

**GEOMORPHOLOGY OF THE MUNICIPALITY OF PARELHAS-RN IN THE
BRAZILIAN SEMI-ARID**

**GEOMORFOLOGIA DO MUNICÍPIO DE PARELHAS-RN NO SEMIÁRIDO
BRASILEIRO**

Adrianny Marx Freitas
adrianny.marx.706@ufrn.edu.br
<https://orcid.org/0009-0007-3682-3198>

Lucas Alves de Araujo
lucasalvesalves987@gmail.com
<https://orcid.org/0009-0009-1236-258X>

Dênis dos Santos Hilário
dhilario76@gmail.com
<https://orcid.org/0000-0002-6768-7308>

Daví do Vale Lopes
davi.lopes@ufrn.br
<https://orcid.org/0000-0003-3336-7397>

ABSTRACT

The use and occupation of space without proper management and planning leads to a series of socio-economic-environmental problems. At this juncture, landscape analysis can help identify the limitations and potential of each landscape compartment. For this, the study of the relief is essential. The objective of this work was to characterize the geomorphology of the municipality of Parelhas-RN, in the Brazilian semi-arid region. Geomorphological mapping of the study area was carried out using QGIS software. Field activities were carried out to analyze the identified relief units. In the study area, five geomorphological units were identified: a) Sertaneja Surface I; b) Countryside Surface II; c) Plains and river terraces; d) inselbergues; e) plateaus and mountains. The Countryside Surfaces are marked by the existence of stony pavements and the monotony of the relief in these units is broken by the existence of some inselbergues. The areas with plains and river terraces are not very extensive, however, they are very important for the country people. The areas of mountains and plateaus have many rocky blocks, being areas of geomorphological risk due to mass movements.

Keywords: Relief. Sertaneja Surface. Environmental planning. Territorial ordering.

RESUMO

O uso e ocupação do espaço sem a devida gestão e planejamento acarreta em uma série de problemas sócio-econômico-ambiental. Nessa conjuntura, a análise da paisagem pode colaborar na identificação das limitações e potencialidades de cada compartimento da paisagem. Para isto é fundamental o estudo do relevo. O objetivo deste trabalho foi fazer uma caracterização da geomorfologia do município de Parelhas-RN, no semiárido brasileiro. Realizou-se o mapeamento geomorfológico da área de estudo com a utilização do software QGIS. Realizou-se atividades de campo para a análise das unidades de relevo identificadas. Na área de estudo foram identificadas cinco unidades geomorfológicas: a) Superfície Sertaneja I; b) Superfície

Sertaneja II; c) Planícies e Terraços fluviais; d) inselbergues; e) planaltos e serras. As Superfícies Sertanejas são marcadas pela existência de pavimentos pedregosos e a monotonia do relevo nestas unidades é quebrada pela existência de alguns inselbergues. As áreas com planícies e terraços fluviais são pouco extensas, porém, são muito importantes para os sertanejos. As áreas de serras e planaltos possuem muitos blocos rochosos, sendo áreas de risco geomorfológico por movimentos de massas.

Palavras-chave: Relevo. Superfície Sertaneja. Planejamento ambiental. Ordenamento territorial.

INTRODUCTION

The integrated analysis of landscapes is of utmost importance and can be applied for various technical purposes, such as in cartographic surveys of land use and occupation, environmental impact studies, and the restoration of degraded areas, among others (Machado et al., 2022). In this perspective, rocks, soils, and landforms are always associated, functioning as complex systems occurring in landscapes, capable of preserving records of current and past conditions and processes (Souza et al., 2023).

The exploitation of natural resources, urban growth, lack of environmental planning, and territorial planning have negatively impacted environmental degradation and posed risks to society.

Faced with this scenario, integrated landscape analysis contributes to territorial planning and management, considering its potential and limitations (Ross, 2009). According to Macêdo et al. (2015), the analysis of landscapes at the municipal scale is of fundamental importance because it is from this scale that actions of land use and occupation can be better planned (Macêdo et al., 2015). This type of approach is still very lacking in the Brazilian semi-arid region, especially when it comes to the desertification nucleus of Seridó.

The objective of this work was to characterize the geomorphology of the municipality of Parelhas-RN.

MATERIALS AND METHODS

This study was conducted using the following methodological procedures:

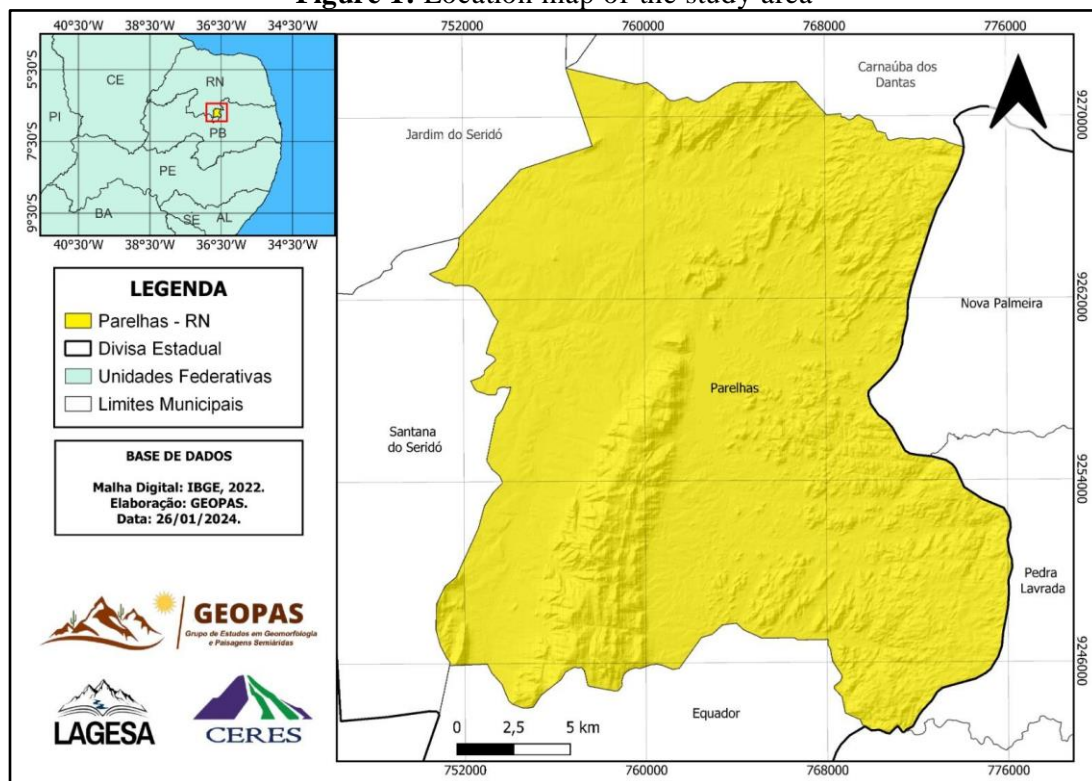
- i) Bibliographical and cartographic survey on the subject;
- ii) Production of cartographic products in GIS environment;
- iii) Fieldwork aimed at surveying the area, identifying and characterizing landform units and associated materials;
- iv) Data reprocessing and writing of the paper.

Study Area

Parelhas is a municipality in Rio Grande do Norte located in the microregion of Seridó Oriental. According to the Brazilian Institute of Geography and Statistics (IBGE), its population in 2022 was 21,499 people, with a territorial area of 513.507 km². The

municipality is part of the intermediate and immediate geographic regions of Caicó-RN. It is bordered to the north by Carnaúba dos Dantas and Jardim do Seridó, to the south by Equador, to the east by Nova Palmeira, Pedra Lavrada, and São Vicente, and to the west by Santana do Seridó and Jardim do Seridó (Figure 1). The main water bodies in the municipality are the Boqueirão Dam, which supplies the urban area of Parelhas, Jardim do Seridó, and Carnaúba dos Dantas, as well as neighboring communities, and the Caldeirão Dam, which supplies the municipality of Santana do Seridó

Figure 1: Location map of the study area



Source: Authors (2024).

Geological Analysis

The geological information of the municipality was obtained through the Geological Survey of Brazil (CPRM) using a sheet referring to the Seridó Province of 2019 at a scale of 1:350,000. The legend was prepared based on the Geological Map of the Seridó Mineral Province, which provides a detailed description of lithostratigraphic units.

Relief Analysis

For the delimitation of relief compartments in the municipality, the DEM (Digital Elevation Model) was used. From this, the Hypsometric Map, Slope Map, and Geomorphological Map were generated. Hypsometry was generated using categories in the visual variable color for every 50 meters, creating a gradient ranging from dark green for lower areas to red for higher altitudes. The slope map was generated from the DEM using the "Reclassification by Table" tool, adopting the methodology proposed by

Embrapa (1979), with the following classes: gentle, gently undulating, undulating, strongly undulating, extremely undulating, and steep. An adaptation was made to "extremely undulating," replacing the term "mountainous," which may cause confusion in understanding local relief forms.

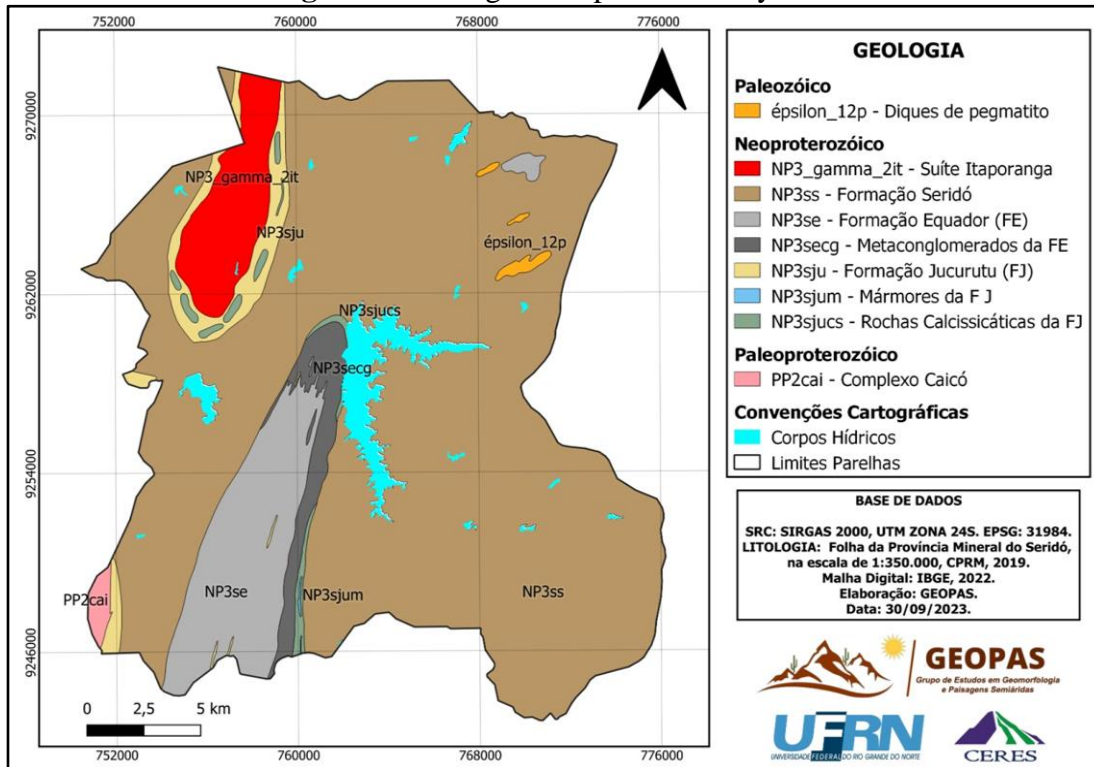
The geomorphological map was divided into the following compartments: Sertaneja Surface II, Plateaus and Ranges, Inselbergs, and Plains and Fluvial Terraces. Altitude and slope were the main criteria used for delimiting the compartments. The Sertaneja Surface II (SSJ II) was compartmentalized using the altimetry criterion, ranging from 251m to 400m in altitude, representing the lowest parts of the relief in the study area. This criterion follows the proposal of Costa et al. (2020). Plateaus were compartmentalized based on altimetry, sedimentary lithology, and flat tops, visualized with the aid of the slope map. Plateaus and Ranges were classified mainly based on altitude, starting from 401 m altitude, involving forms with sharp and convex tops.

Finally, the Plains and Fluvial Terraces were delimited with the aid of a raster file containing slopes of 0-3% (gentle). The polygons were based on the drainage network, thus coinciding with the fluvial accumulation modeling

RESULTS

Geological Characterization The municipality of Parelhas is located within the Borborema Structural Province, consisting of various lithologies (Figure 2). In the area, rocks associated with the Itaporanga Formation (NP2NP3Git) are found, including schists, diorites, gabbros, gneisses, granites, granodiorites, among others. Additionally, the area contains rocks from the Jucurutu Formation (NP3sj) (such as amphibolite, calc-silicate rock, iron formation, gneiss, marble, quartzite), the Equador Formation (NP3seq) (comprising metaconglomerate and quartzite), the Seridó Formation (consisting of biotite schist, calc-silicate rock, garnet-biotite schist, metaconglomerate, metarhytmite, mica schist, pegmatite, schist), and the Caicó Formation (PP2cai) (including amphibolite, biotite schist, migmatite, marble, gneiss, metavolcanic rock) (Figure 2).

Figure 2: Geological map of the study area.

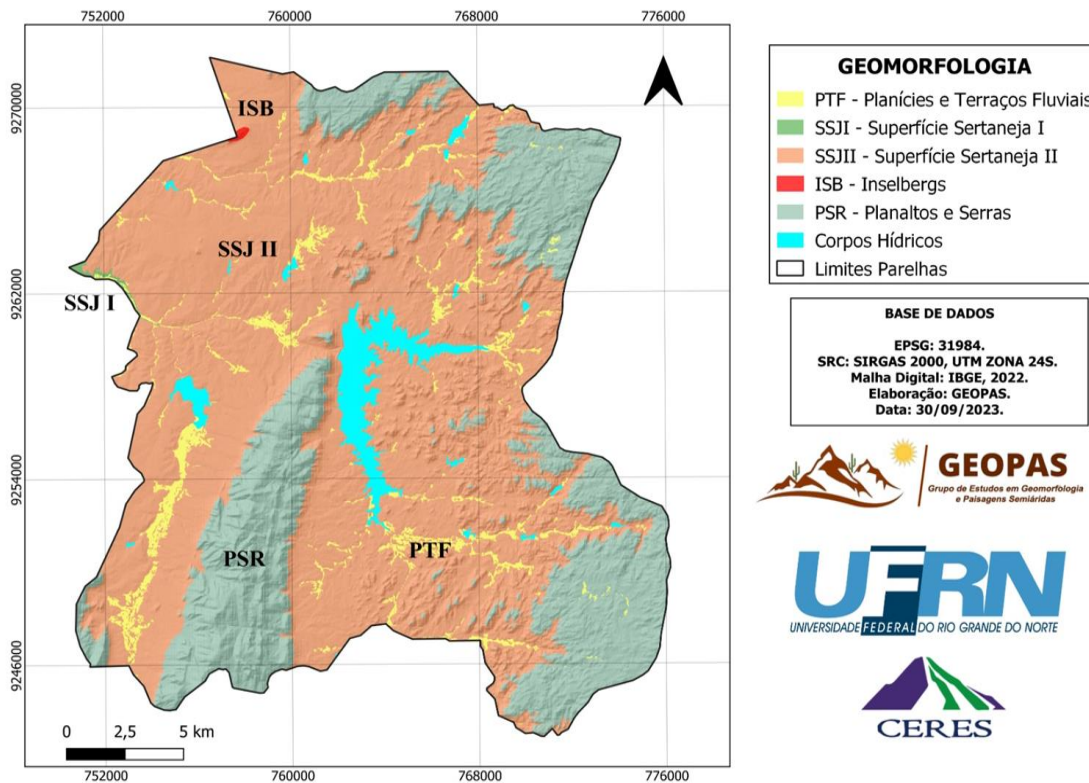


Source: Authors (2024).

Geomorphological Characterization

Five geomorphological units were identified in the study area: a) Sertaneja I Surface; b) Sertaneja II Surface; c) Floodplains and Fluvial Terraces; d) Inselbergs; e) Plateaus and Ridges (Figure 3). The Sertaneja II Surface is the most extensive in the municipality, with some isolated inselbergs occurring within it (Figure 3). The Sertaneja I Surface occurs in a small area to the west of the municipality (Figure 3).

Figure 3: Geomorphological map of the study area.



Source: Authors (2024).

The municipality's summit surfaces are associated with plateaus and mountains, where there are many ridges, mainly associated with quartzites. A large part of this unit is associated with the Borborema Plateau (Figure 4).

Figure 4: (A) Mountainous area located close to the urban area of the municipality of Parelhas-RN; (B) representation of the installation of wind farms at its top; (C) Fluvial

environment and in the background the mountain range of the Ecuador formation close to the border with Ecuador-RN.



Source: Authors, 2024.

In the central to southern part of the municipality lies a large ridge with elongated crests, which exerts strong control over drainage and favors water impoundment, where the Boqueirão Dam was built.ra 5).

Figure 5: (A) Representation of the Boqueirão Reservoir in the municipality of Parelhas-RN; (B) Country surface II and small rocky outcrops with vegetation cover;

(C) Water environment of the municipality of Parelhas-RN and in the background the mountainous areas of structural control of the dam.



Source: Authors, 2024.

DISCUSSION

In the municipality of Parelhas-RN, five (5) geomorphological units were identified: a) Sertaneja Surface I; b) Sertaneja Surface II; c) Plains and Fluvial Terraces; d) inselbergs; e) plateaus and mountains (Figure 3). Sertaneja Surface II is the most extensive in the municipality, with some isolated inselbergs occurring within it (Figure 3). According to IBGE (2009), inselbergs are residual landforms with various features, forming ridges, domes, or "whaleback" shapes, with steep slopes; typically, talus deposits are found at the base, indicating gravitational mass movement. These formations are common in peripheral and inter-plateau depressions, in areas with differential erosion influenced by lithological resistance (IBGE, 2009). In this study, the term "Sertaneja Surface" or

"Lowered Surface" was chosen instead of "Sertaneja Depression," as it is a more current terminology, following the trends of the Brazilian System of Relief Classification (SBCR), which is in the process of development (CEN/SBCR, 2022). In the study area, the inselbergs are associated with crystalline rocks linked to the Precambrian geological period, specifically to the substrate of the Borborema geological province (Mascarenha et al., 2005; Angelim et al., 2006).

Much of Sertaneja Surfaces I and II are associated with rocks of the Seridó Formation (Figure 2). According to Angelim et al. (2006), this Formation belongs to the Seridó Group and constitutes the main lithostratigraphic unit of the folded belt in outcrop areas. Its lithology is predominantly composed of feldspathic or aluminous mica schists, with marbles, calc-silicate rocks, gneisses, metavolcanic rocks, quartzites, and metaconglomerates occurring in the lower portion of the formation (Angelim et al., 2006; Bezerra et al., 2009).

In summary, it is possible to observe in (Figure 3) the Sertaneja Surface II, where the territorial portion of the study area characterized by a flat relief is most representative. The characteristics of this relief outline a pattern of low drainage, which tends to provide less efficient water runoff.

The summit surfaces of the municipality are associated with plateaus and mountains, where crests are found, mainly associated with quartzites (Figure 2). Much of this unit is associated with the Borborema Plateau (Figure 3). In the central area towards the south of the municipality lies a large mountain range with elongated ridges, which exerts strong control over drainage and favors water impoundment, where the Boqueirão Dam was built (Figure 3). According to Santos et al. (2023), the Western Mountains and Borborema Plateau have areas with higher slopes associated with crystalline rocks; these surfaces predominantly have shallow and poorly developed soils, such as Neosols and Cambisols.

The aforementioned mountain range is associated with the Equador Formation (NP3seq), which predominantly consists of quartzites, rocks known for their erosion resistance. This is called the Boqueirão Range, also known as the Princess Range due to its shape resembling a reclining woman. The area is abundant in mineral resources, such as the precious Paraíba Tourmaline, in addition to marble and quartzite extraction, among others.

Further highlighting the potential of the Serra area for tourism, points associated with economic and/or touristic activities stand out, such as the small chapel and the Poço da Princesa (Princess' Well), created for mineral resource exploration purposes. Also within the Equador Formation (NP3seq) lies the Archaeological Geosite Mirador, predominantly composed of quartzites and metaconglomerates, with rock paintings depicting prehistoric ancestors, making the geosite rich in geomorphological and archaeological value. According to Sales et al. (2022), integrated analysis of geodiversity can support geotourism, regional valorization of the semi-arid region, and the preservation of the caatinga, as fauna and flora depend on the substrate that supports life.

Over the past years, areas of mountains and plateaus have also been subject to significant interest from Wind Farms, which are rapidly advancing across northeastern Brazil. It is noteworthy that many areas of mountains and plateaus in the municipality are important enclaves of well-preserved vegetation and fauna refuges. Additionally, these areas pose challenges regarding land use and occupation due to the presence of steep slopes associated with abundant loose rock blocks (with occurrences of boulders being common), making them highly susceptible to gravitational mass movement processes.

Regarding plains and fluvial terraces, the influence of intermittent and ephemeral rivers is notable, located both near the Dix-sept Rosado Dam and Boqueirão Dam, as well as on the "Bajadas" that influence the succession of alluvial deposits that converge.

Facing the lee side of the Boqueirão Range lies the Dix-Sept Rosado Dam, also known as the State Dam. Its waters are polluted due to the discharge of sewage from the municipality's residences. This water body suffers from prolonged dry periods, exacerbating pollution issues and generating an unpleasant odor for the population living nearby.

The largest water body in the municipality of Parelhas is the Boqueirão Dam, with a capacity of 8.5 million cubic meters of water. Recently, in 2023, it reached only 5% of its water capacity, indicating that the current water level is below 5%, as rainfall has remained scarce in Parelhas from 2023 to the present moment of 2024. This situation greatly concerns the local population and neighboring cities, as the Boqueirão Dam supplies water to the cities of Jardim do Seridó and Carnaúba dos Dantas, as well as to villages like Juazeiro and Santo Antônio.

These areas resulting from hydrogeomorphological processes exhibit similarities in their formation. As observed in (Figure 3), the outlets of these areas are presented in a flat manner, revealing their formation from the confluence of rivers that connect to their reservoirs, thus facilitating the formation of these plains.

The Caldeirão Dam, with a capacity of 1,000 m³, is located between the municipalities of Parelhas and Santana do Seridó, which favored the water supply to Santana do Seridó for many years. However, currently, due to the scarcity of rainfall, the dam has entered a critical state regarding its low water volume.

In this regard, the entire plain and fluvial terrace area of the Caldeirão Dam is located on Sertaneja Surface II, as can be observed in (Figure 3) to the WSW-SW. Thus, in the context of irregular and torrential rains, there is a tendency for morphogenesis to prevail over pedogenesis (Silva et al., 2022). Furthermore, there is a notable intensification of erosive processes, leading to soil degradation and consequently promoting sedimentation in water bodies (Silva et al., 2022). It is worth noting that the area is located on the Sertaneja Surface, whose origin is primarily associated with the dynamics of planation, resulting from semi-arid regions (Vital et al., 2021). Understanding fluvial environments and their dynamics can significantly contribute to environmental planning and issues related to land use and occupation, as city growth often occurs towards river channels (Silva et al., 2023)

CONCLUSIONS

Characterizing the physical environment is essential for promoting a broader dissemination of geoscientific knowledge and increasing its appreciation and understanding. In summary, investing in expanding local physical environment knowledge, raising awareness of its importance, and implementing conservation and sustainable use practices of natural resources are crucial measures to ensure the preservation and valorization of geodiversity.

In the study area, five geomorphological units were identified: a) Sertaneja Surface I; b) Sertaneja Surface II; c) Plains and Fluvial Terraces; d) Inselbergs; and e) Plateaus and Ridges. The Sertaneja Surfaces are characterized by the existence of rocky pavements, and the monotony of the terrain in these units is broken by the presence of some inselbergs. The areas with plains and fluvial terraces are not extensive but are very important for the locals due to the presence of water resources, often found in the form of wells dug into riverbeds. The areas of mountains and plateaus have many rocky blocks, posing geomorphological risk areas due to mass movements.

The municipality of Parelhas-RN still has many gaps regarding the knowledge of its physical environment. Information on geology, soils, and terrain still require more detailed studies; therefore, future studies with more generation of primary data and the production of maps with greater detail scale are needed.

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