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GEOMORFOSSÍTIOS E SUAS CARACTERÍSTICAS NO CONTEXTO GEOMORFOLÓGICO DO GEOPARQUE MUNDIAL DA UNESCO CAMINHOS DOS CÂNIONS DO SUL

GEOMORPHOSITES AND THEIR CHARACTERISTICS IN THE GEOMORPHOLOGICAL CONTEXT OF THE CAMINHOS DOS CÂNIONS DO SUL UNESCO GLOBAL GEOPARK

GEOMORFOSITIOS Y SUS CARACTERÍSTICAS EN EL CONTEXTO GEOMORFOLÓGICO DEL GEOPARQUE MUNDIAL DE LA UNESCO CAMINHOS DOS CÂNIONS DO SUL

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RESUMO

Geoparque Mundial da UNESCO Caminhos dos Cânions do Sul abriga um geopatrimônio predominantemente de conteúdo geomorfológico, que se situa na paisagem compartimentada em quatro unidades geomorfológicas. O trabalho objetiva apresentar os geomorfossítios inventariados neste território, analisando suas características, distribuição nas unidades geomorfológicas, relevância e dinamicidade. A metodologia qualitativa consistiu na compilação de inventários, resultando em 29 geomorfossítios classificados segundo sua dinâmica. Os resultados apontam que os sítios se concentram nas Escarpas e Patamares da Serra Geral, e essas unidades abrigam todos os geomorfossítios de relevância internacional. Identificaram-se apenas dois na Planície e uma lacuna de sítios representativos do Planalto. Por fim, apenas dois geomorfossítios têm características dinâmicas, os demais são estruturais e apresentam uma variedade de escalas.

Palavras-chave: Unidade geomorfológica. Geopatrimônio. Patrimônio geomorfológico. Geossítio. Geomorfodiversidade.

ABSTRACT

The Caminhos dos Cânions do Sul UNESCO Global Geopark hosts a geoheritage predominantly of geomorphological content, situated in four geomorphological units. This study aims to present the geomorphosites inventoried in this territory, analyzing their characteristics, distribution across geomorphological units, relevance and dynamics. The qualitative methodology involved compiling existing inventories, resulting in 29 geomorphosites classified according to their evolutionary dynamics. Results indicate that these sites are concentrated in the Escarpments and Hills of the Serra Geral, units that contain all sites of international relevance. Only two sites were identified in the Plain, and a gap was noted regarding representative sites in the Plateau. Finally, only two geomorphosites exhibit dynamic characteristics, while the others are structural and present a diversity of scales.
Keywords: Geomorphological unit. Geoheritage. Geomorphological heritage. Geosite. Geomorphodiversity.

RESUMEN

El Geoparque Mundial UNESCO Caminhos dos Cânions do Sul alberga un patrimonio geológico predominantemente de contenido geomorfológico, situado en cuatro unidades geomorfológicas. El objetivo de este trabajo es presentar los geomorfositios inventariados en este territorio, analizando sus características, distribución en las unidades geomorfológicas, relevancia y dinámica. La metodología cualitativa consistió en la compilación de inventarios, resultando en 29 geomorfositios clasificados según su dinámica. Los resultados indican que los sitios se concentran en las Escarpas y Patamares de la Serra Geral, unidades que albergan todos los sitios de relevancia internacional. Se identificaron dos en la Llanura y una ausencia de sitios representativos del Altiplano. Por último, dos geomorfositios poseen características dinámicas, mientras que los demás son estructurales y presentan una diversidad de escalas.
Palabras clave: Unidad geomorfológica. Geopatrimonio. Patrimonio geomorfológico. Geositio. Geomorfodiversidad.

RÉSUMÉ

Le Géoparc mondial UNESCO Caminhos dos Cânions do Sul abrite un géopatrimoine à prédominance géomorphologique, réparti en quatre unités géomorphologiques. Ce travail vise à présenter les géomorphosites inventoriés sur ce territoire, en analysant leurs caractéristiques, leur répartition au sein des unités géomorphologiques, leur degré de pertinence et leur dynamique. La méthodologie qualitative a consisté en la compilation d'inventaires, aboutissant à 29 géomorphosites classés selon leur dynamique. Les résultats indiquent que les sites se concentrent dans les Escarpements et les Buttes-témoins de la Serra Geral, unités qui abritent tous les sites d'importance internationale. Seuls deux sites ont été identifiés dans la Plaine côtière et une lacune de sites représentatifs du Plateau a été constatée. Enfin, seuls deux géomorphosites présentent des caractéristiques dynamiques, tandis que les autres sont structurels et présentent une diversité d'échelles.
Mots-clés: Unité géomorphologique. Géopatrimoine. Patrimoine géomorphologique. Géosite. Géomorphodiversité.

INTRODUCTION

Geoparks are areas recognized for their landscapes and geoheritage of international relevance, whose management pillars are based on education, conservation, and sustainable development (UNESCO, 2015). The Caminhos dos Cânions do Sul UNESCO Global Geopark (*Geoparque Mundial da UNESCO Caminhos dos Cânions do Sul* - GMUCCS), located between Santa Catarina and Rio Grande do Sul, south of Brazil, is an example of the recognition of heritage and landscape values associated with the relief.

The GMUCCS was designated in 2022, currently has 30 geosites with geological, geomorphological, and paleontological aspects. These sites are distributed across the four main geomorphological units that compartmentalize the geopark's landscape: Plateau, Escarpment, Hills, and Plain. In this context, most geoheritage sites have geomorphological content and are, therefore, geomorphosites. By concept, geomorphosites are landforms to which values are attributed, whether scientific, aesthetic, or cultural (Panizza, 2001).

The specific characteristics of geomorphosites in relation to other types of geosites lie in the imbrication of scales, dynamic and aesthetic value (Reynard, 2004; 2009). The spatial scale may range from the individual geomorphological object to the landscape scale. From a dynamic perspective, geomorphosites allow the visualization of current geomorphological processes and, consequently, contribute to understanding the continuous evolution of landforms and landscapes (Reynard, 2009). Geomorphosites may also be classified according to their activity.

Reynard (2004; 2009) distinguishes between Active and Passive geomorphosites. Active geomorphosites correspond to landforms in which geomorphological processes can be directly observed in action, whereas Passive geomorphosites correspond to past processes, that is, landforms that no longer evolve under the action of their genetic process and therefore represent testimonies of landscape evolution. In this context, Pelfini and Bollati (2014) describe a third

class, Evolving Passive geomorphosites, which consist of landforms generated by processes that are no longer active but are currently being shaped by another active process.

Analyzing geomorphosites within their geomorphological contexts allows for an understanding of their typology and heritage value, as well as their representativeness and dynamics, both at the unit level and within the geopark as a whole. Recognizing these characteristics supports the development of conservation and management strategies, considering the risk of degradation and integrity.

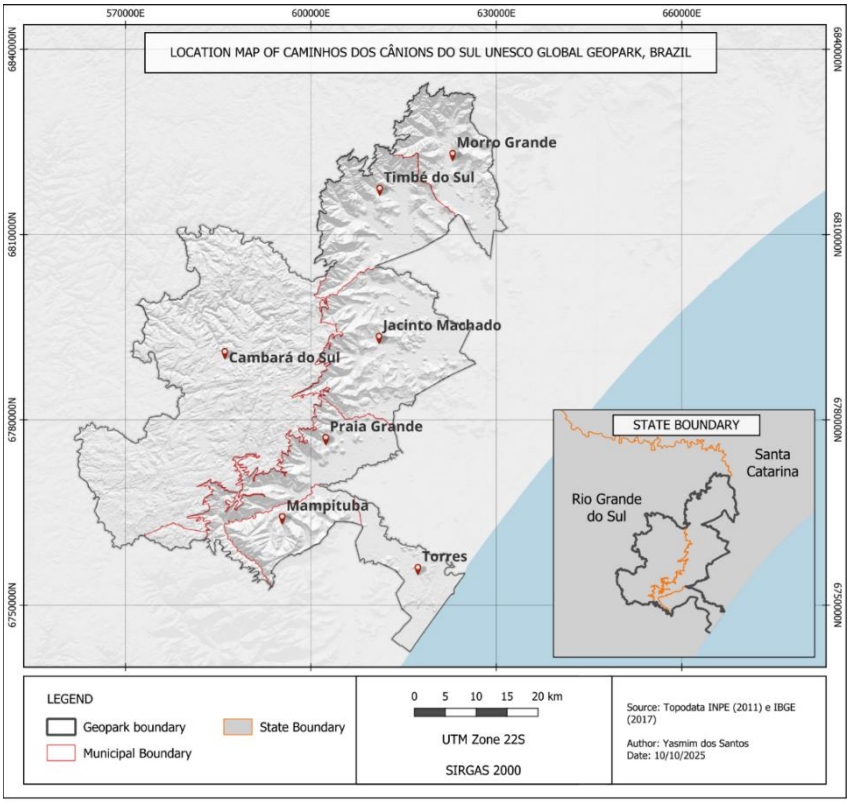
Three publications indicate the geosites of the GMUCCS: Lima and Vargas (2018), Godoy, Binotto and Wildner (2011), and GCCS (2019). Each author attributes the content, values and levels of relevance at regional, national, and international scales. Locally, the geosites listed in the Application Dossier (GCCS, 2019) are considered the official ones.

Based on these three documents, a single list of sites with geomorphological content was compiled, resulting in 29 geomorphosites. The objective of this study is to present the geomorphosites inventoried in the Caminhos dos Cânions do Sul UNESCO Global Geopark, analyzing their characteristics, relevance, representativeness, and dynamics within the geomorphological context of this territory.

STUDY AREA

The Caminhos dos Cânions do Sul UNESCO Global Geopark has its territory delimited by seven municipalities: Praia Grande, Jacinto Machado, Timbé do Sul, and Morro Grande in the state of Santa Catarina, and Torres, Mampituba, and Cambará do Sul in Rio Grande do Sul (Figure 1). There are also 11 protected areas totally or partially inserted within the geopark boundaries, which aim at the conservation of abiotic and biotic aspects at different levels. Furthermore, the Atlantic Forest Biosphere Reserve (*Reserva da Biosfera da Mata Atlântica* - RBMA) also overlaps this territory.

Figure 1 – Study area map



Source: INPE (2011); IBGE (2017). Prepared by the authors.

The geoheritage of geoparks must tell a chapter of Earth's history. In this sense, the storytelling of the GMUCCS refers to the fragmentation of the Gondwana paleocontinent and the opening of the Atlantic Ocean during the Cretaceous period. Fissure volcanism began approximately 137 Ma, also starting the fragmentation process of the paleocontinent and leading to the separation of Africa and South America. These flows originated the volcanic rocks of the Serra Geral Group, although this group records the main event of the GMUCCS, there are older outcrops that compose the Paraná Sedimentary Basin, encompassing additional chapters of geological history.

The narrative of the territory begins with the Teresina Formation from the Permian period, the oldest found in the territory, characterized by fine sandstone and shale heteroliths from an epicontinental environment (Binotto *et al*., 2024). Sequentially, there is the Rio do Rasto Formation, represented by fine sandstones from a continental environment. Together, these two formations mark the end of the Paleozoic Era and the beginning of the Mesozoic Era (Binotto *et al*., 2024). An eolian and arid environment gave rise to the Botucatu Desert during the Juro-Cretaceous period, subsequently forming the sandstone rocks of the Botucatu Formation. This sedimentation was interrupted by the Serra Geral magmatism, characterized by successive flows occurred between 137 and 127 Ma (Milani *et al*., 2007).

The Serra Geral Group is subdivided into the three most recent formations of the territory: Torres, Vale do Sol, and Palmas (Rossetti *et al*., 2021). The Torres Formation consists of basalts and basaltic andesites, at its contact with the Botucatu Formation, peperites occur, evidencing the lava-sediment interaction (Rossetti *et al*., 2021; Binotto et *al.,* 2024). The Vale do Sol Formation is composed of andesites and represents the thickest layer among the three; and the Palmas Formation is composed of dacites and rhyolites derived from more acidic flows (Rossetti *et al*., 2021). Following continental fragmentation, the uplift of the eastern border of the Paraná Basin occurred.

After these events, during the Cenozoic Era, sediment deposition occurred in two systems: continental and coastal. The continental system comprises fluvial, colluvial, and alluvial fan deposits, Godoy, Binotto and Wildner (2011) refer to this as the Alluvial Fan System, characterized by the development of proximal and distal alluvial fans. The coastal system is related to sea-level variations during the Quaternary period and includes Pleistocene and Holocene marine, lagoonal, paludal, and eolian deposits (Horn Filho, 2003).

The climate of the GMUCCS region is subtropical, with temperature variability and rainfall influenced by the relief. According to the Köppen classification, the Subtropical Highland Climate (Cfb) subtype predominates, characterized by mild summers and cold winters, being responsible for the occurrence of frost and snow in the highlands (Ricetti et al., 2025). The Humid Subtropical Climate (Cfa) is recorded in the coastal portion, characterized by cold winters and hot summers. Orographic rainfall and high cloud cover occur in the lowlands near the Serra Geral escarpment, resulting from the interaction between warm, humid air masses from the ocean and the relief barrier (Godoy *et al*., 2011).

The evolution of relief during the Cenozoic leads to the current landscape configuration of the GMUCCS, which is compartmentalized into four main geomorphological units: Plateau, Escarpment, Hills, and Plain. The Campos Gerais Plateau corresponds to the upper formation of the Serra Geral Group, the Palmas Formation acts as a control for the erosive dissection process due to its composition (Ricetti et al., 2025). The unit is predominantly flat to gently undulating, the highest elevations (above 1,000 meters) are located along the eastern margin, decreasing gradually toward the west (Santa Catarina, 1986; IBGE, 2022). Within the

GMUCCS, maximum elevations range between 1,100 and 1,200 meters and area located along the eastern margin of Cambará do Sul, near the boundary with the Serra Geral Escarpment unit in Jacinto Machado.

The Serra Geral (Santa Catarina, 1986; IBGE, 2022), referred to in this study as the Serra Geral Escarpment, represents the dissected margin of the Campos Gerais Plateau. This geomorphological unit is characterized by strong lithostructural control and pronounced topographic gradients, with elevations ranging from approximately 350 to 1000 m. It is marked by steep to locally vertical slopes and deeply incised valleys (IBGE, 2022). Its upper edge defines the state boundary between Rio Grande do Sul and Santa Catarina and constitutes a prominent landscape feature, playing a key role in local climatic conditions and geomorphological dynamics, particularly in relation to the adjacent Plain.

The Serra Geral Hills (*Patamares da Serra Geral*) form a discontinuous unit, an extension of the Escarpment that records its regression over geological time. This intermediate relief is supported by volcanic formations of the Serra Geral Group or by sandstones of the Botucatu Formation and is expressed as lowered spurs extending toward the plain or as isolated hills with convex or tabular tops (Santa Catarina, 1986; IBGE, 2022).

The Plain unit is subdivided according to two classifications: Santa Catarina (1986) distinguishes it based on the predominant landforms, the Colluvial-alluvial Plain and the Littoral Plain; whereas IBGE (2022) recognizes three subdivisions: the Alluvial-colluvial Plain, the Patos-Mirim Lagoonal Plain, and the Littoral Plain. For the purposes of this study, these subdivisions were grouped into a single Plain unit, characterized by lowlands where continental (fluvial and gravitational) and coastal (eolian and marine) landforms and processes occur. The geopark also encompasses a marine extension, including an island on the Continental Shelf.

METHODOLOGY

The GMUCCS has three publications that list the geosites of the territory. The first is the Geoparks proposal by Godoy, Binotto and Wildner (2011), a document that describes 20 geosites from the first Caminhos dos Cânions do Sul Geopark project, which began in 2007 and encompassed 18 municipalities. Eight sites indicated in this work are outside the current geopark boundaries and, for this reason, were disregarded in this analysis. The authors describe the value of the sites and their relevance in regional, national, and international contexts.

The second document is the Geodiversity Report by Lima and Vargas (2018), which presents the inventory of 23 geosites of the Santa Catarina municipalities within the current geopark limits. This inventory provides a qualitative and quantitative evaluation of the sites according to the Brilha (2016) methodology. The third document is the Geoparque Caminhos dos Cânions do Sul Application Dossier (GCCS, 2019), which contains a list of 30 geosites distributed throughout the geopark territory, with their type of content and relevance. The present work considers these the "official" geosites, as they are recognized, promoted and signposted in the territory.

Few variations in the types of geosites are observed among these studies, when the lists are combined and duplicates are removed, a total of 34 geosites are recorded. From this set, those with geomorphological content are considered geomorphosites. It should be noted that geomorphological content is not necessarily exclusive, as it may be associated with paleontological or geological aspects. Some sites were repeated across the documents, however, for the purposes of this analysis, each site was considered only once and integrated into a single list of 29 geomorphosites. These geomorphosites were represented on maps prepared using QGIS 3.40 software.

The analysis conducted in this study is qualitative and focuses on the characterization of the geomorphosites, their scientific value within each geomorphological unit, as well as their spatial distribution and relevance. The geomorphosite classification by activity – Active, Passive and Evolving Passive (Reynard, 2004; Pelfini & Bollati, 2014) – was applied to discuss the dynamism of the inventoried sites within the geomorphological context of the GMUCCS.

CLASSIFICATION OF GEOMORPHOSITES IN THE GEOMORPHOLOGICAL CONTEXT OF THE GEOPARK

Based on the information presented by Godoy, Binotto and Wildner (2011), Lima and Vargas (2018), and GCCS (2019), 29 geomorphosites were identified in the GMUCCS (Table 1).

Table 1 – Geomorphosites of the GMUCCS

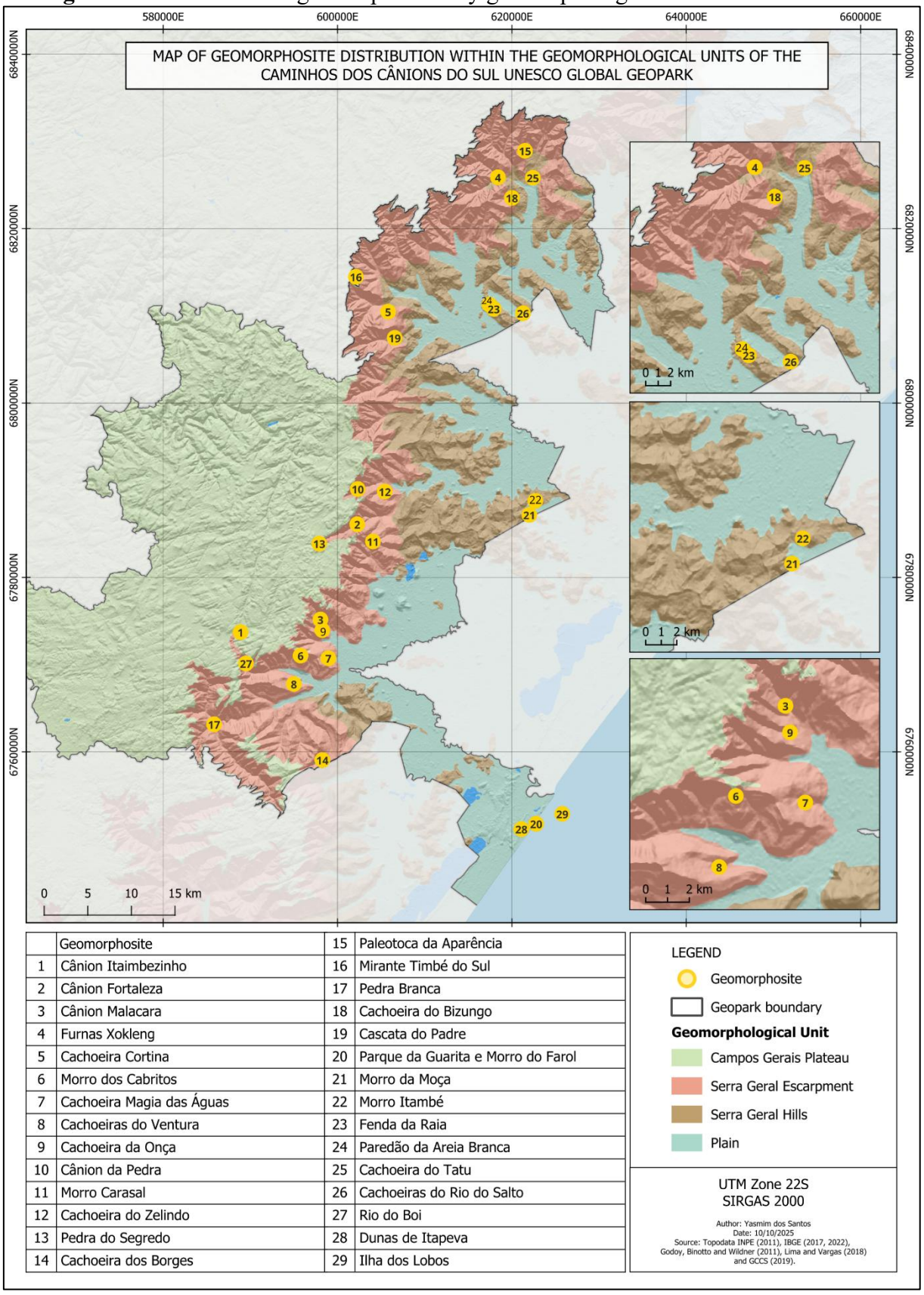
Geomorphosite		Scale	Geomorphological Unit	Content	Relevance	Inventory
1	Itaimbezinho Canyon	Area	Escarpment	Geomorphological	International	Godoy, Binotto and Wildner (2011), Lima and Vargas (2018) and GCCS (2019)
2	Fortaleza Canyon	Area	Escarpment	Geomorphological	International	Godoy, Binotto and Wildner (2011), Lima and Vargas (2018) and GCCS (2019)
3	Malacara Canyon	Area	Escarpment	Geomorphological and Tectonic	International	Godoy, Binotto and Wildner (2011), Lima and Vargas (2018) and GCCS (2019)
4	Furnas Xokleng/Três Barras Paleoburrows	Point	Escarpment	Geomorphological and Paleontological	International	Lima and Vargas (2018) and GCCS (2019)
5	Cortina Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
6	Morro dos Cabritos	Area	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
7	Magia das Águas Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
8	Ventura Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
9	Onça Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
10	Pedra Canyon	Area	Escarpment	Geomorphological	Regional	Godoy, Binotto and Wildner (2011), Lima and Vargas (2018) and GCCS (2019)
11	Morro Carasal	Area	Escarpment	Geomorphological and Stratigraphic	Regional	Lima and Vargas (2018) and GCCS (2019)
12	Zelindo Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
13	Pedra do Segredo	Point	Escarpment	Geomorphological and Tectonic	Regional	Godoy, Binotto and Wildner (2011)

14	Borges Waterfall	Point	Escarpment	Geomorphological and Stratigraphic	Regional	GCCS (2019)
15	Aparência Paleoburrow	Point	Escarpment	Geomorphological and Paleontological	Regional	Lima and Vargas (2018) and GCCS (2019)
16	Timbé do Sul Viewpoint	Point	Escarpment	Geomorphological and Tectonic	Regional	Godoy, Binotto and Wildner (2011)
17	Pedra Branca	Area	Escarpment	Geomorphological	Regional	Godoy, Binotto and Wildner (2011)
18	Bizungo Waterfall	Point	Escarpment	Geomorphological and Stratigraphic	Regional	Lima and Vargas (2018) and GCCS (2019)
19	Padre Waterfall	Point	Escarpment	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
20	Guarita Park and Morro Farol	Area	Hills	Geomorphological and Stratigraphic	International	GCCS (2019)
21	Morro da Moça	Area	Hills	Geomorphological, Sedimentological and Speleological	Regional	Godoy, Binotto and Wildner (2011)
22	Morro Itambé	Area	Hills	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
23	Fenda da Raia	Linear	Hills	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
24	Paredão da Areia Branca	Area	Hills	Geomorphological and Stratigraphic	Regional	Lima and Vargas (2018) and GCCS (2019)
25	Tatu Waterfall	Point	Hills	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
26	Rio do Salto Waterfalls	Point	Hills	Geomorphological	Regional	Lima and Vargas (2018) and GCCS (2019)
27	Boi River	Linear	Plain	Geomorphological	National	GCCS (2019)
28	Itapeva Dunes	Area	Plain	Geomorphological	National	GCCS (2019)
29	Lobos Island	Area	Continental Shelf	Geomorphological	National	GCCS (2019)

Source: adapted from Godoy, Binotto and Wildner (2011), Lima and Vargas (2018) and GCCS (2019).

In this context, 19 are in the Serra Geral Escarpment, 7 in the Hills of Serra Geral, 2 in the Plain, and one on the Continental Shelf (Figure 2)

Figure 2 - Distribution of geomorphosites by geomorphological unit of the GMUCCS



	Geomorphosite	15	Paleotoca da Aparência
1	Cânion Itaimbezinho	16	Mirante Timbé do Sul
2	Cânion Fortaleza	17	Pedra Branca
3	Cânion Malacara	18	Cachoeira do Bizungo
4	Furnas Xokleng	19	Cascata do Padre
5	Cachoeira Cortina	20	Parque da Guarita e Morro do Farol
6	Morro dos Cabritos	21	Morro da Moça
7	Cachoeira Magia das Águas	22	Morro Itambé
8	Cachoeiras do Ventura	23	Fenda da Raia
9	Cachoeira da Onça	24	Paredão da Areia Branca
10	Cânion da Pedra	25	Cachoeira do Tatu
11	Morro Carasal	26	Cachoeiras do Rio do Salto
12	Cachoeira do Zelindo	27	Rio do Boi
13	Pedra do Segredo	28	Dunas de Itapeva
14	Cachoeira dos Borges	29	Ilha dos Lobos

Source: INPE (2011); IBGE (2017; 2022). Prepared by the authors.

The Campos Gerais Plateau is the largest unit in the territory, in addition to the undulating relief, there are also peatlands, however, no geomorphosites specific to this unit representing its typical landforms were recorded.

The Serra Geral Escarpments connect the plateau to the plain, a significant unit in the GMUCCS landscape due to topographic variation. It is in this unit that the largest number of geomorphosites and the geopark's heritage of international relevance are concentrated: the canyons and paleoburrows. Fluvial and gravitational processes, associated with tectonic systems, carved deep fluvial valleys into the rocks of the Serra Geral Group, forming the canyons, whose current forms were conditioned by tectonic lineaments.

The Itaimbezinho, Fortaleza and Malacara geosites are the canyons of international relevance according to the three documents, representing the main features of the unit and being located within National Parks. These sites show structural control, the clearest example of which is Itaimbezinho, where a change in direction occurs after 1.5 km from the canyon head, totaling 5.6 km in length. The Malacara canyon is 1.5 km long, through which the river of the same name flows.

The Fortaleza canyon is the largest in the territory, with its valley excavated by the Pedra River for 7.8 km, reaching 2 km in width in its final portion. On its slopes is the *Pedra do Segredo*, described by Godoy, Binotto and Wildner (2011) as having regional relevance. This is geomorphosite consisting of a monolithic block 5 m high and a few centimeters wide at the base, resulting from natural erosive processes. The Pedra canyon, with 5 km in length, is the only one with regional relevance. It is a bifurcated valley, where the Pai José River forms a sub-basin that configures this bifurcation (Godoy; Binotto; Wildner, 2011). The canyons were listed as area sites, but they can be considered landscape geomorphosites due to their scale, representativeness, and scenic composition in the GMUCCS landscape.

Due to the characteristics of the Escarpments unit, a large number of waterfalls occur. Among them, 7 are geomorphosites of regional relevance distributed along the Serra Geral Escarpment: Cortina, Magia das Águas, Ventura, Onça, Zelindo, Borges, Bizungo, and Padre. Although some waterfalls are well-known for being on the canyon slopes, such as *Tigre Preto* in the Fortaleza canyon, and *Véu de Noiva* and *Andorinhas* in Itaimbezinho canyon, they are not considered geosites on their own.

In the Escarpments, sites of structural origin predominate, with some geomorphosites consisting of bioerosive features from a geomorphological perspective and ichnofossils in paleontology: the paleoburrows (*paleotocas*). According to Buchmann *et al.* (2009), paleoburrows are records of shelters excavated by Megafauna and Grandefauna of the Quaternary period. The species consist of giant armadillos and ground sloths of the Superorder Xenarthra (Vizcaíno et al., 2001). Although GCCS (2019) and Lima and Vargas (2018) attribute geomorphological content to the paleoburrows, the paleontological content is considered the primary one as it records, according to Valdati *et al.* (2024), species endemic to South America and important indicators of paleobiogeographic changes. In this work, these features are considered point geomorphosites defined by the cavity entrance, however, they unfold into extensive galleries reaching tens to hundreds of meters.

The Furnas Xokleng (Três Barras Paleoburrows) is a complex of 11 tunnels of international relevance, they are located at approximately 320 meters of altitude and total more than 100 meters in length (Lima; Vargas, 2018; Bechtel, 2025). The Aparência Paleoburrow is at 430 meters of altitude and has a single gallery 61 meters long (Valdati et al., 2024), this being a site of regional relevance. These paleoburrows share the common characteristic of being located within the Botucatu Formation portion of the Escarpments (Valdati et al., 2024).

Most of the Serra Geral Hills consist of spurs, extensions that cause difficulties in the delimitation between Escarpments and Hills. In this context, the geomorphosites Morro

dos Cabritos, Morro Carasal, Timbé do Sul Viewpoint and Pedra Branca are located. The first three also function as landscape viewpoints and strategic points for visualizing the geomorphological units that compose the geopark, especially overlooking the plain.

A distinct characteristic of the Serra Geral Hills unit is that it is not continuous, presenting isolated residual hills, such as the geomorphosites: Paredão da Areia Branca, Morro da Moça, Morro Itambé, Guarita Park and Morro do Farol. The Paredão da Areia Branca is an elongated, irregular landform with discontinuous convex tops sustained by the sandstones of the Botucatu Formation, at approximately 340 meters of altitude. Associated with the Paredão, there is the site called *Fenda da Raia*, which consists of a corridor landform originated by the widening of a fracture in the outlier hill. The Fenda da Raia is considered a linear site, approximately 200 m long, 12 m high, and 2.5 m wide (Lima; Vargas, 2018).

The Paredão da Areia Branca also presents ruiniform features, such as towers and columns, characteristic of sandstone rocks. Morro Itambé also presents such features, with columns reaching 30 m in height (Lima; Vargas, 2018). Morro da Moça is an isolated hill with a convex top, also constituted by the Botucatu Formation, approximately 230 meters high (Godoy; Binotto; Wildner, 2011). These three are geomorphosites of regional relevance.

The Guarita Park and Morro do Farol is an international geomorphosite. The site consists of three isolated hills located on the coastline, being the most advanced continental residual hill of the Serra Geral Escarpment and, thus, significant in the geomorphological evolution of the territory. The hills expose basaltic columns of the Torres Formation; the contact with the Botucatu Formation and the presence of peperites are also observed (GCCS, 2019; Binotto et al., 2024). The Guarita is shaped like a garrison tower, while the others are hills approximately 40 m high with flat tops, becoming important viewpoints of the GMUCCS landscape from the plain.

In the Plain, there are only two sites, both of national relevance. These are representative of the main geomorphological dynamics of the unit, expressing continental and coastal processes. The Boi River is the one that carves the Itaimbezinho canyon. On the plateau, it flows as the Perdizes River until it reaches the edge of the escarpment and forms the Andorinhas waterfall, continuing confined within the canyons under the toponym Boi River. There is no delimitation of a specific river segment as a site, therefore, the 6 km of length confined in the valley are considered. However, the Boi River is 15 km long from the canyon upstream to its confluence with the Mampituba River, in this course, 6 km are confined in the valley, and upon entering the plain, it presents a braided morphology, becoming meandering near the mouth.

The Itapeva Dunes can be considered the most dynamic site in the geopark, as most of their landforms exhibit seasonal changes. The site is characterized by active and inactive eolian processes, expressed as foredunes, mobile interior dunes, nebkas, interdune areas, and deflation basins (Rockett, 2016).

On the Continental Shelf, the Lobos Island (*Ilha dos Lobos*) geomorphosite is located approximately 3 km from Guarita Park and Morro do Farol. The site consists of an island of basaltic rocks from the Serra Geral Group, a maritime witness of the Escarpment. GCCS (2019) attributes geomorphological content, but geological content can be considered due to the record of the Escarpment regression. Although not all values of the site are specified, the island has significant ecological value, given that it is a Wildlife Refuge (REVIS).

According to the classification by activity (Reynard, 2009; Pelfini; Bollati, 2014), the geomorphosites presented are classified as Active, Passive or Evolving Passive (Table 2).

Table 2 - Geomorphosites classification

Geomorphological Unit	Geomorphosite	Classification	Description
Campos Gerais Plateau	No inventoried geomorphosites	-	-
Serra Geral Escarpment	Canyons (Itaimbezinho, Fortaleza, Malacara, Pedra)	Evolving Passive	Structural forms, conditioned by lithology and under active fluvial and gravitational processes
	Waterfalls (Cortina, Magia das Águas, Ventura, Onça, Zelindo, Borges, Bizungo and Padre)	Evolving Passive	Structural forms, where the fluvial process is active and continuous
	Pedra do Segredo	Passive	Structural residual landform shaped by differential erosion
	Paleoburrows (Furnas Xokleng/Três Barras and Aparência)	Evolving Passive	Biogenic landforms and ichnofossils resulting from megafauna activity, currently exposed to gravitational processes
Serra Geral Hills	Hills (spurs) (Morro dos Cabritos, Morro Carasal, Mirante de Timbé do Sul and Pedra Branca)	Evolving Passive	Spurs, residual landforms resulting from escarpment retreat, subject to fluvial and gravitational processes
	Isolated hills (Paredão da Areia Branca, Morro da Moça and Morro Itambé)	Evolving Passive	Residual landforms, some exhibiting ruiniform features, indicating modification by erosive processes in sandstone rocks over time
	Fenda da Raia	Evolving Passive	Linear landform conditioned by fractures with development associated with active fluvial processes
	Isolated hills (Guarita Park and Morro do Farol)	Evolving Passive	Advanced residual hills on the coastline, currently modified by marine and gravitational processes
Plain	Boi River	Active	A river of dynamic morphology, representing an active fluvial system
	Itapeva Dunes	Active	Mobile dunefields where active eolian processes are observable
Continental Shelf	Lobos Island	Evolving Passive	Continental island with continuous marine erosion

It is noteworthy that the geomorphosites of the Serra Geral Escarpments and Hills units account for 89% of the list. The majority are structural, with the exception of the paleoburrows due to their former biological origin. Although these structural geomorphosites are associated with active geomorphological processes, their landforms may convey a predominantly static perspective at the human time scale. When addressing scales, Reynard (2009) refers only to spatial scale, therefore, it is emphasized here that the temporal scale of geomorphosites should also be discussed.

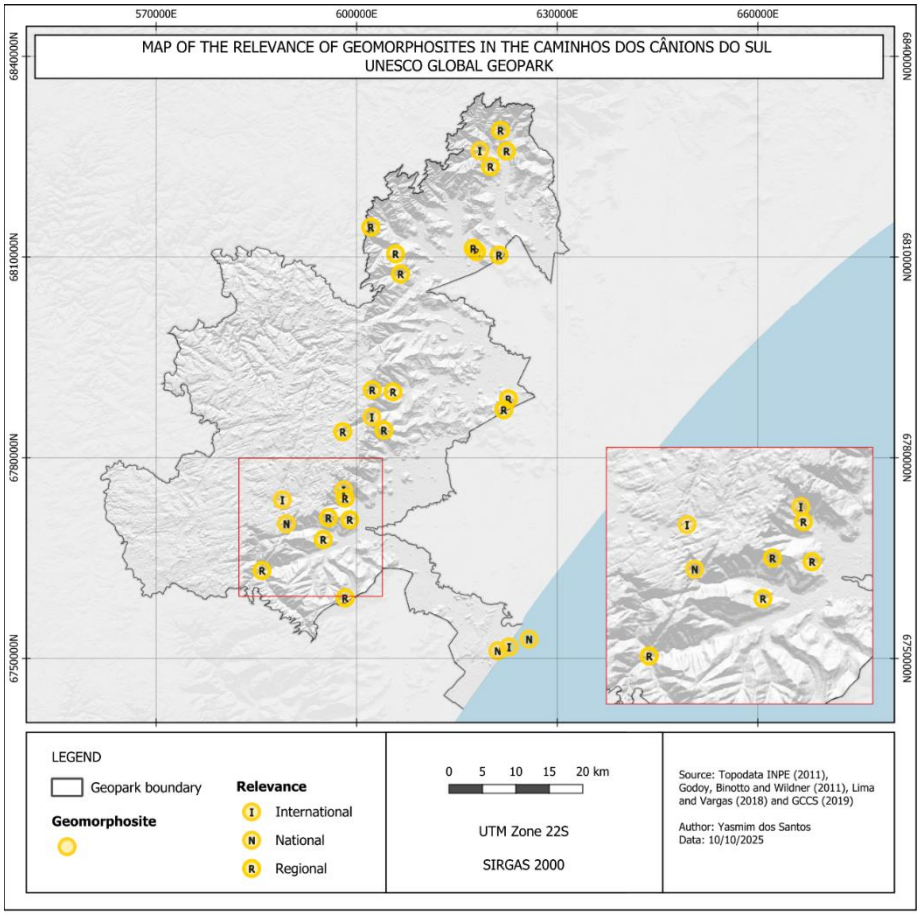
In contrast, the Boi River and Itapeva Dunes exhibit perceptible changes associated with active geomorphological processes. These are classified as Active Geomorphosites, as the

processes that originated the landforms are still observable, representing the current dynamics of the GMUCCS. In this case, the presence of active geomorphological diversity must be considered in relation to its spatial and temporal scales, which makes delimitation, management and conservation strategies particularly challenging (Table 2).

There is a diversity of scales among these geomorphosites, ranging from point features to areal extents. Although the authors of the analyzed documents did not define the official boundaries, in this study, geomorphosite scale was determined based on landform characteristics (Table 1), resulting in different scale categories: 14 point sites, 2 linear sites and 13 areal sites. Canyons may also be considered landscape geomorphosites, given their dimension and expressive role in the scenic composition of the territory. In addition, three cases of overlap were identified: one point site (Pedra do Segredo) and two linear sites (Boi River and Fenda da Raia), all of which are associated with areal geomorphosites. Thus, the variety of scales and dynamics corroborates the particularities of geomorphosites described by Reynard (2009).

In terms of relevance, 5 are sites of international relevance (Figure 3), 4 of which are located in the Serra Geral Escarpment, including 3 canyons and one paleoburrow. The fifth geomorphosite, Guarita Park and Morro do Farol, is located in the Hills, reinforcing the formation and regression of the Escarpment as a fundamental heritage of the GMUCCS. There are 3 sites of national relevance, 2 in the Plain and one on the Continental Shelf. Lobos Island should be highlighted as a maritime outlier, as well as for the important association between abiotic and biotic scientific values. Finally, the 21 sites of regional relevance are also concentrated in the Escarpment and Hills, mainly waterfalls and hills (Figure 3).

Figure 3 – Distribution of geomorphosites and their relevance



Source: INPE (2011); IBGE (2017). Prepared by the authors.

CONCLUSIONS

The geoheritage of the Caminhos dos Cânions do Sul UNESCO Global Geopark tells a chapter of Earth's history through its geomorphosites and geomorphological units. The Escarpment has the highest concentration of geomorphosites, with the most representative landforms of the unit and the geomorphological and landscape context of the geopark. In this context, there is a predominance of structural geomorphosites and an intersection between geomorphological and paleontological content, exemplified by the paleoburrows, reinforcing the unit's importance as heritage across all types of relevance.

The Serra Geral Hills is also a fundamental unit for the narrative of relief evolution in this territory due to the arrangement of the spurs and, primarily, the isolated hills, from the continental island to the isolated hills that present ruiniform features. The Escarpment and the Hills encompass the widest variety of scales – point, linear and area – while the canyons can also be considered at a landscape scale due to their relevance to the GMUCCS.

The Plain and Campos Gerais Plateau units occupy most of the territory, nevertheless, they have fewer geomorphosites, also revealing a discrepancy in geomorphosites between the states of Santa Catarina and Rio Grande do Sul. Both units have the potential to expand the list of geomorphosites, representing the landscape evolution on the Plateau, as well as inactive and active forms and processes, such as eolian, gravitational, and fluvial processes that drive the dynamics of the Plain.

Finally, it is highlighted that biogeomorphological aspects were not considered in the present analysis. This gap represents an important future research front to improve the understanding of geomorphosites and the interaction between the existing biotic and abiotic heritage in the geopark, which is also marked by the overlap with the Atlantic Forest Biosphere Reserve.

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