

Technical note

Relief Macro-Compartments and Morphostructures in the state of Paraná: a reinterpretation based on the Brazilian Landform Classification System (SBCR)

Macrocompartimentos e morfoestruturas do relevo do estado do Paraná: uma reinterpretação à luz do Sistema Brasileiro de Classificação de Relevo (SBCR)

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Abstract: The Brazilian Landform Classification System (Sistema Brasileiro de Classificação de Relevo — SBCR) has organized a new geomorphological structure, placing macro-compartments at the first level and morphostructural domains and subdomains at the second. This study applies the two SBCR taxonomic levels to the territory of the state of Paraná and compares them with previous geomorphological representations. In the first taxonomic level, three macro-compartments were identified: (i) Mountains, (ii) Plateaus, and (iii) Plains. In the second level, nine units were delineated, integrating morphostructural domains and subdomains: 1) Shield Mountains on Granite-Gneissic Terrains; 2) Shield Plateaus on Granite-Gneissic Terrains; 3) Plateaus in Paleozoic and Mesozoic Lithified Sedimentary Basins and Covers (Paraná Basin); 4) Plateaus in Sedimentary Basins and Covers with Neojurassic-Early Cretaceous Volcanic Sequences (Serra Geral Basin); 5) Plateaus in Neocretaceous Lithified Sedimentary Basins and Covers (Bauru Basin); 6) Plateaus in Cenozoic Slightly Lithified Sedimentary Basins and Covers (Curitiba and Tijucas do Sul Basins); 7) Plains in Coastal Sedimentary Covers with marine genesis; 8) Plains in Coastal Sedimentary Covers with Continental genesis; 9) Plains in Continental Sedimentary Covers. The application of the SBCR proved to be feasible and consistent with classical geomorphological interpretations and pre-existing mapping, as it does not depart from the geomorphological tradition territory of the state of Paraná. Rather, it reorganizes its hierarchical structure, preserves a substantial portion of the units historically recognized, and allows for refinements that were not possible at the same taxonomic level in previous classification frameworks.

Keywords: Relief macro-compartments; Morphostructural domains and subdomains; Mountains; Plateaus; Plains.

Resumo: O Sistema Brasileiro de Classificação de Relevo (SBCR) organizou uma nova estrutura taxonômica geomorfológica, posicionando macrocompartimentos no primeiro nível e domínios e subdomínios morfoestruturais no segundo. Este artigo aplica os dois táxons do SBCR ao território do Paraná e os compara com representações geomorfológicas anteriores. No primeiro táxon, foram identificados três macrocompartimentos: (i) Montanhas, (ii) Planaltos e (iii) Planícies. No segundo, foram delimitadas nove classes, integrando-os com os domínios e subdomínios morfoestruturais: 1) Montanhas em Escudo sobre Terrenos Granito-Gnáissicos; 2) Planaltos em Escudo sobre Terrenos Granito-Gnáissicos; 3) Planaltos em Bacias Sedimentares Litificadas Paleozoicas e Mesozoicas e Coberturas (Bacia do Paraná); 4) Planaltos em Bacias Sedimentares e

Coberturas com Sequências Vulcânicas Neojurássicas-Cretáceas Inferiores (Bacia da Serra Geral). 5) Planaltos em bacias e coberturas sedimentares litificadas do Neocretáceo (Bacia do Bauru); 6) Planaltos em bacias e coberturas sedimentares pouco litificadas do Cenozoico (Bacias de Curitiba e Tijucas do Sul); 7) Planícies em coberturas sedimentares costeiras de gênese marinha; 8) Planícies em coberturas sedimentares costeiras de gênese continental; 9) Planícies em coberturas sedimentares continentais. A aplicação do SBCR mostrou-se exequível e consistente com as interpretações clássicas e o mapeamento preexistente, pois não rompe com a tradição geomorfológica paranaense, reorganiza sua hierarquia, preserva parte importante das unidades reconhecidas historicamente e permite refinamentos que não eram possíveis no mesmo nível taxonômico.

Palavras-chave: Macrocompartimentos de relevo; Domínios e subdomínios morfoestruturais; Montanhas; Planaltos; Planícies.

1. Introduction

Brazilian geomorphological mapping is currently in the midst of an intense period of debate regarding the revision of the conceptual foundations that underlie the representation of national landforms. These discussions have laid the groundwork for the collaborative development of the Brazilian Landform Classification System (Sistema Brasileiro de Classificação de Relevo — SBCR). This initiative unites the Brazilian geomorphological community, represented by the Brazilian Geomorphology Union (União de Geomorfologia Brasileira — UGB), the Brazilian Institute of Geography and Statistics (IBGE), and the Geological Survey of Brazil (Serviço Geológico do Brasil — SGB-CPRM).

The SBCR was conceived during the Geomorphological Mapping Workshop, which was held as part of the 18th Brazilian Symposium on Applied Physical Geography in Fortaleza, Ceará, in 2019. There, the scientific community discussed the premises and advances in representing Brazilian landforms (Botelho; Pelech, 2019). The initiative was formalized at the first Workshop on the Brazilian Landform Classification System, which took place in Rio de Janeiro in the same year (IBGE, 2020).

The SBCR has made several advances, including: (i) maintaining the hierarchical representation of Brazilian landforms through taxonomic levels, (ii) representing the first taxonomic level with landform classes instead of morphostructures, (iii) defining and conceptualizing the macro-compartments of Brazilian landforms at the first taxonomic level: Mountains, Plateaus, Plains, Lowlands, and Tablelands, and (iv) assigning morphostructural domains and subdomains to the second taxonomic level (CEN/SBCR, 2022; IBGE, 2024; 2025). This framework differs from earlier, more widely adopted proposals by Ross (1992) and IBGE (2009), which place morphostructures at the first hierarchical level.

This taxonomic inversion emphasizes landforms as the central object of classification. This approach enables the delineation, quantification, and spatial representation of landforms. It also promotes the dissemination of geomorphological terminology across different levels of education and territorial planning (CEN/SBCR, 2022). The Morphostructural Domains of the second taxonomic level are based on the primary geological domains of the South American Platform, including shields, sedimentary basins and cover sequences, and young fold belts (Hasui, 2012). These are supplemented by morphostructural subdomains corresponding to Brazil's major lithostratigraphic domains (Marques et al., 2006; IBGE, 2025; 2026).

Despite the consolidation of the criteria for the first two taxonomic levels of the SBCR, there had yet to be a systematic application of this framework to the state of the Paraná that could assess the correspondence among landform macro-compartments, morphostructural domains and subdomains, and previously established geomorphological units simultaneously.

The present study aims to apply the first two taxonomic levels of the SBCR to the representation of landforms in the state of Paraná. This study is based on the guidelines established by CEN/SBCR (2022) and IBGE (2025, 2026). The study will assess the applicability of the criteria to Paraná's landforms and evaluate the equivalence between the resulting units and the classical interpretations of Maack (1968). These interpretations were adopted as morphosculptural units in the regional geomorphological mapping of Santos et al. (2006) and Oka-Fiori (2006).

2. Regional geomorphological setting of the state of Paraná

The state of Paraná is located in southern Brazil and covers 199,575 km². It is bordered by the state of São Paulo to the north, the Atlantic Ocean to the east, the state of Santa Catarina to the south, and Argentina and Paraguay to the southwest and west. The state of Mato Grosso do Sul borders Paraná to the northwest.

Paraná was chosen as the geographic framework in which to apply the first two taxonomic levels of the SBCR because of its geomorphological and morphostructural diversity, which makes it possible to identify distinct landform units. Additionally, Paraná has a well-established tradition of classical landform interpretation and previous geomorphological mapping. This enables a comparison between the results of this study with previous findings and update the regional landform framework using the SBCR's criteria.

From a geomorphological perspective, Paraná's landforms are characterized by the regional framework proposed by Maack (1968). Maack identified five major natural geographic regions and their sub-zones. This framework has served as a reference for physiographic studies of the state and has been reproduced for decades in educational maps, scientific studies, and technical documents. The regions are: 1) the Coastal Zone, 2) the Serra do Mar, 3) the First Paraná Plateau, 4) the Second Paraná Plateau, and 5) the Third Paraná Plateau (Figure 1).



Figure 1. Natural Geographic Regions and Natural Subzones of the state of Paraná. Source: Maack (1968).

During the 1970s and 1980s, the RADAMBRASIL Project made an unprecedented effort to systematically map Brazil's natural resources at a scale of 1:1,000,000. The project developed specific methodologies for each thematic area (IBGE, 2025). Based on the concepts of Tricart (1965), the project developed a geomorphological taxonomy with four levels: 1) morphostructural domains, 2) geomorphological regions, 3) geomorphological units, and 4) landform patterns. This taxonomy was later formalized in the Technical Manual of Geomorphology (IBGE, 1995; 2009).

Despite the importance and robustness of the RADAMBRASIL Project's work, its mapping products were not readily available. In the state of Paraná, for example, access to the geomorphological reports and maps was

restricted until 2018 when they were published as part of the SG.22 Curitiba Map, the SG.21 Asunción Map, the SG.23 Iguape Map (IBGE, 2018a), and the SF.22 Paranapanema Map (IBGE, 2018b).

The long interval between the production, publication, and dissemination of the RADAMBRASIL surveys, as well as the lack of geomorphological mapping studies that provide more detailed compartmentalization and representation of Paraná's landforms than Maack's (1968) framework, prompted Santos et al. (2006) and Oka-Fiori et al. (2006) to conduct the first systematic geomorphological mapping of Paraná State. They adopted the taxonomy proposed by Ross (1992) and the methodological contributions of Ross and Moroz (1997).

Ross (1992) adapted and systematized the methodology developed by the RADAMBRASIL Project, incorporating the concepts of morphostructure and morphosculpture proposed by Mescerjakov (1968) into his taxonomic framework. In this framework, landforms are represented by six spatiotemporal orders of magnitude: 1) Morphostructural units; 2) Morphosculptural units; 3) Landform patterns; 4) Landform types; 5) Slope types; 6) Landforms derived from active morphodynamics. This approach was widely adopted in Brazil and decisively influenced state-level geomorphological mapping. It has been applied in São Paulo (Ross; Moroz, 1997), Paraná (Santos et al., 2006; Oka-Fiori et al., 2006), Rio Grande do Norte (Diniz et al., 2017), and Mato Grosso (Silveira, 2023; Silveira; Silva, 2026).

In their geomorphological map of Paraná State, Santos et al. (2006) and Oka-Fiori et al. (2006) mapped the first three taxonomic levels at a scale of 1:250,000. They identified the following levels: (i) three morphostructural units at the first taxonomic level (the Atlantic Orogenic Belt, the Paraná Sedimentary Basin, and the Cenozoic Sedimentary Basins and Tectonic Depressions); (ii) five morphosculptural units at the second taxonomic level (the Plains, the Serra do Mar, the First Paraná Plateau, the Second Paraná Plateau, and the Third Paraná Plateau); and (iii) fifty morphosculptural subunits at the third taxonomic level (Figure 2).

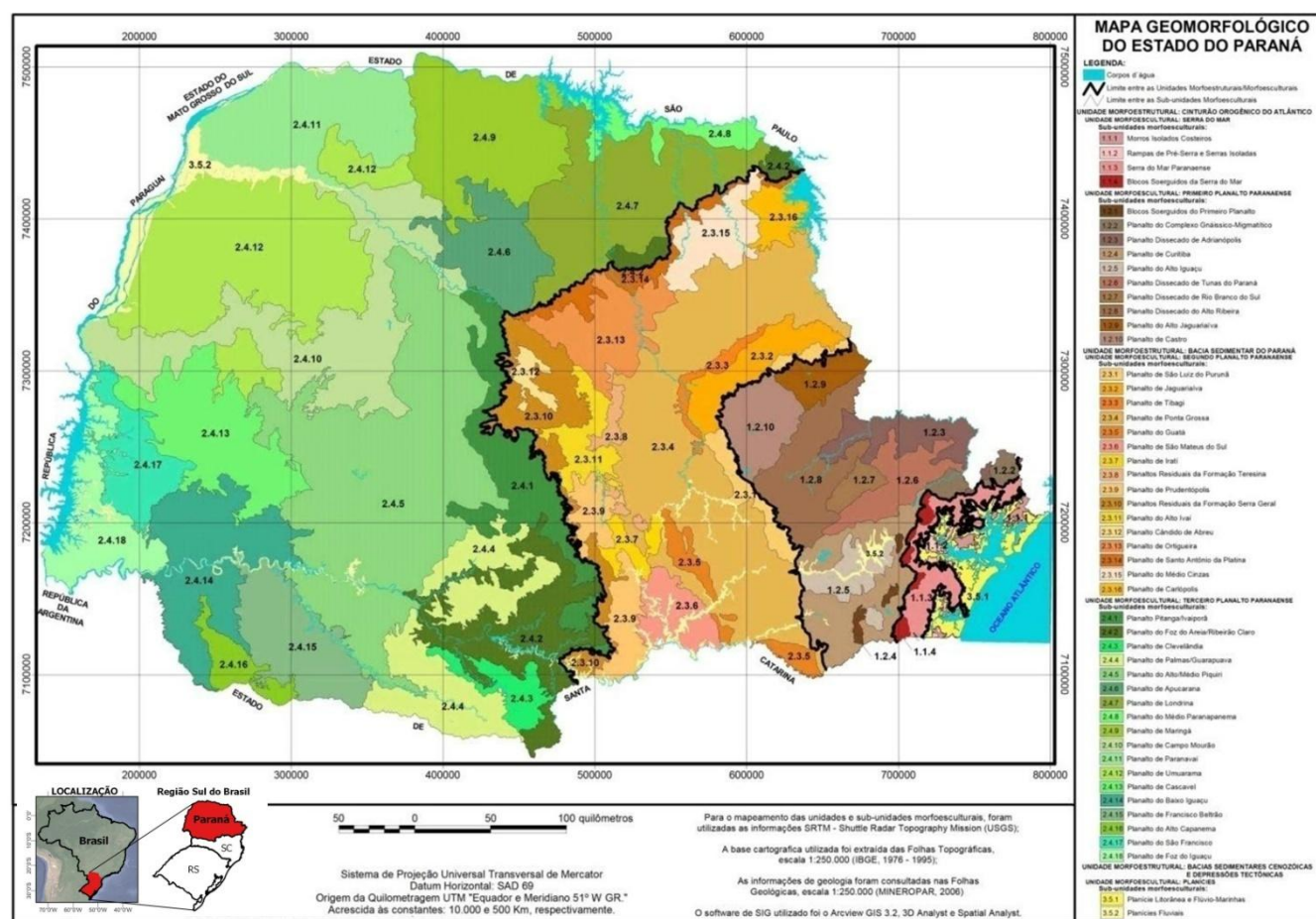


Figure 2. The Geomorphological Map of the state of Paraná showing the three taxonomic levels: morphostructural units, morphosculptural units and morphosculptural subunits. Source: Santos et al., 2006.

The Paraná portion of the Serra do Mar (SMP) is an impressive mountain range that runs along the eastern edge of the state. Its formation and development are closely tied to tectonic processes that impacted the Brazilian continental margin. According to Ab'Saber (1975; 2006), the SMP is a fault-block mountain system formed by Cenozoic tectonic reactivations that uplifted and tilted blocks of the crystalline basement.

The SMP is shaped on Precambrian granite-gneissic and migmatitic terrains, which are part of the Mantiqueira Province (Heilbron et al., 2004; Hasui, 2012). These terrains include the Paranaguá and Luís Alves terranes, as well as granitic suites (Besser et al., 2021). The area is characterized by abrupt escarpments, steep slopes, and elevations reaching 1,877 meters at the summit of Pico Paraná. Denudation rates on the ocean-facing slope are 2.1 to 2.4 times higher than on the continental-facing slope (Salgado et al., 2014).

In the geomorphological mapping of Santos et al. (2006) and Oka-Fiori et al. (2006) at a scale of 1:250,000, the SMP was identified as a morphosculptural unit within the Atlantic Orogenic Belt morphostructure. It was then subdivided into four subunits: 1.1.1) Isolated Coastal Hills; 1.1.2) Piedmont Ramps and Isolated Ranges; 1.1.3) Serra do Mar; and 1.1.4) Uplifted Blocks of the Serra do Mar.

The First Paraná Plateau (FPP) is located between the Purunã cuesta to the west and the western flank of the SMP to the east. This crystalline plateau was formed primarily on Precambrian basement rocks belonging to the Mantiqueira Province (Heilbron et al., 2004), including the Curitiba and Apiaí terranes, as well as granitic suites (Besser et al., 2021). Mesozoic mafic dikes crosscut these rocks, and in the central-southern portion of the plateau, they are partially covered by unconsolidated Cenozoic sedimentary deposits from the Curitiba (Salamuni et al., 1999) and Tijucas do Sul (Moreira et al., 2019) sedimentary basins.

The FPP exhibits a diverse topography, alternating between relatively flat surfaces, interpreted by Ab'Sáber and Bigarella (1961) as remnants of post-Cretaceous planation cycles, and intensely dissected areas characterized by elongated ridges, rounded hills, and deeply incised valleys (Silveira et al., 2025).

In their 1:250,000-scale geomorphological mapping, Santos et al. (2006) and Oka-Fiori et al. (2006) recognized the FPP as a morphosculptural unit within the Atlantic Orogenic Belt morphostructure. The FPP was subdivided into ten morphosculptural subunits: 1.2.1) Uplifted Blocks of the First Paraná Plateau; 1.2.2) Gneiss-Migmatite Complex Plateau; 1.2.3) Adrianópolis Dissected Plateau; 1.2.4) Curitiba Plateau; 1.2.5) Upper Iguaçu Plateau; 1.2.6) Tunas do Paraná Dissected Plateau; 1.2.7) Rio Branco do Sul Dissected Plateau; 1.2.8) Upper Ribeira Dissected Plateau; 1.2.9) the Upper Jaguariaíva Plateau, and 1.2.10) the Castro Plateau.

The Second and Third Paraná Plateaus are characterized by landforms developed on rocks of the Paraná Sedimentary Basin (PSB). The PSB is a vast sedimentary basin on the South American continent with a total area of approximately 1,500,000 km². Milani et al. (2007) organized the tectonic-stratigraphic evolutionary synthesis of the PSB into six supersequences: Rio Ivaí (Ordovician–Silurian); Paraná (Devonian), represented by the Furnas and Ponta Grossa formations; Gondwana I (Carboniferous–Early Triassic), comprising the Itararé, Guatá, and Passa Dois groups; Gondwana II (Middle to Late Triassic), whose units only occur in Rio Grande do Sul and northern Uruguay (Silva et al., 2003), and therefore are absent from Paraná; Gondwana III (Late Jurassic–Early Cretaceous), comprising the Botucatu and Serra Geral formations, interpreted by Besser et al. (2021) as the Serra Geral Group; and the Bauru (Late Cretaceous) supersequence, consisting of sedimentary rocks comprising the Caiuá and Bauru groups (Fernandes; Coimbra, 2000).

The Second Paraná Plateau (SPP) is developed on subhorizontal monoclinical structures dipping westward. It extends from the back of the Purunã cuesta (also known as the Devonian Escarpment), developed on sandstones of the Furnas Formation, where mean summit elevations range from 1,100 to 1,200 m, to its western limit at the foot of the Serra Geral cuesta escarpment front, regionally known as Serra da Esperança and Serra do Cadeado, where elevations range from 400 to 500 m (Oka-Fiori et al., 2006).

The mapping by Santos et al. (2006) and Oka-Fiori et al. (2006) recognized the SPP as a morphosculptural unit within the PSB morphostructure, subdividing it into sixteen sub-units: 2.3.1) São Luiz do Purunã Plateau, 2.3.2) Jaguariaíva Plateau, 2.3.3) Tibagi Plateau, 2.3.4) Ponta Grossa Plateau, 2.3.5) Guatá Plateau, 2.3.6) São Mateus do Sul Plateau, 2.3.7) Irati Plateau, 2.3.8) Residual Plateaus of the Teresina Formation, 2.3.9) Prudentópolis Plateau, 2.3.10) Residual Plateaus of the Serra Geral Formation, 2.3.11) Upper Ivaí Plateau, 2.3.12) Cândido de Abreu Plateau, 2.3.13) Ortigueira Plateau, 2.3.14) Santo Antônio da Platina Plateau, 2.3.15) Middle Cinzas Plateau, and 2.3.16) Carlópolis Plateau.

The Third Paraná Plateau (TPP) is the most extensive plateau in the state. It is developed on the volcanic rocks of the Serra Geral Group and the sandstones of the Caiuá Group (Besser et al., 2021), with mean summit elevations

ranging from 1,100 to 1,250 m on the back of the Serra da Esperança/Cadeado cuesta, decreasing to 220–300 m near the Paraná River valley (Oka-Fiori et al., 2006). It is recognized as a morphosculptural unit within the PSB morphostructure and is subdivided into eighteen subunits: 2.4.1) Pitanga/Ivaiporã Plateau, 2.4.2) Foz do Areia/Ribeirão Claro Plateau, 2.4.3) Clevelândia Plateau, 2.4.4) Palmas/Guarapuava Plateau, 2.4.5) Upper/Middle Piquiri Plateau, 2.4.6) Apucarana Plateau, 2.4.7) Londrina Plateau, 2.4.8) Middle Paranapanema Plateau, 2.4.9) Maringá Plateau, 2.4.10) Campo Mourão Plateau, 2.4.11) Paranavaí Plateau, 2.4.12) Umuarama Plateau, 2.4.13) Cascavel Plateau, 2.4.14) Lower Iguaçu Plateau, 2.4.15) Francisco Beltrão Plateau, 2.4.16) Upper Capanema Plateau, 2.4.17) São Francisco Plateau, and 2.4.18) Foz do Iguaçu Plateau (Santos et al., 2006; Oka-Fiori et al., 2006).

More recently, Silveira et al. (2025) published a new geomorphological map of the state of Paraná, based on the work of Santos et al. (2006) and Oka-Fiori et al. (2006). The mapping corresponds to the fourth geomorphological taxonomic level, which is equivalent to the fourth taxon in Ross (1992). It identifies 226 landform-pattern units at a scale of 1:100,000. Despite continued progress in the systematic survey of Paraná's relief, the representation of the first two geomorphological taxa, which are already established, has not yet been updated in line with the guidelines agreed upon at the SBCR Workshops (IBGE, 2020, 2024, 2025, 2026).

2. Materials and Methods

The proposed geomorphological representation of Paraná State at the first two taxonomic levels of the SBCR was developed based on the concepts and defining criteria for each landform macro-compartment, as well as each morphostructural domain and subdomain, as established by CEN/SBCR (2022) and IBGE (2024; 2025; 2026). In this study, the second taxonomic level was operationalized by combining the landform class defined at the first taxonomic level with its corresponding morphostructural domain and subdomain. This resulted in composite cartographic units. These units were then compared with classical frameworks for representing regional landforms in Paraná, particularly those of Maack (1968), Santos et al. (2006) and Oka-Fiori et al. (2006).

To implement the quantitative criteria associated with the conceptual framework operationally, a Digital Terrain Model (DTM) with a spatial resolution of 20 meters was used. This was interpolated from topographic maps at scales of 1:25,000 and 1:50,000 (Silveira; Silveira, 2017). The TopoGrid interpolator was used to generate the DTM, following the approach proposed by Hutchinson (1989) and adapted in ArcGIS as the 'Topo to Raster' tool. The resulting raster model consists of a regular grid that emphasizes hydrological consistency.

The determination of the DTM cell (pixel) size, set at 20 m, was supported by the contributions of Hengl (2006), considering the relationship between area (ground-truth extent) and contour-line density, as expressed in Eq. (1). Accordingly, the greater the geomorphological complexity, the smaller the recommended cell size.

$$C = \frac{A}{2 \cdot \sum l} \quad (1)$$

Where C is the cell size, A is the total area and $\sum l$ is the sum of the lengths of the contour lines. All the variables are expressed in meters.

Geomorphometric attributes were derived from the digital terrain model (DTM) to support interpretation and mapping. These included altimetric amplitude (Eq. 2), slope and its conversion to average slope. These parameters were processed in a geographic information system (GIS) environment using ArcGIS version 10.8 (ESRI, 2020) and QGIS version 3.40.5 - Bratislava (QGIS DEVELOPMENT TEAM, 2024).

$$\text{Altimetric amplitude} = \bar{Z}_{max} - \bar{Z}_{min} \quad (2)$$

Altimetric amplitude is the difference between the maximum elevation ($\bar{Z}_{max}$) and minimum elevation ($\bar{Z}_{min}$) values recorded within a moving analysis window. Aili (2008) treats this metric as a quantitative expression of local relief. Focal statistics were used to perform the operation with a circular window of 1 km radius, which is compatible with the spatial resolution of the digital terrain model (DTM) and the intended scale of analysis for delineating regional-scale landform macroforms at a scale of 1:600,000.

Slope was calculated as a percentage using a 3×3 pixel moving window based on directional variations according to the Horn (1981) polynomial, which estimates the local topographic gradient by comparing the central cell with its eight neighbouring cells. The average slope was then derived from this parameter to represent the

mean slope values within a given area, as expressed in Eq. (3). Here $\sum_D$ represents the sum of the slope values of each pixel within the analysis radius and n represents the number of pixels in the circular window used for focal statistics. The analysis radius was set to 1 km, which was also used to calculate the altimetric amplitude.

$$\text{Average slope} = \frac{\sum_D}{n} \quad (3)$$

The concepts established by the SBCR (CEN/SBCR, 2022; IBGE, 2024) were applied for classification at the first taxonomic level, assessing their representation in the state of Paraná. This was carried out through an analysis of the classical framework of Paraná's landform compartmentalization (Maack, 1968) and available state-level geomorphological mappings (Santos et al., 2006; Oka-Fiori et al., 2006; IBGE, 2018a, 2018b; Silveira et al., 2025). Maps representing the landforms of Brazil were also used (Azevedo, 1949; Ab'Saber, 1964; Ross, 1985; IBGE, 2006, 2019). Three landform macro-compartments were identified and delineated at a scale of 1:600,000 based on available datasets (Oka-Fiori et al., 2006; Besser et al., 2021) that supported their representation and mapping: Mountains, Plateaus, and Plains.

The classification of Mountains linked the concept predefined by the SBCR to the quantitative parameters that characterize the geomorphometric signature of this class at the first taxonomic level. Delineation was based on continuous areas with an altimetric amplitude greater than 300 meters and slope values exceeding 20 percent. Slope breaks were used as boundaries with adjacent macro-compartments. In this context, the Anhangava Granite Massif was reassessed. Previously, it was included in the First Paraná Plateau (FPP) (Santos et al., 2006; Oka-Fiori et al., 2006) and classified as a high hill by Silveira et al. (2025). However, based on the SBCR criteria, it was reclassified as a mountain due to its proximity and continuity with the Paraná portion of the Serra do Mar (SMP), as well as its geomorphometric parameters consistent with the mountainous context.

The Plains were mapped based on Quaternary formations identified in Paraná's geological map (Besser et al., 2021), supplemented by coastal hills mapped by Silveira et al. (2025). These hills consist of isolated elevations with a lower altimetric amplitude than Mountains and occur within Plains on Coastal Sedimentary Cover Sequences of Continental Genesis.

The delineation of Plateaus was based on the aggregation of the polygons corresponding to the morphosculptural units mapped by Oka-Fiori et al. (2006) and adjusted by Bortolini et al. (2016), after subtracting the adjustments resulting from the classification of Mountains and the representation of Plains.

For the classification of the Morphostructural Domains and Subdomains at the second taxonomic level of the SBCR (IBGE, 2025; 2026), data from the geological map of the state of Paraná (Besser et al., 2021) were used, jointly considering the age and rock classes. For sedimentary formations, subdivision was based on sedimentation systems and deposition environments.

3. Results

The first taxonomic level of the SBCR is represented by the major macroforms of the Brazilian landscape, comprising five classes: Mountains, Plateaus, Plains, Lowlands and Coastal Tablelands (CEN/SBCR, 2022; IBGE, 2024). The application of these classes to the territory of Paraná resulted in a novel compartmentalization that alters the logic of previous representations, particularly those based on the methods most widely used in Brazil (Ross, 1992; IBGE, 2009), by reversing the order of the first and second geomorphological taxonomic levels.

Mountains are defined by the SBCR as elevated landforms with an elevation range exceeding 300 m relative to the surrounding areas, predominantly characterized by sharp summits or ridgelines and steep slopes, whose occurrence is generally associated with continuous dissected assemblages in orogenic systems or cratons (CEN/SBCR, 2022; IBGE, 2024). In the state of Paraná, they are expressed by the Serra do Mar Mountains, with summits exceeding 1,800 m and an elevation range frequently exceeding 1,200 m relative to the Coastal Plain and 300 m relative to the Plateau. The Serra do Mar, therefore, fully meets the criteria defining the Mountains class. Other landforms in Paraná may locally exhibit an elevation range exceeding 300 m; however, because they do not occur as spatially continuous assemblages, they are classified as elevated hills (Silveira et al., 2025).

Plateaus are conceptualized as elevated landforms relative to adjacent surfaces, at least along one of their margins, with varying degrees of dissection and diverse slopes and elevations, sculpted on different geological substrates (CEN/SBCR, 2022; IBGE, 2024), and constitute the dominant class in Paraná. Among the five regional units described by Maack (1968) and adopted by Santos et al. (2006), three fall directly within this class: the First,

Second and Third Paraná Plateaus. Together, these plateaus encompass approximately 95% of the state's territory, making Paraná one of the Brazilian states with the greatest proportion of plateau relief (Botelho et al., 2024), considering their proportional representation within the state's territory.

Plains are recognized as predominantly flat landform developed over unconsolidated sedimentary deposits of Quaternary age, where accumulation exceeds erosion, resulting in landforms associated with fluvial, marine, lacustrine, lagoonal and aeolian processes (CEN/SBCR, 2022; IBGE, 2024). In Paraná, they correspond to the Coastal Plain and the fluvial plains distributed along the state's main rivers. The Coastal Plain extends from the Serra do Mar Mountains to the Atlantic Ocean coastline and consists of continental and coastal sedimentary deposits associated with fluctuations in relative sea level during Quaternary transgressive and regressive cycles (Angulo, 2004).

Lowlands, which comprise landforms lower than adjacent areas and result from denudational processes, with low to moderate slopes and elevation variations, may occur in interplateau, intermontane or marginal settings and may contain residual landforms (CEN/SBCR, 2022; IBGE, 2024), were not represented in the territory of Paraná. This is because the state of Paraná did not develop an extensive circumdenudation zone, as occurs in the neighboring state of São Paulo, where the opening of the São Paulo Peripheral Depression represents a legitimate lowland surface at the contact with the Crystalline Plateau. This morphosculptural feature was not developed with the same expression in Paraná because it abruptly loses its character as a true marginal depression and assumes the condition of a broad and relatively rugged monocline depression, located in Paraná between the back-slope of the Devonian cuesta and the base of the sandstone-basaltic escarpments, forming a second plateau (Ab'Sáber, 1998). In São Paulo, the Peripheral Depression of the Eastern Margin of the Paraná Basin presents elevations ranging from 600 to 750 m, whereas toward the state of Paraná the unit gains elevation, reaching 900 m, thereby changing its morphological characteristics. The crystalline area is known as the First Plateau, while the step maintained by Devonian sediments is known as the Second Plateau (Ross, 1985).

Coastal Tablelands, which represent predominantly tabular landforms with flat and/or gently undulating summits, potentially exhibiting stepped levels, low slopes, steep margins, elevations below 250 m, an elevation range of 20 to 60 m, Neogene sedimentary cover, and poorly lithified rocks (CEN/SBCR, 2022; IBGE, 2024), are likewise not represented in Paraná. The Curitiba Sedimentary Basin, located within a graben in the interior of the FPP, presents low-amplitude landforms developed over poorly lithified sedimentary rocks of Cenozoic age. However, its summits do not exhibit tabular forms but rather rounded forms, constituting a typical gentle-hill landscape that forms part of a relatively lower compartment of the First Paraná Plateau itself. Accordingly, no tablelands were mapped in the state of Paraná.

Thus, the relief macro-compartments represented in the state of Paraná are Mountains, Plateaus and Plains (Figure 3). Plateaus are predominant, with a calculated area of 185,830 km², representing 93.2% of the territory of Paraná; Mountains total 3,022 km², or 1.52%; and Plains encompass 7,213 km², or 3.6%. Water bodies account for 1.63% of the territory, covering 3,255 km².

The second taxonomic level of the SBCR corresponds to the Morphostructural Domains, based on the main geological domains of the South American Platform that are relevant to the development of the present-day landscape, which, in accordance with Hasui (2012), are: (i) shields; (ii) sedimentary basins and covers; and (iii) modern fold belts. The representation of Morphostructural Subdomains was added to this taxonomic level, corresponding to the main lithostratigraphic domains present within the Brazilian territory (Marques et al., 2006; IBGE, 2025; 2026). Thus, the second taxonomic level of the SBCR complements the representation of the macro-compartments established at the first taxonomic level through the incorporation of morphostructural information (Table 1).

Despite the significant changes introduced in the representation of the Morphostructural Domains, with their position reversed within the representation of the first two taxonomic levels, the definition adopted within the SBCR was maintained in accordance with IBGE (2009), considering that these domains occur at a regional scale (IBGE, 2025), represented here at a scale of 1:600,000, in accordance with the geological base map of Besser et al. (2021).

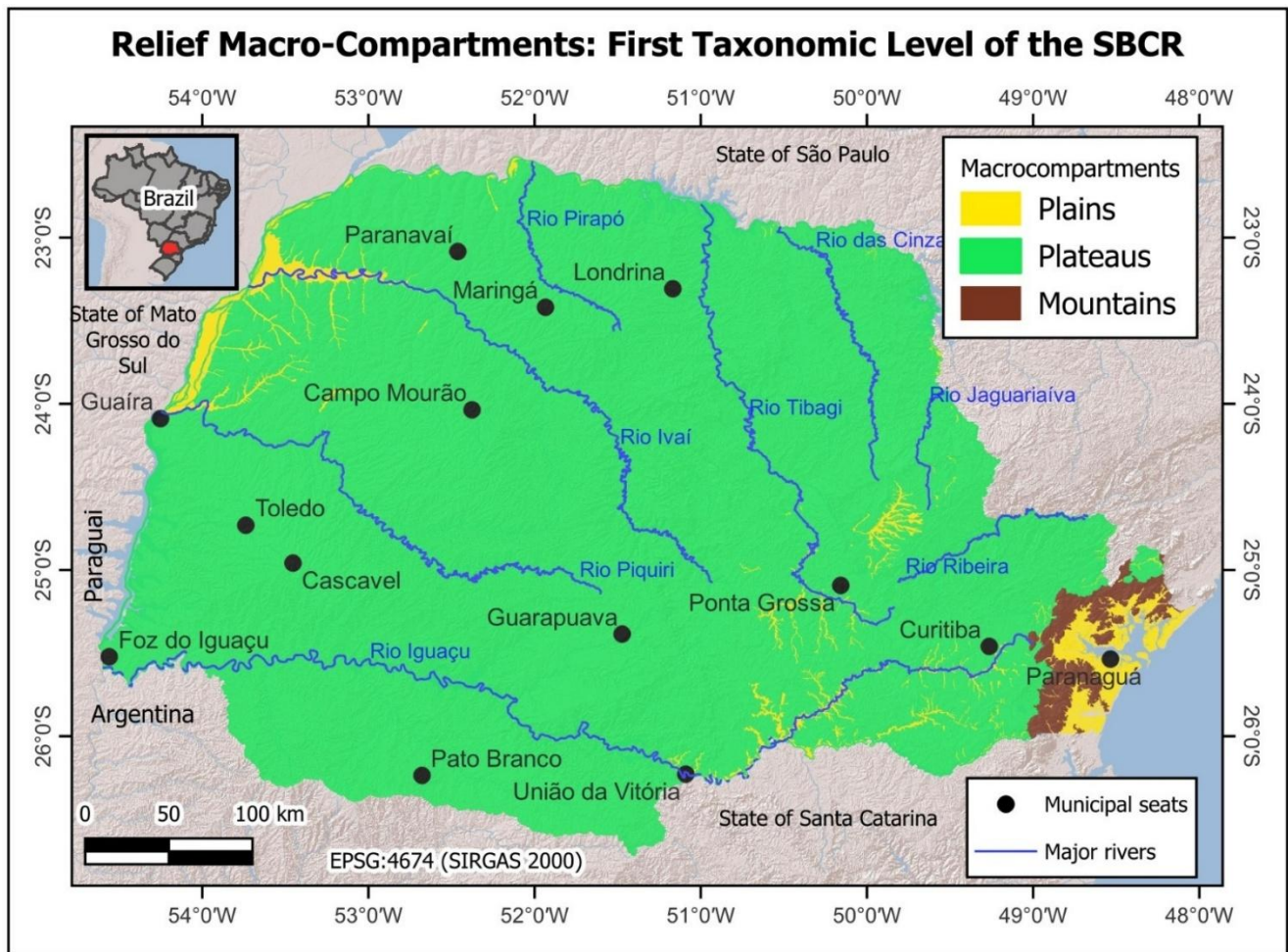


Figure 3. Map of the geomorphological macro-compartments of the state of Paraná (representation of the 1st taxon of the SBCR).

The Shield Morphostructural Domain of the SBCR (IBGE, 2025; 2026) was previously recognized as the Atlantic Orogenic Belt morphostructural unit (Santos et al., 2006; Oka-Fiori et al., 2006; Ross, 1992). This unit is identified by Schobbenhaus and Brito Neves (2003) as the Atlantic Shield, corresponding to the assemblage of Precambrian crystalline terranes that form the eastern portion of the South American Platform. From a geotectonic perspective, the Atlantic Shield forms part of the domains associated with the Mantiqueira Province, a Neoproterozoic orogenic system extending from the southern part of the state of Bahia to Rio Grande do Sul (Heilbron et al., 2004). The Southern Plateau (Azevedo, 1949), or Atlantic Plateau (Ab'Saber, 1964), is developed on this basement and, regionally within the territory of Paraná, comprises the Serra do Mar and First Plateau.

The Sedimentary Basins and Covers Morphostructural Domain of the SBCR (IBGE, 2025; 2026) in the territory of Paraná comprises predominantly the Paraná Sedimentary Basin (PSB), which was previously treated as a morphostructural unit at the first taxonomic level (Santos et al., 2006; Oka-Fiori et al., 2006; Ross, 1992). The PSB corresponds to the Paraná Province (Silva et al., 2003), which encompasses most of the state territory. The application of morphostructural subdomain criteria to its differentiation made it possible to distinguish three units within the state, the same units established by Silva et al. (2003), corresponding to independent sedimentation areas separated by major unconformities (Figure 4): 1) Paraná Basin, corresponding to the Rio Ivaí, Paraná, Gondwana I, and Gondwana II supersequences (Milani et al., 2007); 2) Serra Geral Basin, representing the Gondwana III Supersequence; and 3) Bauru Basin, corresponding to the eponymous supersequence. The first unit corresponds to the Second Plateau, whereas the second and third units correspond to the Third Plateau.

Table 1. Taxonomy of the Brazilian Landform Classification System (SBCR) – 1st and 2nd taxon.

1st taxon	2nd taxon	
Relief Macro-compartments	Morphostructural Domain	Morphostructural Subdomain (lithostratigraphic terrains)
Mountains	Shield	Granite-gneissic terrains
		Schistose and quartzitic terrains
		Intrusive massifs
	Modern Folds	–
Plateau	Shield	Granite-gneissic terrains
		Schistose and quartzitic terrains
		Intrusive massifs
		Metavolcanic and metavolcano sedimentary sequences
	Sedimentary Basins and Covers	Volcanic sequences
		Rocks that have not recently undergone metamorphism
		Weakly lithified
		Lithified
Lowlands	Shield	Granite-gneissic terrains
		Schistose and quartzitic terrains
		Intrusive massifs
		Metavolcanic and metavolcano sedimentary sequences
	Sedimentary Basins and Covers	Volcanic sequences
		Non-metamorphosed to weakly metamorphosed rocks
		Weakly lithified
		Lithified
Coastal Tablelands	Continental Sedimentary Basins and Covers	–
	Coastal Sedimentary Basins and Covers	Continental Genesis
		Marine Genesis
Plains	Continental Sedimentary Basins and Covers	–
	Coastal Sedimentary Basins and Covers	Continental Genesis
		Marine Genesis

Source: IBGE (2026)

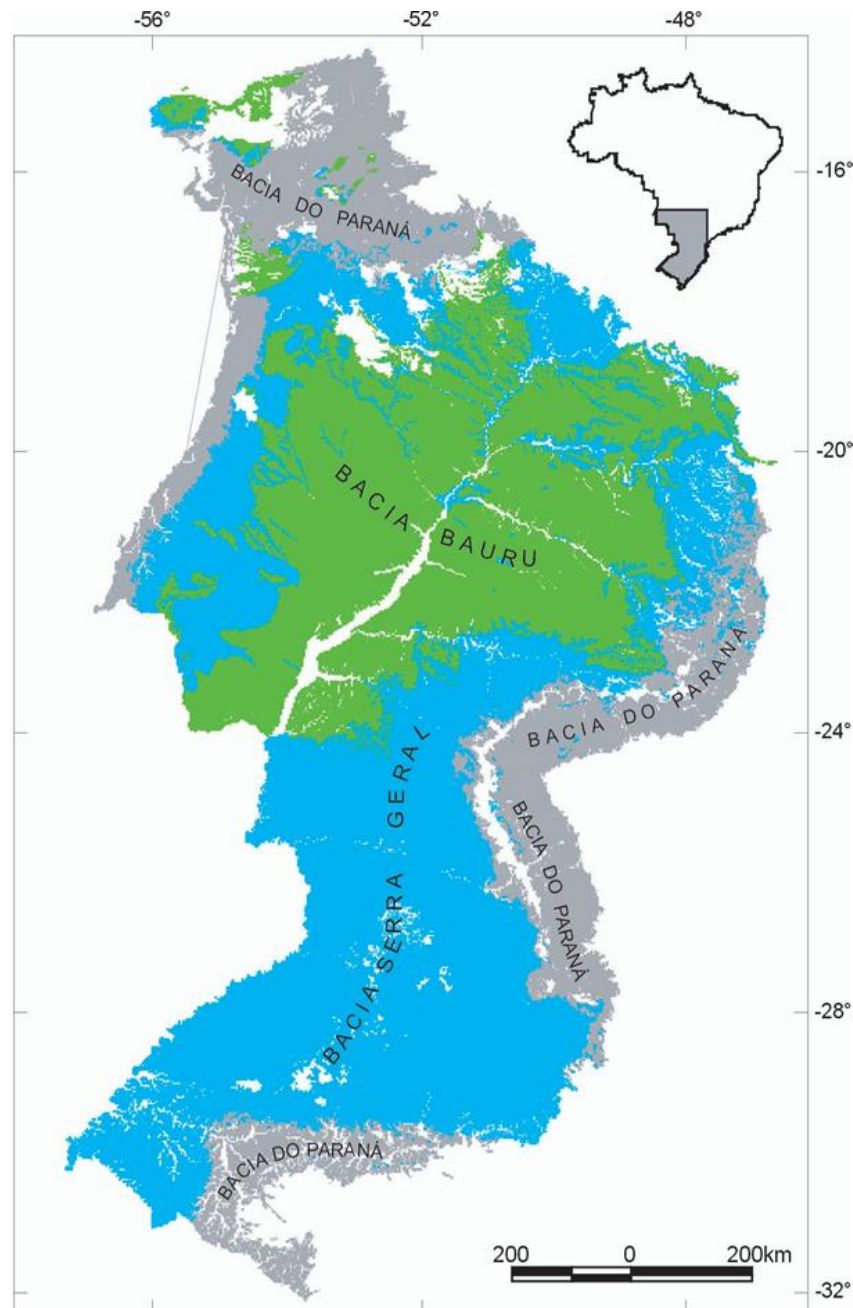


Figure 4. Geological sketch of the Paraná Province showing the three independent sedimentary areas: Paraná Basin, Serra Geral Basin and Bauru Basin. Source: Silva et al. (2003).

Another Morphostructural Domain and Subdomain present in the territory of Paraná is the Poorly Lithified Sedimentary Basins and Covers unit, represented by the Curitiba and Tijucas do Sul Sedimentary Basins, located in the central-southern portion of the First Paraná Plateau, over granitoid-gneissic terrains of the Atuba Complex. Although geographically separated, these basins are commonly correlated (Moreira et al., 2019). The Curitiba Sedimentary Basin (CSB) forms part of the group of Cenozoic taphrogenic basins associated with the Continental Rift of Southeastern Brazil (Riccomini, 1989). Its architecture was controlled by faults reactivated during the Cenozoic, which conditioned the depositional geometry and were influenced by paleoclimatic conditions. Its sedimentary covers comprise the Guabirotuba Formation, which has the greatest extent, and the Tinguis Formation, which overlies the former along an erosional unconformable contact (Salamuni et al., 1999; 2004; De Lima et al., 2013). The Tijucas do Sul Basin, in turn, is not part of the tectono-depositional cycle of the Continental Rift of Southeastern Brazil and represents a new continental sedimentary cycle, characterized by the Tabatinga Formation (Moreira et al., 2019; Besser et al., 2021). Its sedimentation occurred under humid climatic conditions during the Late Pleistocene or Holocene, in contrast to the semiarid paleoclimate proposed for the CSB.

The Quaternary deposits of the coastal region of Paraná and the fluvial plains in the interior of the state are organized into two Morphostructural Domains, one of which is subdivided into two Morphostructural Subdomains, resulting in three relief units corresponding to plains: i) Coastal Sedimentary Basins and Covers of Marine Genesis; ii) Coastal Sedimentary Basins and Covers of Fluvial Genesis; and iii) Continental Sedimentary Basins and Covers (of Fluvial Genesis). The distinction among these units was established based on their geographic position within the South American Platform and their genesis, which implies distinct process and landform contexts (IBGE, 2025; 2026).

Thus, the representation of the Paraná up to the second taxonomic level of the SBCR resulted in the definition of nine classes: 1) Mountains on Shields over Granito-Gneissic Terrains – the Serra do Mar Mountains; 2) Plateaus on Shields over Granito-Gneissic Terrains – the First Paraná Plateau; 3) Plateaus on Paleozoic and Mesozoic Lithified Sedimentary Basins and Covers (Paraná Basin) – Second Paraná Plateau; 4) Plateaus on Sedimentary Basins with Neojurassic–Early Cretaceous Volcanic Sequences (Serra Geral Basin) – the Paraná Volcanic Third Plateau; 5) Plateaus on Neocretaceous Lithified Sedimentary Basins and Covers (Bauru Basin) – the Paraná Sandstone Third Plateau; 6) Plateaus on Poorly Lithified Cenozoic Sedimentary Basins and Covers (Curitiba and Tijucas do Sul Basins) – the Curitiba Basin Plateau; 7) Plains on Coastal Sedimentary Covers of Marine Genesis – the Marine and Fluviomarine Plain; 8) Plains on Coastal Sedimentary Covers of Continental Genesis the Fluvial Plains; and 9) Plains on Continental Sedimentary Covers – the Fluvial Plains (Table 2 and Figure 5).

Table 2. Area and percentage of representation within the state of Paraná of the geomorphological classes of the first two taxonomic levels of the SBCR (Macro-compartments and Morphostructural Domains and Subdomains).

Relief Macro-compartments with Morphostructural Domains and Subdomains (First and Second Taxonomic Levels of the SBCR)	Area (km²)	%
Plains on Coastal Sedimentary Covers of Marine Genesis (Marine and Fluviomarine Plains)	1264	0,63
Plains on Coastal Sedimentary Covers of Continental Genesis (the Fluvial Plains)	1191,3	0,6
Plains on Continental Sedimentary Covers (Fluvial Plains)	8013	4,02
Mountains in Shields on Granite-Gneissic Terrains (Serra do Mar Paranaense)	3022	1,52
Plateaus in Shields on Granite-Gneissic Terrains (Paraná First Plateau)	16938,7	8,5
Plateaus in Basins and Poorly Lithified Cenozoic Sedimentary Covers (Curitiba Basin Plateau)	746,3	0,37
Plateaus in Basins and Lithified Paleozoic Sedimentary Covers (Paraná Basin) (Second Paraná Plateau)	43555,6	21,85
Plateaus in Sedimentary Basins with Neojurassic–Early Cretaceous Volcanic Sequences (Serra Geral Basin) (Paraná Volcanic Third Plateau)	97812,7	49,08
Plateaus in Basins and Lithified Late Cretaceous Sedimentary Covers (Bauru Basin) (Paraná Sandstone Third Plateau)	26777	13,43

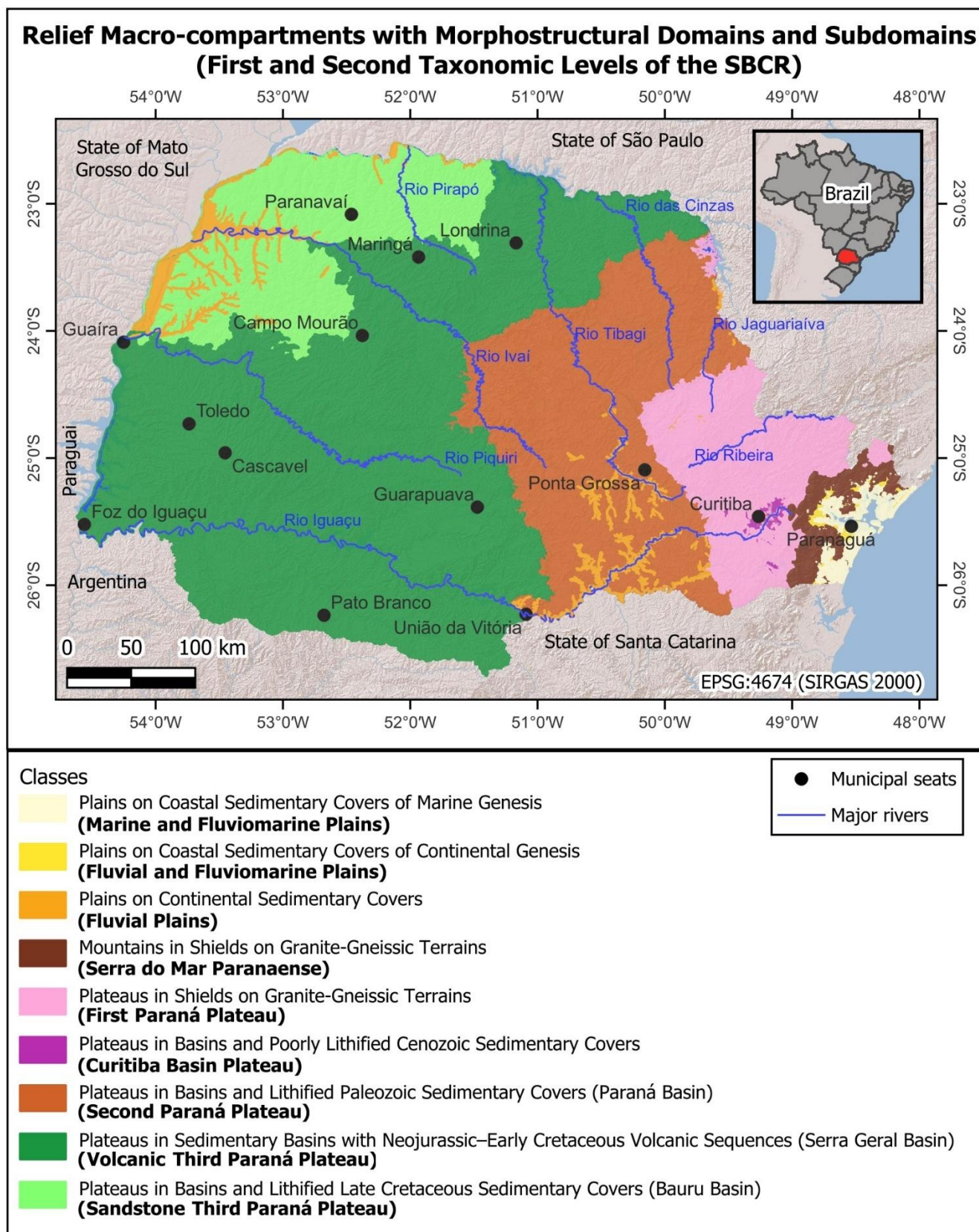


Figure 5. Map of the macroforms of the state of Paraná, represented by the first two taxa of the SBCR (Macro-compartments and Morphostructural Domains and Subdomains).

4. Discussion

The reinterpretation of the Paraná landforms in light of the concepts and criteria established by the SBCR led to a novel organization that differs from previous mappings and classifications, while revealing correspondences in the individualization of landform units with some classical representations of Paraná, such as the natural regions of Paraná proposed by Maack (1968), as well as the mappings by Santos et al. (2006) and Oka-Fiori (2006). At the same time, it highlighted relevant conceptual changes, such as the inversion of the first and second taxonomic levels proposed by Ross (1992) and IBGE (2009), giving emphasis to the macro-compartments of the Brazilian relief rather than to morphostructures at the uppermost level of representation.

Regarding the first taxonomic level, while the pre-existing geomorphological mapping by Santos et al. (2006) and Oka-Fiori (2006) places morphostructures at the first taxonomic level, in accordance with the guidelines of Ross (1992), organizing them into three morphostructural units: (i) Atlantic Orogenic Belt, (ii) Paraná Sedimentary Basin and (iii) Cenozoic Sedimentary Basins and Tectonic Depressions, the SBCR defines the following relief macro-compartments for this hierarchical position: (i) Mountains, (ii) Plateaus and (iii) Plains. Consequently, the units that previously represented the first taxonomic level in the pre-existing geomorphological mapping became criteria for distinguishing the relief units corresponding to the second taxonomic level of the SBCR.

Another distinction resulting from the application of the SBCR in Paraná was the recognition of Mountains as a geomorphological class present in the state, represented by the Serra do Mar, since it fully meets all the criteria defining this macro-compartment. Botelho et al. (2023), when addressing the Serra do Mar in the state of Rio de Janeiro, had already recognized it as mountainous landscape, constituting a true mountain range due to its significant spatial extent within the Brazilian territory. According to these authors, the SBCR imposes no restrictions on the use and mention of established toponyms of mountainous areas as proper names in maps and texts concerning landforms in Brazil, as is the case with the well-established designation “Serra do Mar”. Therefore, “Serra do Mar Mountains” constitutes a plausible designation.

When combined with the second taxonomic level of the SBCR, this macro-compartment constitutes Mountains on Shields in Granito-Gneissic Terrains (Figure 6A), corresponding to the boundaries recognized for the Serra do Mar Mountains (Maack, 1968), and broadly equivalent to the second taxonomic level of Santos et al. (2006) and Oka-Fiori et al. (2006). Although mountains were not explicitly included as a geomorphological class in the classification methods of Ross (1992) and IBGE (2009), nor were they represented in the Radam Brasil mapping (IBGE, 2018a; 2018b), they had already been recognized by Ab’Saber (1975; 1985), who defined the Serra do Mar as Mountains in fault-block terrain. Consistent with this interpretation, Sartori and Sartori (2004) had previously discussed and recognized Mountains within the Brazilian territory, while Botelho et al. (2023) presented the Serra do Mar in the state of Rio de Janeiro as mountainous landscape, in accordance with the SBCR. The corresponding morphostructural domain and subdomain are Mountains on Shields in Granito-Gneissic Terrains, represented by the lithostructures of the Luís Alves and Paranaguá Terranes (Besser et al., 2021).

The Plateaus were individualized into two Morphostructural Domains: (i) Shields and (ii) Sedimentary Basins and Covers. The former constitutes Plateaus on Shields over Granito-Gneissic Terrains (Figures 6B and 6C), largely corresponding to the region with the well-established designation of First Paraná Plateau (Maack, 1968), treated at the second taxonomic level as a morphosculptural unit by Santos et al. (2006) and Oka-Fiori et al. (2006). The interpretation of this plateau environment converges with national designations such as the Atlantic Plateau in Azevedo (1949), the Eastern and Southeastern Plateaus in Ab’Saber (1964), the Plateaus and Ranges of the Eastern-Southeastern Atlantic in Ross (1985), and the Paranapiacaba Plateau in IBGE (2006). The corresponding Morphostructural Domain and Subdomain are represented by the lithostructures of the Curitiba and Apiaí Terranes, Granitic Suites, and the Atuba and Setuva Complexes (Besser et al., 2021).

There is a pronounced distinction between the landforms in the northern and southern regions of the Paraná First Plateau. In the north, in the Ribeira River Valley region, Dissected Plateaus predominate (Santos et al., 2006), developed over the lithostructures of the Apiaí Terrane and Granitic Suites (Besser et al., 2021), with predominant landform patterns ranging from hills and dissected hills to elevated hills (Silveira et al., 2025). When the criteria for identifying mountains are applied to this region, the requirements for elevation range, slope and summit morphology are met. However, the region does not constitute an elevated position relative to the surrounding areas, as it comprises a strongly eroded valley that, under the effects of differential erosion, has resulted in relief with pronounced morphographic variations across the landscape (Botelho et al., 2024). This area is categorized as the Ribeira Highland Range (Costa et al., 2018) and is represented by Santos et al. (2006) by four morphosculptural

subunits of Dissected Plateaus (Adrianópolis, Tunas do Paraná, Rio Branco do Sul, and Alto Ribeira). To the south, the terrain is undulated, with hill patterns (Silveira et al., 2025), represented by the Curitiba Plateau morphosculptural subunit (Santos et al., 2006), developed over the lithostructures of the Curitiba Terrane and the Atuba and Setuva Complexes (Besser et al., 2021).

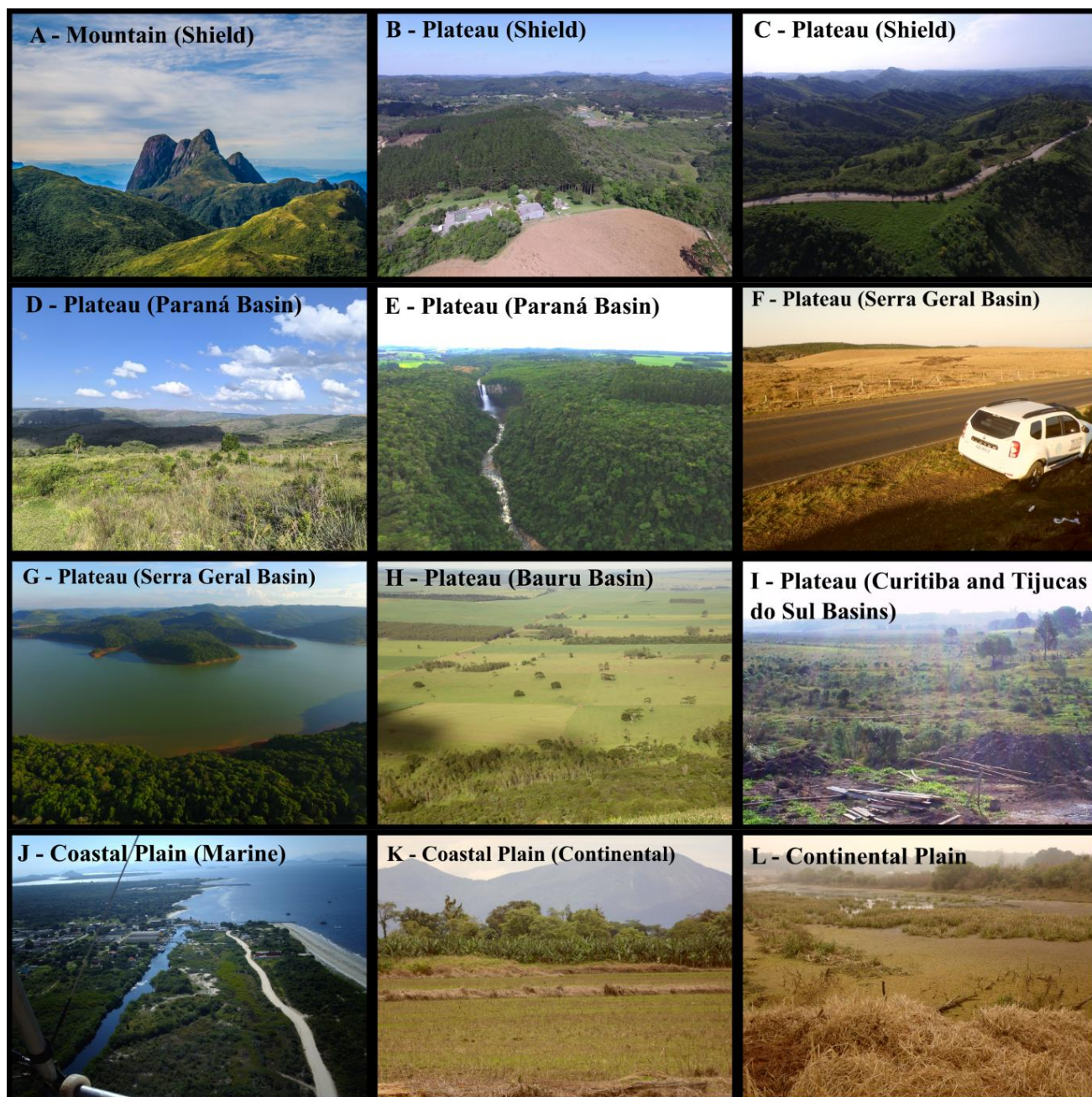


Figure 6. Representative field photographs of the second-taxonomic-level classes (Morphostructural Domains and Subdomains) of the SBCR. A: Mountains on Shields over Granito-Gneissic Terrains. B and C: Plateaus on Shields over Granito-Gneissic Terrains. D and E: Plateaus on Paleozoic and Mesozoic Lithified Sedimentary Basins and Covers (Paraná Basin). F and G: Plateaus on Sedimentary Basins with Late Jurassic–Early Cretaceous Volcanic Sequences (Serra Geral Basin). H: Plateaus on Late Cretaceous Lithified Sedimentary Basins and Covers (Bauru Basin). I: Plateaus on Cenozoic Poorly Lithified Sedimentary Basins and Covers (Curitiba and Tijucas do Sul Basins). J: Plains on Coastal Sedimentary Covers of Marine Genesis. K: Plains on Coastal Sedimentary Covers of Continental Genesis. L: Plains on Continental Sedimentary Covers in Paraná. Source: photograph A by Diego Samy Frantz; photographs B–L from the LAGEO/UFRP collection.

It is worth emphasizing that the singularity of the upper Ribeira River Valley, in relation to the other plateau compartments of the state of Paraná, stems from the fact that this drainage basin is directly adjusted to the general base level represented by the Atlantic Ocean in southern São Paulo state. The other plateau surfaces, in turn, are adjusted to the base level of the Iguaçu and Paraná rivers, whose elevations are maintained above the regional base level by the significant local base-level control (knickpoint) represented by Iguaçu Falls. As a result, the upper Ribeira River Valley region presents markedly rough terrain, with a degree of dissection considerably greater than that of the other compartments, controlled by the pronounced incision of the Ribeira de Iguape River channel. This morphological distinction is evidenced by the denudation rates obtained by Bortolini et al. (2025) from the concentration of in situ-produced cosmogenic ^{10}Be . The authors obtained a weighted mean denudation rate of $10.0 \pm 0.3 \text{ m Ma}^{-1}$ for sub-basins in the upper Ribeira River Valley, whereas the sub-basins of the other compartments draining toward the continental interior recorded values of $8.6 \pm 0.4 \text{ m Ma}^{-1}$ for the Piraí Depression and $5.8 \pm 0.2 \text{ m Ma}^{-1}$ for the reverse slope of the Devonian Escarpment.

The Plateaus on Sedimentary Basins and Covers unit can be subdivided in Paraná into four distinct morphostructures, two of which are lithified, one developed over a volcanic sequence, and the other consisting of poorly lithified deposits. The first three are present in the Paraná Sedimentary Province and correspond to sedimentation areas: (1) Paraná Basin, (2) Serra Geral Basin, and (3) Bauru Basin (Silva et al., 2003); the fourth (4) is represented by the Curitiba and Tijucas do Sul Basins (Salamuni et al., 1999; 2004; De Lima et al., 2013; Moreira et al., 2019).

The unit Plateaus on Paleozoic and Mesozoic Lithified Sedimentary Basins and Covers (Paraná Basin) (Figures 6D and 6E) corresponds to the Second Paraná Plateau (Maack, 1968), represented as a morphosculptural unit under the same designation by Santos et al. (2006) and Oka-Fiori et al. (2006). The age qualification, referring to the Paleozoic and Mesozoic eras, corresponds to the tectono-stratigraphy of the Rio Ivaí, Paraná, Gondwana I, and Gondwana II supersequences (Milani et al., 2007), corresponding to the unit identified by Silva et al. (2003) as the Paraná Basin, present in the Paraná Province. The same area is referred to by different nomenclature by Ross (1985) as the “Peripheral Depression of the Eastern Margin of the Paraná Basin” and by IBGE (2006; 2018a; 2018b) as the “Steps of the Eastern Margin of the Paraná Basin,” generating inconsistencies that the SBCR reduces by resolving the classificatory ambiguity through the inclusion of this compartment within the Plateau representation at the first taxonomic level, rather than as a depression or steps.

The unit Plateaus on Sedimentary Basins with Neojurassic–Early Cretaceous Volcanic Sequences (Serra Geral Basin) (Figures 6F and 6G) is partly contained within the Third Paraná Plateau and therefore does not fully correspond to the region established by Maack (1968), nor to the morphosculptural unit identified at the second taxonomic level by Santos et al. (2006) and Oka-Fiori et al. (2006). This unit corresponds to plateau developed over rocks of the Serra Geral Group (Besser et al., 2021), equivalent to the Gondwana III Supersequence (Milani et al., 2007) and the Serra Geral Basin (Silva et al., 2003). It represents the largest geomorphological unit in the state of Paraná based on the application of the first two taxonomic levels established by the SBCR, encompassing practically half of the state's total area (Table 1). Its designation as a plateau macro-compartment is consistent with previous authors, including the Southern Plateau (Azevedo, 1949; Ab'Saber, 1964), Plateaus and Tablelands (Chapadas) of the Paraná Basin (Ross, 1985), and the Araucaria Plateau and Upper Paraná River Plateaus (IBGE, 2006; 2018a; 2018b).

The unit Plateaus on Neocretaceous Lithified Sedimentary Basins and Covers (Bauru Basin) (Figure 6H) is likewise contained within the Third Paraná Plateau (Maack, 1968; Santos et al., 2006; Oka-Fiori et al., 2006), coinciding exclusively with the area where the terrain was developed over rocks of the Caiuá Group (Besser et al., 2021), correlated with the Caiuá Group and the Bauru Group (Fernandes; Coimbra, 2000). The Neocretaceous age qualification refers to the tectono-stratigraphy of the Bauru Supersequence (Milani et al., 2007), equivalent to the Bauru Basin of the Paraná Province (Silva et al., 2003). The designation of Plateau is likewise consistent with the literature, including the Southern Plateau (Azevedo, 1949; Ab'Saber, 1964), Plateaus and Chapadas of the Paraná Basin (Ross, 1985), and the Upper Paraná River Plateaus (IBGE, 2006; 2018a; 2018b). Distinguishing this unit from sectors developed over Neojurassic–Early Cretaceous volcanic sequences made it possible to separate environments with distinct morphologies within the Third Paraná Plateau. It represents one of the flattest geomorphological units in the territory of Paraná, consisting of extensive hills (Silveira et al., 2025), whose morphodynamics are marked by high susceptibility to linear erosional processes, particularly gullies and rills (Santos et al., 2007).

The unit Plateaus on Poorly Lithified Cenozoic Sedimentary Basins and Covers (Curitiba and Tijucas do Sul Basins) (Figure 6I) comprises landforms developed over the Curitiba and Tijucas sedimentary basins, on the Guabirotuba Formation (Salamuni et al., 1999; 2004; De Lima et al., 2013; Besser et al., 2021) and the Tabatinga Formation (Moreira et al., 2019; Besser et al., 2021), characterized by hill patterns with fluvial plains occupying valley bottoms (Silveira et al., 2025). This unit was found to have a much smaller area than the other plateau units in Paraná, covering 746.3 km² and accounting for 0.37% of the state's territory (Table 1). The other plateau units also exhibit spatial continuity across neighboring states and countries, which further increases their dimensions in comparison with this unit, which constitutes an enclave within the First Paraná Plateau. The distinction of the "Poorly Lithified" subdomain within the Morphostructural Domain of Sedimentary Basins and Covers resulted in the individualization of small areas in terms of spatial extent, as is the case of the Curitiba and Tijucas do Sul Basins in Paraná. These areas have limited significance for representation at very small scales, smaller than 1:5,000,000, as is generally the case for maps covering the entire country or large regions. Previously, in the representation of the second hierarchical level of the geomorphological map of Paraná, this unit had been generalized within the Paraná First Plateau at the second taxonomic level and was only individualized at the third taxonomic level as the Alto Iguaçu Plateau morphosculptural subunit (Santos et al., 2006; Oka-Fiori et al., 2006).

The units Plateaus on Coastal Sedimentary Covers of Marine Genesis (Figure 6J) and Plains on Coastal Sedimentary Covers of Continental Genesis (Figure 6K) constitute the Coastal Zone (Maack, 1968). The former corresponds to the Coastal Plain morphosculptural subunit, whereas the latter corresponds to the Fluvio-Marine Plains; both were represented in the pre-existing mapping at the third taxonomic level (Santos et al., 2006; Oka-Fiori et al., 2006). The Paraná coastal plain is defined by Bigarella et al. (1978) as a Quaternary depositional complex characterized by high facies heterogeneity, whose genesis is intrinsically linked to Pleistocene and Holocene eustatic oscillations, which shaped the stratigraphic framework and present-day geomorphological configuration through the interaction of marine, estuarine and continental processes. The resulting landforms include sandy coastal plains, estuaries and lagoons (Angulo et al., 2009). This environment is organized as a mosaic of units; considering morphogenesis and morphography, Comerlato et al. (2023) identified seven geomorphological classes in the Central Portion of the Paraná Coastal Plain: Paleodunes, Estuarine Plains, Estuarine Terraces, Marine Plains, Marine Terraces, Fluvial Plains and Fluvial Terraces. The first five classes represent the morphostructural subdomain of Marine Genesis, whereas the latter two represent Fluvial Genesis within the coastal environment.

The area of the unit Plateaus on Coastal Sedimentary Covers of Marine Genesis also includes coastal hills (Silveira et al., 2025), which represent isolated elevations within the coastal plain and have heights below those of Mountains (300 m), surrounded by sediments. The presence of these landforms in the Paraná Coastal Plain is supported by an interpretation analogous to the understanding of inselbergs as residual landforms within the Lowlands macro-compartments occurring in the semiarid landscapes of the Sertaneja Surface (Sales et al., 2025).

Finally, the Plains on Continental Sedimentary Covers in Paraná (Figure 6L), represented by the Fluvial Plains morphosculptural subunit (Santos et al., 2006; Oka-Fiori et al., 2006), are aggradational geomorphological units with flat morphology, located within the interior of the Paraná territory, which originated during the Quaternary. Unlike coastal plains, their genesis is associated with the reworking of continental sediments from the Paraná Basin, resulting in the accumulation of unconsolidated alluvial and colluvial materials, with an evolutionary dynamics marked by active fluvial processes across extensive floodplains. In the state of Paraná, these plains are concentrated mainly along the Paraná River plain, characterized by an anastomosing channel system; along the Iguaçu River plains, both in its upper course in the Curitiba region and in its middle course in the União da Vitória region; within the active floodplain of the lower Ivaí River; and along the plains of tributaries of the upper Tibagi River.

The application of the SBCR demonstrated that the proposed taxonomic framework was operationally feasible for the territory of Paraná. The nine resulting units proved coherent from both morphological and lithostratigraphic perspectives, despite one of them, the Plateaus on Poorly Lithified Cenozoic Sedimentary Basins and Covers (Curitiba and Tijucas do Sul Basins), being substantially smaller in spatial extent than the other plateau units. This raises the question of whether the morphostructural subdomain "Poorly Lithified," assigned to Sedimentary Basins and Covers (Table 1), should in fact be used as a criterion for subdividing geomorphological units representing the second taxonomic level, given their limited areal extent at this hierarchical level, which is customarily organized into units of regional extent.

The greatest conceptual consistency lies in adopting landform as the criterion for the first hierarchical level of representation. This eliminates dependence on the geological substrate for defining the macro-compartments and facilitates geomorphological communication across different scales and contexts of use. In the state of Paraná, the application of the concepts and criteria of the first taxonomic level resolved conceptual conflicts among geomorphological classes that tended to cause confusion by retaining Plateaus rather than Steps and Depressions in the representation at the first hierarchical level.

The preceding mapping units of Santos et al. (2006) and Oka-Fiori et al. (2006) maintained an identifiable correspondence with the nine units constituted by the macro-compartments combined with the morphostructural domains and subdomains of the second taxonomic level of the SBCR, with only minor variations in area among them (Table 3). The correspondence between these representations allows the preservation of the toponyms associated with the classical natural units of Maack (1968). Exceptions include the subdivision of two units that now represent the Third Paraná Plateau, one comprising terrain developed over a volcanic substrate (Serra Geral Basin) and the other over sandstones (Bauru Basin); and the subdivision of two additional units within the Paraná First Plateau, one developed over the Paraná Shield and encompassing almost its entirety, and the other, much smaller in extent, developed over non-lithified sedimentary deposits of the Curitiba and Tijucas do Sul Basins.

Table 3. Correspondence between the morphosculptural units of the geomorphological mapping (Santos et al., 2006; Oka-Fiori et al., 2006) and the geomorphological Macro-compartments and Morphostructural Domains and Subdomains (first and second taxonomic levels of the SBCR).

Geomorphological mapping of Paraná (Santos et al., 2006; Oka-Fiori et al., 2006)	Area (km ²)	%	Relief Macro-compartments with Morphostructural Domains and Subdomains (First and Second Taxonomic Levels of the SBCR)	Area (km ²)	%	Variation (%)
Plains	5228,9	2,62	Plains on Coastal Sedimentary Covers of Continental Genesis	1264	0,63	0,99
			Plains on Coastal Sedimentary Covers of Marine Genesis	1191,3	0,6	
			Plains on Continental Sedimentary Covers	4758	2,39	
Serra do Mar Paranaense	3228,7	1,62	Mountains in Shields on Granite-Gneissic Terrains	3022	1,52	-0,1
First Paraná Plateau	18492,6	9,28	Plateaus in Shields on Granite-Gneissic Terrains	16939	8,5	-0,41
			Plateaus in Cenozoic Basins and Poorly Lithified Sedimentary Covers	746,3	0,37	
Paraná Second Plateau	43754	22	Plateaus in Basins and Lithified Paleozoic Sedimentary Covers	43556	21,9	-0,11
Third Paraná Plateau	125234	62,9	Plateaus in Sedimentary Basins with Volcanic Sequences	97813	49,1	-0,35
			Plateaus in Basins and Lithified Sedimentary Covers of the Late Cretaceous	26777	13,4	
Bodies of water	3294	1,65	Bodies of water	3255	1,63	0,02

5. Conclusions

The application of the first two taxonomic levels of the Brazilian Landform Classification System (SBCR) to the territory of Paraná demonstrated that the new taxonomic framework is both conceptually consistent and operationally feasible. The results obtained for Paraná suggest that the SBCR has the potential to be applied to other Brazilian states with comparable morphological and morphostructural diversity.

At the first taxonomic level, the state of Paraná is represented by three macro-compartments: Mountains, Plateaus and Plains, with a clear predominance of Plateaus over the other classes, accounting for 93.22% of the state's territory. The Lowlands and Coastal Tablelands classes were not identified within Paraná.

At the second taxonomic level, the combination of Morphostructural Domains and Subdomains with the macro-compartments resulted in the identification of nine distinct units. This framework made it possible to distinguish, within the Third Paraná Plateau, sectors developed over volcanic sequences of Neojurassic–Early Cretaceous age from those developed over sedimentary covers of Late Cretaceous age; within the Paraná First Plateau, it allowed the individualization of the Curitiba and Tijucas do Sul Basins subdomain, distinguishing it from the Shield Plateaus; and, in the Coastal Plain, it allowed the distinction between marine and fluvial genesis, a refinement that previous mappings did not accommodate at the same taxonomic level.

The hierarchical inversion promoted by the SBCR proved beneficial for the Paraná case, overcoming the classificatory ambiguity historically associated with the Second Paraná Plateau, which had been variously referred to as a depression or as steps, and coherently integrating it into the Plateau class, in accordance with classical geomorphological interpretations. The application also highlighted limitations that should be considered in future studies: the establishment of morphometric criteria for distinguishing the boundaries between macro-compartments and the dependence on the quality of the underlying geological mapping for delimiting the second taxonomic level.

The proposed representation is compatible with the guidelines established during the SBCR Workshops and converges with the main interpretations of the geomorphology of Paraná and Brazil available in the literature. Its adoption in Paraná represents a step toward consolidating a standardized national geomorphological language, with potential for systematic application to other Brazilian states and for integration with the lower taxonomic levels already mapped within the territory of Paraná.

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Data availability: Vector files of the geomorphological map of the state of Paraná, represented by the first two taxa of the SBCR (relief macro-compartments and morphostructural domains and sub-domains), are available at <https://doi.org/10.5281/zenodo.22692258>

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