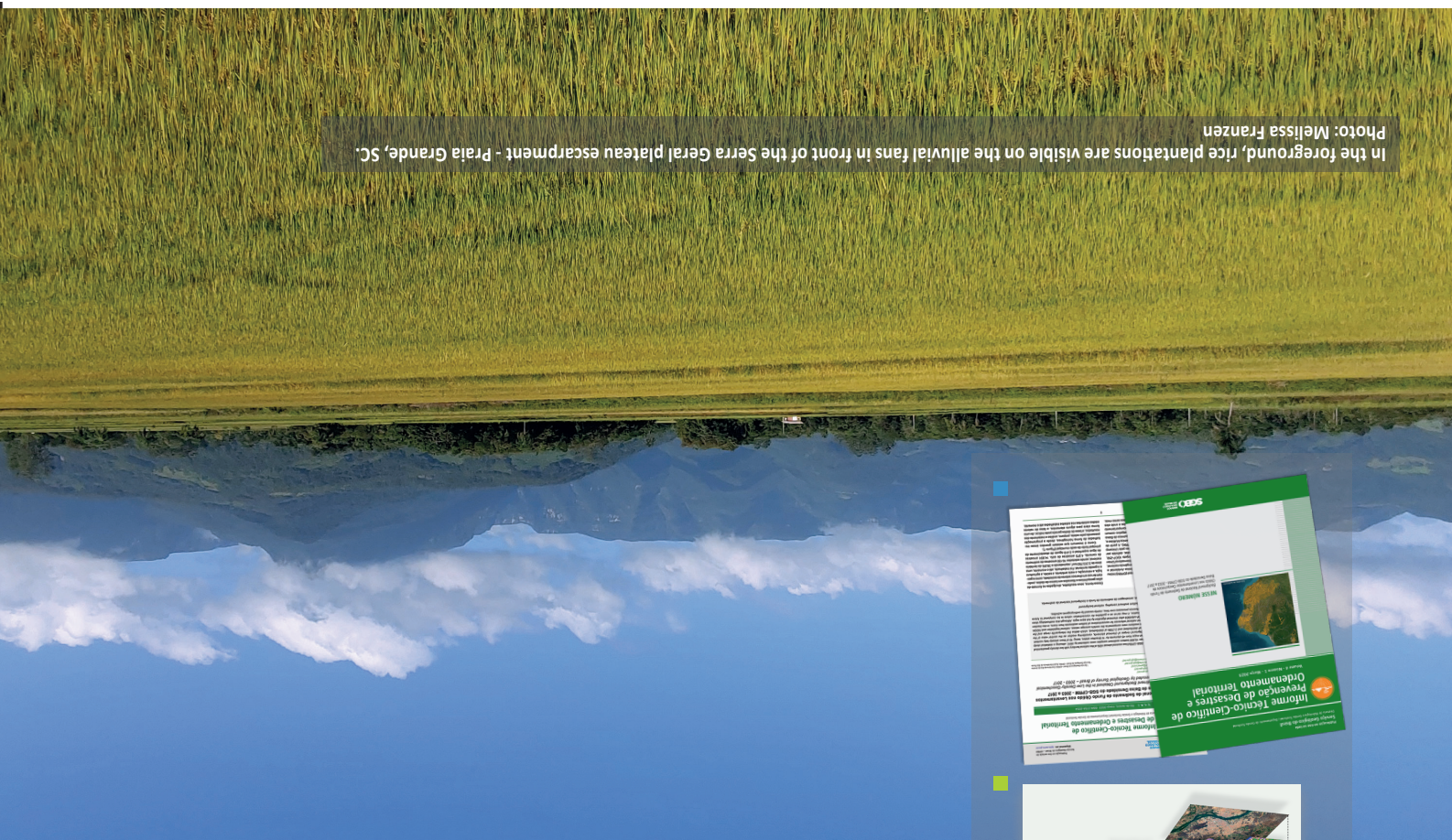
This initiative is based on a multidisciplinary approach involving professionals from diverse backgrounds in geosciences, offering integrated understanding and recommendations regarding the physical complexity of the landscape, and addressing abiotic elements for environmental territorial planning across different regions of Brazil.

Brazil is home to remarkably rich geodiversity. Based on this premise, through integrated analysis of geology and geomorphology (as well as other geoscience topics), geodiversity units are mapped, providing a territorial basis for management focused on urban development, agriculture, water resources, mineral resources, and geotourism.

Given humankind's strong connection to the physical environment, the sustainability of national development necessarily depends on achieving harmony between human needs and the responses of the natural world, without compromising the ability to meet the needs of future generations.

The Geological Survey of Brazil (SGB/CPRM) is honored to contribute—with the effort and expertise of its researchers—to the promotion of territorial planning initiatives that increasingly incorporate geodiversity. The expectation is that this technical-scientific production will be capable of opening new frontiers of knowledge, generating value, and enhancing quality of life for humanity.

Directorate of Hydrology and Territorial Management



■ GEODIVERSITY MAP
Presents the cartography of the geological-environmental units and legends summarizing their respective potential and limitations regarding the following uses: urban occupation, agriculture, water occupation, mineral resources, and geotourism.

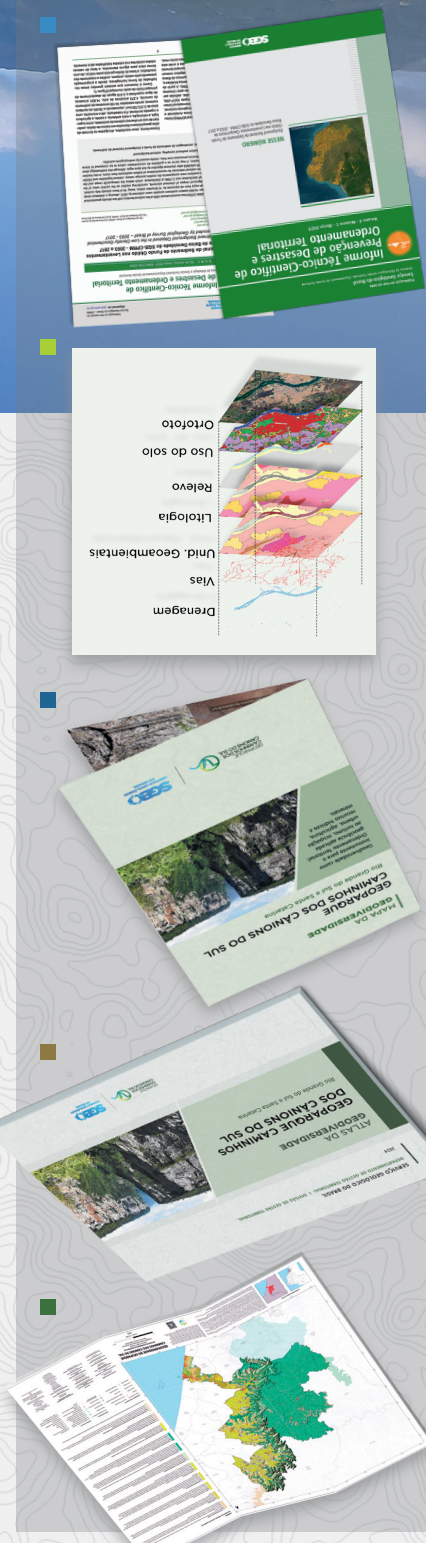
■ DIGITAL ATLAS
A document in A3 format, richly illustrated, which presents the study in detail and accessible language.

■ FOLDER
A document that synthesizes the general aspects of the study, its use, main results and recommended use, as well as scientific events and other journals.

■ GEOGRAPHIC INFORMATION SYSTEM
The data produced by the project are organized within a GIS environment, facilitating spatial understanding and relationships, which are important for planning, decision-making, and information sharing.

■ TECHNICAL REPORT
The results of the work were further developed through the preparation of articles for the Technical-Scientific Report on Disaster Prevention and Territorial Planning of the SGB, the Journal of Geological Survey of Brazil (JCSB), as well as scientific events.

PRODUCTS



GEODIVERSITY MAP

SOUTHERN CANYONS PATHWAYS UNESCO GLOBAL GEOPARK

Rio Grande do Sul and Santa Catarina

Geodiversity as an Instrument for Territorial Planning: Geoscience Applied to Tourism, Urban Occupation, Agriculture, Water Resources, and Mineral Resources



GEOPARQUE CAMINHOS DOS CÂNIÕES DO SUL



SGB
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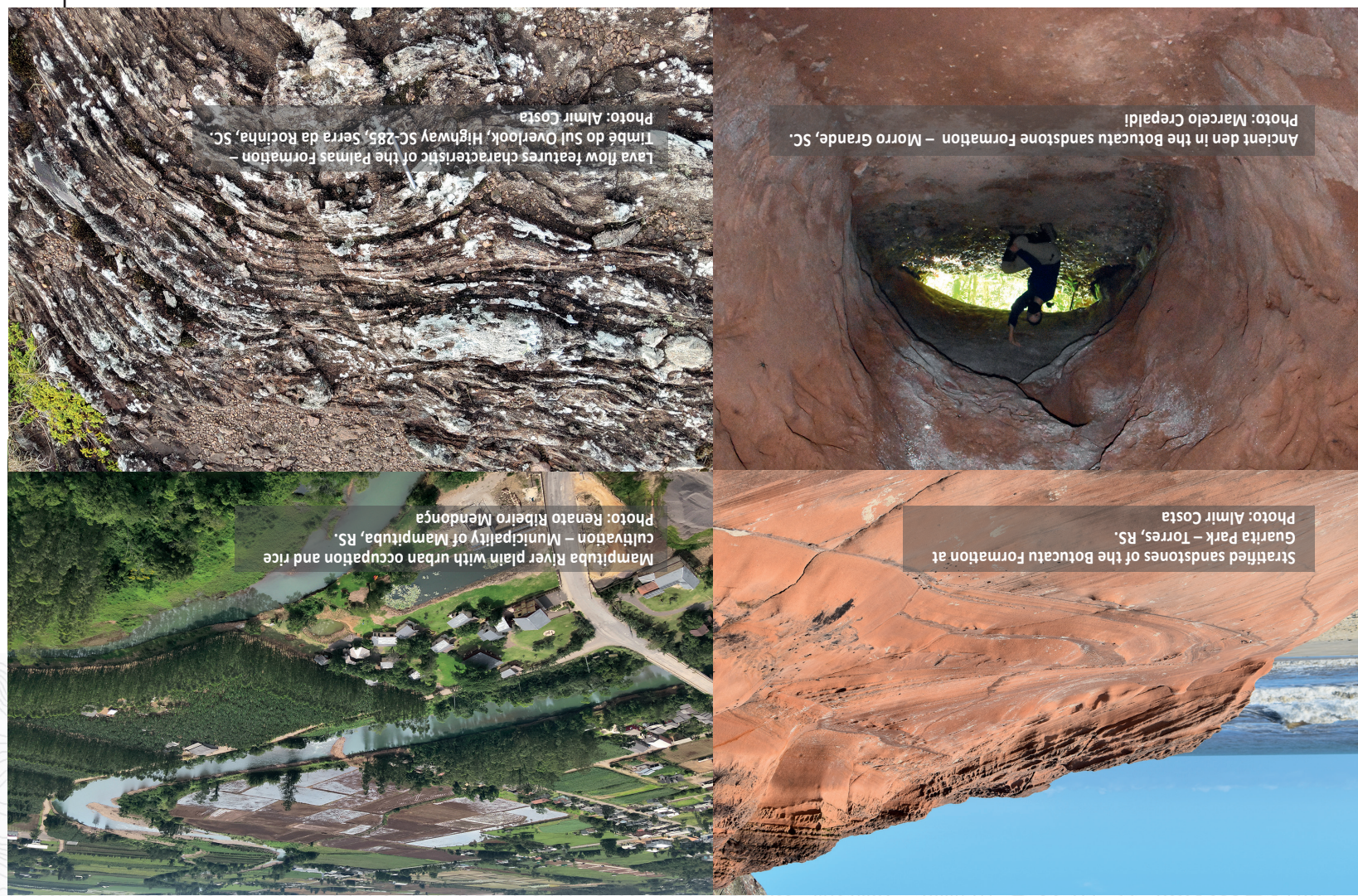
Cover Photo
Cânion do Itaimbezinho,
Parque Nacional de
Aparados da Serra,
Cambará do Sul.
Photo: Almir Costa

WEBSITE

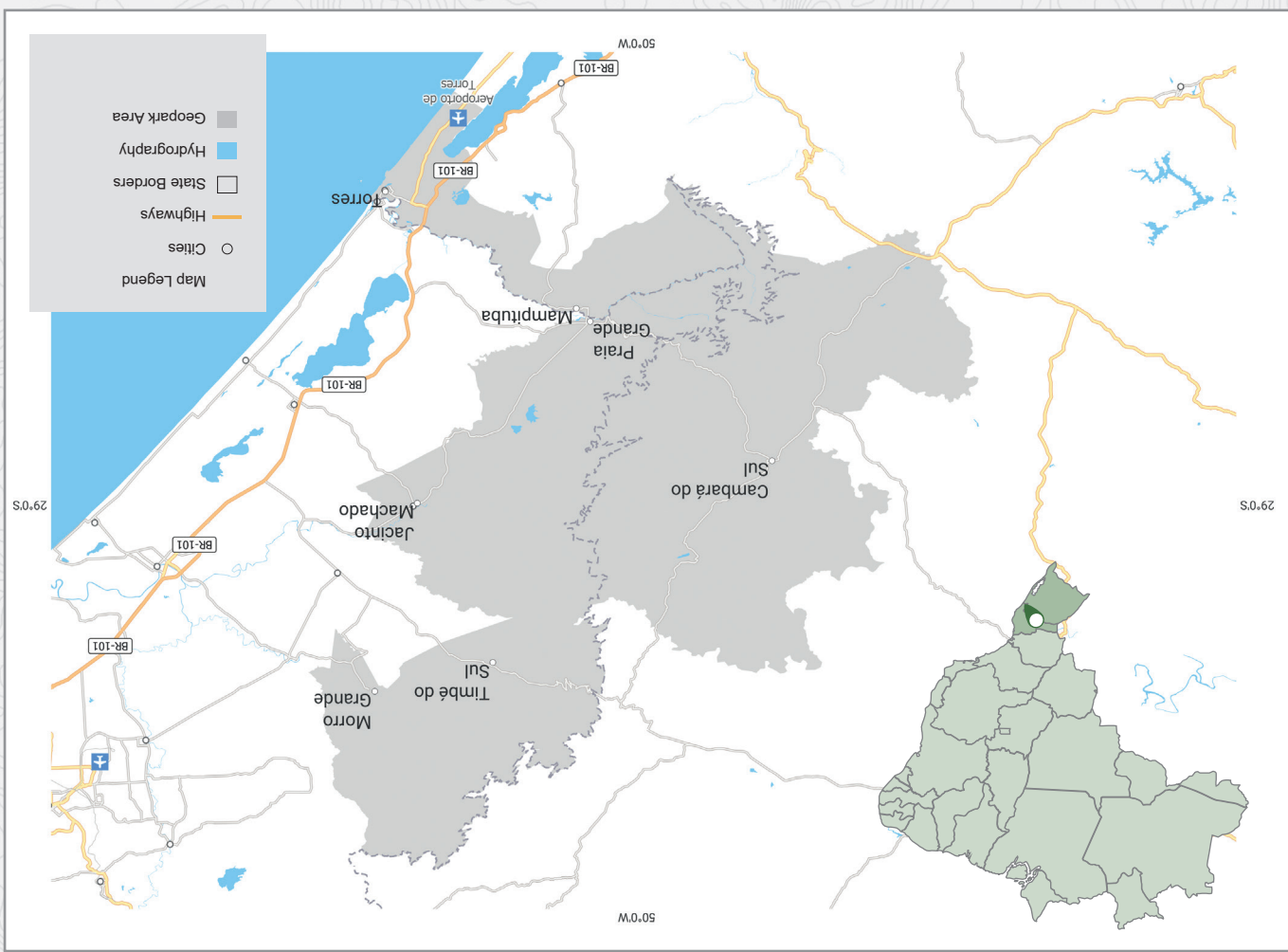


SGB
GEOLOGICAL SURVEY OF BRAZIL
MINISTÉRIO DE MINAS E ENERGIA

GOVERNO FEDERAL
BRASIL
UNIÃO E RECONSTRUÇÃO



Location of the Southern Canyons Pathways Unesco Global Geopark



METHODOLOGY

A METODOLOGIA DE TRABALHO CONSISTE EM REALIZAR and interpreting preexisting data, such as scientific articles, books, websites, geological, geomorphological, and cartographic databases, to generate Geological-Environmental Units, considered a synthesis of the area's geodiversity. The entire dataset is subsequently validated through fieldwork as new information related to water and mineral resources, urban occupation, agriculture, and geotourism is added.

The figure below shows the detailed **METHODOLOGICAL FLOW**.

PRE-FIELD SURVEY	FIELD	POST-FIELD
1 Survey and organization of the available data in GIS – Geographic Information System.	1 Characterization of the Geological-Environmental Units based on geological-geotechnical aspects, surface hydrology, hydrogeology, mineral resources, and geotourism.	1 Interpretation of the field data.
2 Harmonization of the geological map.	2 Evaluation of specific themes, depending on the project (water quality, soil, agricultural potential, among others).	2 Development of the final maps.
3 Development of preliminary Geological-Environmental Units.		3 Corrections in GIS.
4 Creation of preliminary maps (topography, soil, geotechnical issues, etc.).		4 Creation of the Digital Atlas.
		5 Preparation of a technical-scientific report on Disaster Prevention and Territorial Planning.

SGB

GEOLOGICAL SURVEY OF BRAZIL

MINISTÉRIO DE MINAS E ENERGIA

GOVERNO FEDERAL
BRASIL
UNIÃO E RECONSTRUÇÃO

GEODIVERSITY MAP

SOUTHERN CANYONS PATHWAYS UNESCO GLOBAL GEOPARK | Rio Grande do Sul and Santa Catarina

THE ROCKS AND THE LANDSCAPE

THE GEOLOGICAL HISTORY OF THE Caminhos dos Cânions do Sul Geopark (GCCS) spans events that occurred in very distant geological times. It contains exposures of continental sediments and shallow shelf deposits from the Paraná Basin, deposited on the paleocontinent Gondwana, as well as volcanic magmatism from the Serra Geral, deposited on these sediments along escarpments, terraces, and the Serra Geral Plateau. This is in addition to Cenozoic covers that overlie the aforementioned units on a broad plain east of the plateau escarpment.

The landscape is the result of the reworking of the rocks by regressive erosion, triggered by the uplift of the eastern continental margin since the Cretaceous, forming an extensive escarpment trending NNE/SSO.

The sediments produced by the weathering/erosion process were deposited by gravity, occupying the area from the coastline to the base of the escarpments. Thus, in topographical terms, there are two major compartments—the plateau and the plain—whose boundary is defined by the escarpment itself, with elevation differences of over one thousand meters.

These compartments are part of two distinct morphostructural units. The higher compartment, reaching up to 1,300 meters, belongs to the Gondwanan Vulcanosedimentary Basin, while the remaining compartment, with elevations of up to 150 meters, is part of the Quaternary Sedimentary Cover.

MINERAL RESOURCES

THE MINERAL RESOURCES IN THE GCCS are mainly used in civil construction, for highway surfacing, floor and wall coatings, and in various industries.

Refractory clays used in the ceramics industry are already being exploited in the Permian sedimentary rocks of the Paraná Basin, more specifically in the Teresina Formation in Morro Grande, SC and its surrounding areas.

Along the highways that are being paved in the geopark region, the opening and operation of borrow pits is common.

The sandstones of the Botucatu Formation are exploited for the construction of sidewalks, walls, foundations, as well as for terrain retention and supporting foundations. Colluvial-alluvial deposits serve as a source of sand, gravel, and pebbles along the region's watercourses, exemplified by the designated areas for gravel in the Mampituba River, which are used in civil construction.

Areas registered—but not yet exploited—for mineral water and bentonite have been identified by the National Mining Agency (ANM) in the municipality of Torres.

In general, there is a homogeneous and distributed use of mineral resources throughout the Geopark area.

It is essential that the use of the region's mineral resources be carried out in a manner compatible and harmonious with demands for public supply and irrigation, creating a scenario of conscious and sustainable exploration.

SURFACE WATER RESOURCES

THE GCCS IS LOCATED IN THE SOUTH ATLANTIC HYDROGRAPHIC REGION and is situated within four river basins: Taquari/Antas (36%), Araranguá (35%), Mampituba (27%), and Tramandaí (1%). The escarpments act as a watershed divide: in the plateau is located the Taquari/Antas River Basin, and the rivers originating in this region drain towards the interior of the state of Rio Grande do Sul, to the west; in the lower part of the canyons, in the plain area, the rivers flow eastward towards the coast through the Araranguá and Mampituba river basins. Only a portion of the area, specifically the municipality of Torres, is part of the Tramandaí River Basin, which drains towards the southern coast.

The Antas and Tainhas rivers have the highest flow rates from July to October, while in the Manoel Alves and Mampituba rivers, in the plain, the highest flows are observed during the summer months, from January to March.

In terms of the use of surface water resources, the best conditions are observed in the plateau and escarpment areas, while the greatest compromise of surface water resources occurs in the plain regions.

GROUNDWATER RESOURCES

THE POROUS AQUIFERS IN THE GCCS are composed of the sedimentary rocks of the Paraná Basin (Teresina, Rio do Rastro, and Botucatu Formations) and unconsolidated Quaternary sediments. These aquifers cover about 30% of the area and exhibit varying potentials, ranging from low to moderate productivity. In general, the groundwater present in these porous aquifers is potable.

The fractured aquifers make up approximately 70% of the GCCS and are formed by the volcanic rocks of the Palmas, Vale do Sol, and Torres Formations. Their productivity is quite variable depending on terrain conditions and, primarily, on the presence of geological and tectonic discontinuities. Higher groundwater productivity occurs in the Cambará do Sul region. In qualitative terms, its groundwater is generally excellent.

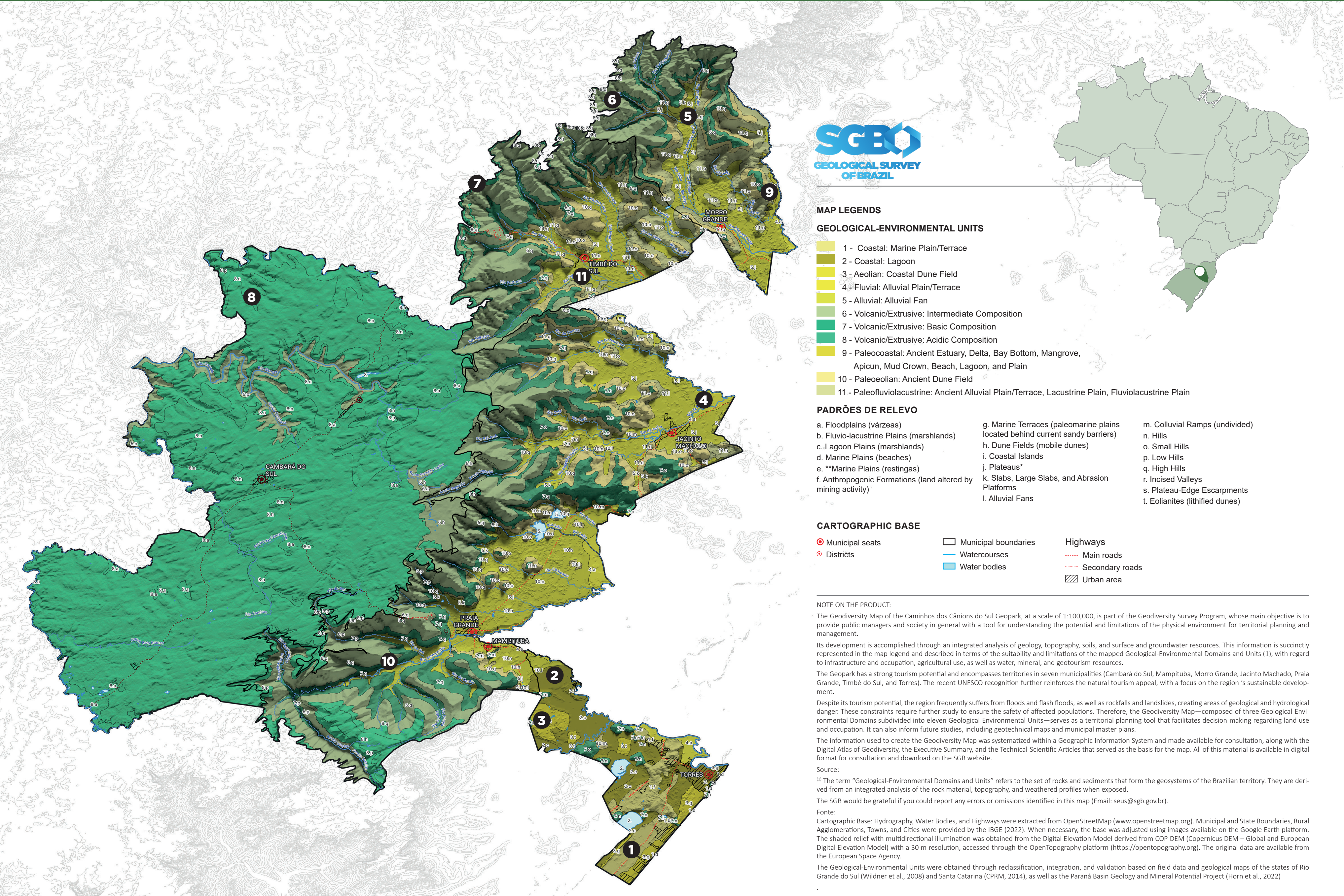
The most common methods for extracting groundwater from the porous aquifers within the GCCS are through hand dug wells and shallow small diameter tubular wells in the plains, as well as the spring capture on hill slopes. In the case of the fractured aquifers, water is extracted via deep tubular wells in areas of higher potential, and by tapping springs in highly dissected and steep regions.

In terms of natural vulnerability, the porous aquifers are the most susceptible to contamination, due to the high permeability and shallow water table.

AGRICULTURAL SUITABILITY

OVERALL, THE REGION OF THE GEOPARK presents good agricultural potential, provided that the suitability of each area—based on its different soil types—is respected. Some areas face issues related to low soil fertility; in some cases, these issues can be easily resolved with fertilizers and amendments, while other areas are more suited for pasture production instead of crop production.

Similarly, there are several areas with shallow soils that should be used exclusively for pastures. Many areas, because they occur in very rugged terrain and/or sandy surface texture, have a high potential for soil loss through erosion and must be used with specific soil management and conservation practices.



1 Coastal: Marine Plain/Terrace

Occurs in 1.4% of the Geopark and constitutes the current and former beach sand deposits in Torres. The rocky shores, Lobos Island, and the breakwaters north of Praia Grande influence coastal dynamics and wave patterns. This area is environmentally fragile and requires ongoing conservation efforts.

2 Coastal: Lagoon

Occupying marshes and marine terraces in the coastal municipality of Torres, this unit covers about 3% of the Geopark area and includes paleolagoons such as Lagoa do Jacaré. The lagoon facies occupy the substrate of current water bodies, such as Lagoa de Itapeva and the small Lagoa do Violão in Torres, with sandy facies predominant in the marginal areas and muddy facies in the more central and deeper parts.

3 Aeolian: Coastal Dune Field

It represents approximately 1% of the total area and consists of fine/very fine sands of quartz composition, well-rounded and well-sorted, which form the dune fields that occur along the entire coast, or even further inland, of the Rio Grande do Sul State. These areas have important ecosystem functions that contribute to maintaining coastal dynamics, playing a key role in controlling erosion, advancing the salt wedge, and recharging the coastal aquifer. They have high scenic value and host several protected areas.

4 Fluvial: Alluvial Plain/Terrace

It occurs in the form of sediments associated with floodplains and river dynamics. They have a very shallow water table, making them highly vulnerable to groundwater contamination and highly susceptible to flooding. They have low occupancy potential and high environmental fragility.

5 Alluvial: Alluvial Fan

It occupies 13% of the Geopark's area and occurs in the form of sediments (sand, clay, and gravel) associated with alluvial fans, colluvium slopes, and slope foothills. The urban centers of Mampituba, Praia Grande, Jacinto Machado, and Timbó do Sul are located within this unit. The soils have good natural fertility. The shallow water table hinders mechanization. Landslides, mass flows, and flash floods are frequent, especially at the foothills of the escarpments.

6 Volcanic/Extrusive: Intermediate Composition

It covers approximately 20% of the Geopark's area and occurs on plateau-edge escarpments and enclosed valleys. It is related to the thick basaltic andesite flows of the Vale do Sol Formation. On the Serra Geral escarpments, brecciated levels (canyons) are visible from a distance and allow the development of vegetation lines. Landslides and rockfalls or rolling are frequent. This area focuses on adventure tourism and the contemplation of the scenic beauty formed by the plateau escarpment

7 Volcanic/Extrusive: Basic Composition

This unit is represented by Torres Formation basalts that occur from the plateau's edge escarpment to the residual reliefs on the coastal plain (high and low hills). The regolith profile is well developed, with predominant red and red-yellow argisols and argillic chernozols, with low resistance to environmental impacts. Landslides and block rollovers are recorded. Adventure and rural tourism are common.

8 Volcanic/Extrusive: Acidic Composition

This unit consists of rhyolites, rhyodacites, dacites, and autobreccias of the Palmas Formation, in plateau and dissected plateau terrain. Its main occurrence is in the municipality of Cambará do Sul. Its soils are shallow and developed, making them suitable for pasture and forestry. They have moderate resistance to environmental impacts. Rural, cultural, and adventure tourism are common, particularly in the various canyons and national parks.

9 Paleocoastal: Ancient Estuary, Delta, Bay Bottom, Mangrove, Apicum, Mud Crown, Beach, Lagoon, and Plain

This unit covers less than 2 km² and occurs in the form of high hills. It consists of the Teresina Formation, characterized by intercalations of fine to very fine sandstone and shale. Clayey soils, low natural fertility, and erosion are predominant. They have mineral potential for the extraction of refractory clays, used in the ceramics industry.

10 Paleolic: Ancient Dune Field

It occupies approximately 6.5% of the Geopark's territory in the form of testimonial hills and plateau-edge escarpments. It consists of sandstone formed in a desert environment and is recognizable in the field by its pinkish-orange hue and extensive cross-stratification. Viewing from viewpoints and visiting paleoburrows dug by extinct animals are common tourist activities.

11 Paleofluvial-Lacustrine: Ancient Alluvial Plain/Terrace, Lacustrine Plain, and Fluvial-lacustrine Plain

It covers approximately 4% of the geopark's area, located on the escarpments at the edge of plateau and hills. It is predominantly characterized by fine-grained, red to reddish-purple sandstone. The soils are predominantly imperfectly drained, with a clayey texture and a darker surface horizon, with low natural fertility and susceptible to erosion and frequent excess moisture. It has potential for tourism, as evidenced by the Rio do Salto and Rio do Tatu waterfalls.

Activities such as livestock farming and reforestation are considered suitable in environments formed on acidic volcanic rocks of the plateaus, while rice farming is more appropriate in soils developed from colluvial-alluvial deposits and in river plains—a practice effectively observed in the vicinity of the Mampituba River. Additionally, banana cultivation on the mid-slopes of Serra Geral, although common in the region, should be more carefully evaluated in view of the steep slopes observed and the potential for inducing erosive processes and mass movements.

The preservation of the forested areas along the escarpments at the edge of the plateau—where the national parks are located—is the best approach for land use and management within the Geopark.

SOIL RESISTANCE TO DIVERSE ENVIRONMENTAL IMPACTS

WITHIN THE GEOPARK AREA, the soils with higher resistance to environmental impacts (medium resistance) are the Cambisols, which occur in the acidic rocks of the plateau in Cambará do Sul and in the colluvial-alluvial deposits along the escarpment base. Similar behavior is presented by the Argisols of medium to high depths and which are found in gentle slopes.

The Red Argisols and Chernozols, which occur in volcanic units on the escarpment and plains, on the other hand, have low resistance to environmental impacts.

The Litholic and Regolithic Neosols, shallow soils found in areas with rolling to mountainous terrain, mainly on plateaus, are considered the least resistant to environmental impacts. Added to this group are Gleysols, which are very poorly drained, and Quartzops Neosols, which are very sandy.

According to the classification of resistance to environmental impacts, it appears that 59% of the area of the Caminhos dos Cânions do Sul Geopark has soils with very low resistance to environmental impacts. This fact highlights the need to adopt environmental conservation and preservation practices.

GEOTOURISM

THE GCCS SHOWCASES AN EXUBERANT and diverse natural landscape, encompassing geological and geomorphological features specific to a region located between the Atlantic Ocean and the Serra Geral Plateau in southern Brazil. The diversity and unique characteristics of this territory are highlighted by the presence of geosites of international significance, such as the Itambezinho and Fortaleza canyons and the Guarita/Morro do Farol Park.

Within the GCCS territory, national and state parks and conservation units play an important role in promoting sustainable tourism and the conservation of natural heritage.

In addition to biodiversity conservation, the other elements that make up the geological substrate (rocky outcrops, beaches, dunes, lagoons, meanders, and river channels) can be appreciated and protected, including a rocky island on the coast, frequented by sea lions.

The presence of waterfalls, canyons, rocky cliffs, and viewpoints, accessed via trails of varying difficulty levels, adds to the area's tourist appeal. Even outside the demarcated perimeter of conservation units, tourists can enjoy waterfalls, viewpoints, canyons, rocky cliffs, hills, caves, paleoburrows, and beaches

LAND USE

OVER THE LAST THREE DECADES (1991 to 2021), the landscape of the GCCS region has undergone significant transformations in land cover, reflecting the dynamism and demands of regional development, combined with the suitability of different soil types.

The systematized information sheds light on important changes in some categories of use over time, with emphasis on the expansion of human activities on natural ecosystems, such as the substantial increase in areas designated for forestry, the migration and expansion of agricultural and livestock activities, and the notable expansion of urban areas.

Sustainable management of these changes is crucial to ensuring the region's economic prosperity, while also protecting the rich biodiversity and geodiversity of local ecosystems.

URBAN OCCUPATION

URBAN SPACES WITHIN THE GEOPARK'S TERRITORY have undergone a considerable change in terms of occupied area over the last three decades (1991 to 2021), increasing from 16.94 km² to 28.17 km². This phenomenon, driven by the furniture industry and the agricultural sector, has led to the combined growth of the main cities that comprise the Geopark, such as Cambará do Sul, Timbó do Sul, Jacinto Machado, Praia Grande, Morro Grande, and, above all, the district of Vila São João, located in the northwestern portion of Torres, registering an increase of nearly 70% in the urban area.

The municipality of Torres, in the urban area bordering the coast, deserves special attention given the growing and notable process of vertical construction, resulting in population density.

Indeed, the fragile coastal environmental systems subject to such urban growth processes require special attention. The same applies to the plateau's edge escarpments, due to their high potential for mass movements (floods, landslides, rockfalls, etc.), and to the alluvial plains, which are susceptible to flooding.

The assessment of the preferred growth axes of the Geopark's headquarters and urban centers is an important element for planning the responsible use and occupation of the territory and for the implementation of safe tourism activities.