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Geodiversity of the coast of the state of Pernambuco, northeastern Brazil

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Abstract

The study of geodiversity provides insight into the potential and limitations of an area's physical environment, making it highly valuable for public and private managers in supporting the development of appropriate land use and occupation proposals for a region. In this perspective, the Geodiversity Map of the coast of the state of Pernambuco was created by combining the Geodiversity Map of the Recife Metropolitan Region (RMR) and the Geodiversity Map of the Southern Coast of Pernambuco. Both were developed by the Geological Survey of Brazil through bibliographic studies and field surveys of geology, geomorphology, soils, and superficial formations, resulting in fifteen geological-environmental units composed of materials that significantly influence the suitability and usage constraints of the region. An example is the DCT unit, which covers a substantial area along the coastal zone of the northernmost municipalities of the RMR. Composed of sediments with varied composition (irregular alternation between layers of sandstone, siltstone, claystone, and gravel), it is widely used for urban occupation and mineral exploitation (borrow material in civil construction). However, on the slopes of the plateaus, particularly near the cliffs along the coastline, this area is unsuitable for housing due to the risk of landslides caused by slope gradients and the high susceptibility of these materials to erosion. Other information of significant importance and interest for public managers can be obtained as a result of this geodiversity study, such as mineral resources, groundwater potential and quality, geotechnical characterization, and areas prone to geological-geotechnical events that could impact land use, among others. All this knowledge is valuable for developing public policies and guiding actions by managers to generate employment and income, protect the environment, and promote health in the region.

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1. Introduction

Knowledge of a region's geodiversity is of significant importance in identifying the type of rock, relief, soil, water quality, and other physical aspects of a given area, providing insight into its suitability and limitations for land use. This knowledge enables appropriate territorial management, with the planning of productive economic activities as well as environmental protection and sustainable land use (Figure 1).

There are several practical examples in which we can observe that knowledge of geodiversity can assist in appropriate land use planning, potentially preventing the emergence of serious issues, such as:

- The improper occupation of flood-prone areas for residential use along riverbanks and floodplains, resulting in floods that affect numerous homes almost every year during the rainy season;

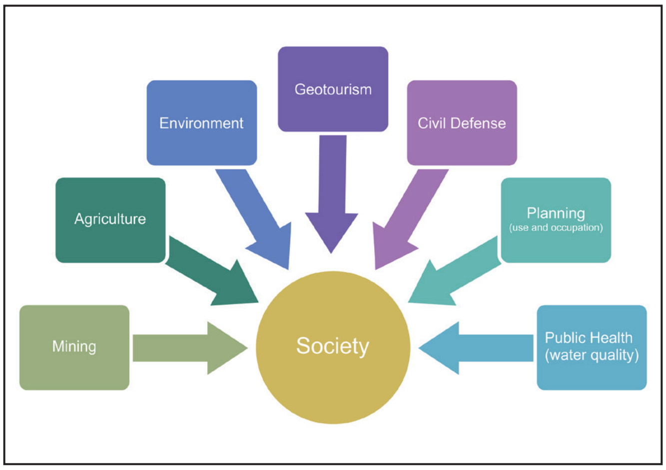

Figure 1. Various applications of geodiversity. Adapted from Silva (2008).

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- Inappropriate buildings in fluvial-lacustrine environments with sedimentary deposits rich in organic matter, containing compressible soils formed by peat and soft clays, causing subsidence and settlement of the land where buildings and public roads were constructed.
- The use of land for urban, industrial, or agricultural activities without proper planning, which can lead to intense erosive processes that, in addition to seriously impacting the environment, will also cause significant financial losses to users and the surrounding population.

Thus, the Geodiversity Map of the coast of the state of Pernambuco was created to provide information about the physical environment of the municipalities located along the Pernambuco coast, using simple language and making it easily accessible to the public and to public and private managers. This map was generated by combining the Geodiversity Map of the Recife Metropolitan Region and the Geodiversity Map of the Southern Coast of Pernambuco.

2. Location and characterization of the study area

The study was conducted along the coast of the state of Pernambuco, in northeastern Brazil (Figure 2). The region covers 20 municipalities in Pernambuco, totaling an area of 4,325.479 km² with an estimated population of approximately 3,808,029 inhabitants and a population density of 27,811.47 inhabitants/km² (IBGE 2023).

The area encompasses two very important economic regions in the state of Pernambuco: the Recife Metropolitan Region (RMR), which spans over 143 km along the coast of Pernambuco, and the southern coastal stretch of Pernambuco, which extends for more than 44 km, as well as the municipality of Goiana, which, at the time of the geodiversity map's creation, belonged to the RMR.

From a geological perspective, the coast of Pernambuco is characterized by a stratigraphic column composed of crystalline basement rocks, the Pernambuco and Paraíba

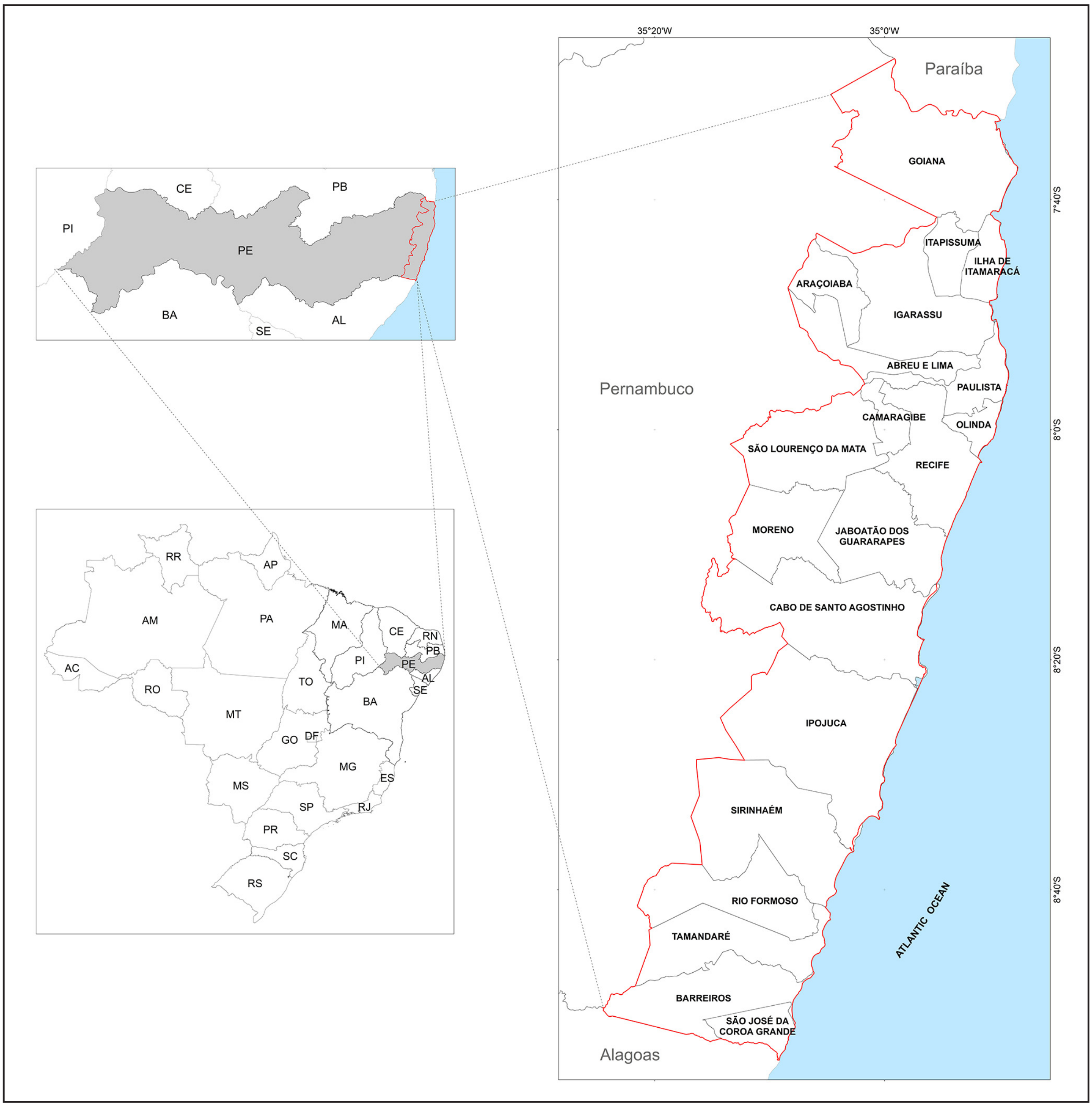


Figure 2. Location of the municipalities along the coast of the state of Pernambuco.

coastal sedimentary basins (separated by the Pernambuco Lineament), Cenozoic sedimentary rocks, and recent sediments. These units are overlain by surface formations represented by materials derived from the weathering of these lithologies or transported materials.

The terrain is relatively gentle, with the area closest to the coast consisting of beaches and lagoon and fluvial-lagoon plains. Further inland, the terrain becomes slightly more varied, featuring elevations that form plateaus, high hills, and mountain range.

3. Methodology

The information presented in this work was gathered from the results obtained in the Geodiversity projects of the Recife Metropolitan Region and the Southern Coast of Pernambuco. The methodology developed for the study of Geodiversity by the Geological Survey of Brazil (SGB) was initiated in 2006 at a national scale. Later, from 2010 onwards, the methodology was refined to accommodate more detailed scales, with a new classification of geological-environmental units. Beginning in 2018, a new element was also incorporated for more detailed scales: the classification of superficial formations (Ramos et al. 2021). Thus, the work presented here reflects the results of these updates.

Due to the large amount of preexisting information as well as data obtained through fieldwork and bibliographic research related to geology, geomorphology, hydrology, hydrogeology, and other aspects of the physical environment, it was possible to create the Geodiversity Map of the coast of the state of Pernambuco at a scale of 1: 100,000. This map was crafted in a representative and didactic manner by organizing this information to meet various uses according to the methodology of Silva (2008).

For the preparation of this work, the geodiversity maps of the Recife Metropolitan Region (RMR) and the Southern Coast of Pernambuco were used according to the methodology developed by Silva (2008), which serves as the basis for the Geodiversity projects of the Geological Survey of Brazil (SGB). Thus, in the studied area, Geoenvironmental Domains were defined large geosystems that form the national territory (Maia et al. 2024) based on sixteen intrinsic characteristics of each lithological type, such as mineralogy, texture, fracturing, etc. Subsequently, these domains were subdivided into 15 (fifteen) distinct geoenvironmental units, characterizing the rocks, landforms found, and observed surface formations. In this way, the aim was to describe the particularities of each in the most comprehensive manner possible, providing government managers with data to be used for better territorial planning in light of land use and increasing urban occupation.

During the creation of the maps used, the methodology described in Figure 3 was employed.

4. Geoenvironmental Units - GUs

The coast of the state of Pernambuco has been subdivided into 15 Geoenvironmental Units (GUs), which were classified according to their lithological, geomorphological characteristics, and types of surface cover (Figure 4).

4.1. Geoenvironmental Unit DCBr_Rec

The Geoenvironmental Unit DCBr_Rec is composed of beach rocks, which include reefs made up of sand, gravel, and accumulations of biochemical and organic sediment fragments (calcareous algae, mollusks, bryozoans, benthic foraminifera), cemented by iron oxide, carbonate, and silica, deposited at a certain distance from their origin (Figure 5A). They are located along the beaches or in shallow waters near the coast, serving as evidence of past sea level variations (Figure 5B).

These units are of great importance in protecting the coastline against the destructive action of waves, acting as a natural breakwater in front of the beaches and providing habitat for numerous marine species. Therefore, they are considered preservation areas under environmental legislation, boasting great scenic beauty and high potential for geotourism. Their removal makes the beaches and coastline more vulnerable to wave action, which can lead to or intensify erosive processes.

4.2. Geoenvironmental Unit DCa_Dpbc

The Geoenvironmental Unit DCa_Dpbc is composed of floodplain deposits in low-energy, lower-course areas, consisting of sediments deposited in the lower reaches of rivers. These deposits exhibit easy excavability, moderate load-bearing capacity, and good potential for water supply, with aquifers (granular type) very close to the surface, providing good flow rates, and displaying significant vulnerability to contamination, which increases as the layers of clay covering the aquifer become thinner (Figure 6A).

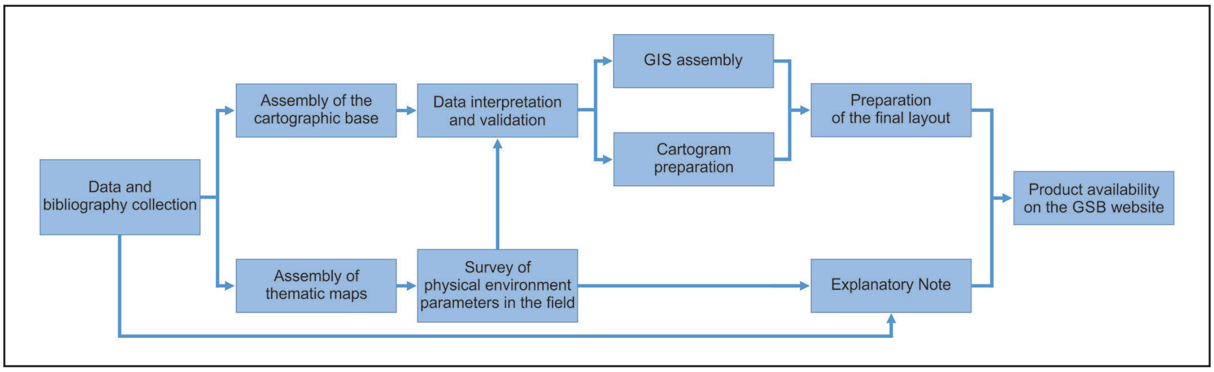


Figure 3. Methodology applied during the development of the Geodiversity maps.

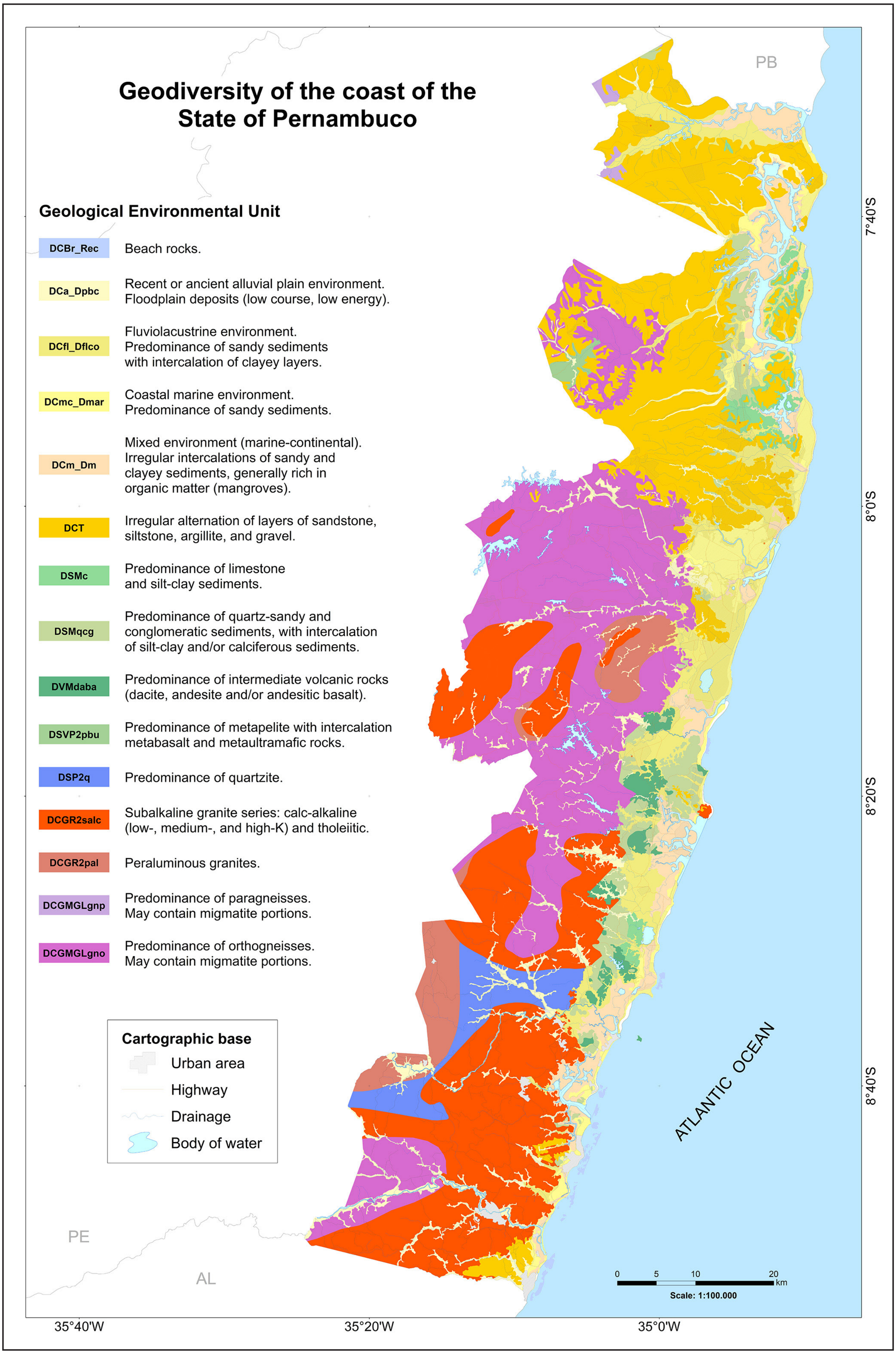


Figure 4. Geodiversity Map of the coast of the state of Pernambuco. Adapted from Pfaltzgraff and Torres (2020, 2021).

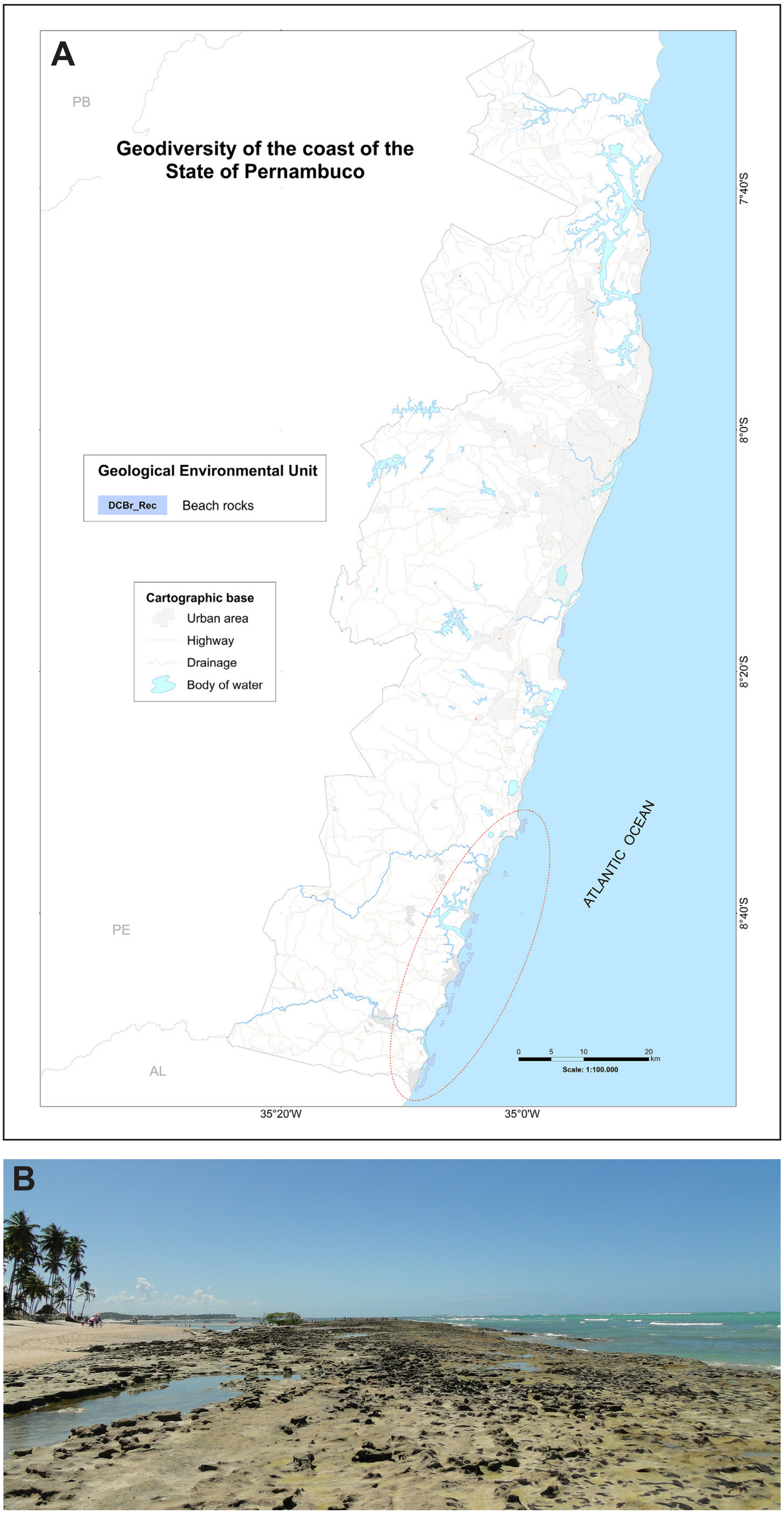


Figure 5. A - Location of the Geoenvironmental Unit DCBr_Rec along the coast of the state of Pernambuco; B - Sandstone reefs at Carneiros Beach, municipality of Tamandaré. Adapted from Pfaltzgraff and Torres (2020).

These areas feature deep soils with good natural fertility and ample water availability, developed in flat terrain. However, they have moderate load-bearing capacity with a shallow water table, making them subject to periodic flooding, and are not recommended for urban occupation or perennial agriculture due to excess moisture or oxygen deficiency (Figure 6B).

Thus, these areas are suitable for short-cycle crops, which are only cultivated during the dry season.

In engineering works, gravel is used as a source of borrow material and can also be used in civil construction or road paving. When there is an excess of organic matter, the quality of the material is compromised, and this organic matter can release corrosive substances that affect the equipment and structures of the works. There are also possibilities for mineral extraction of sands in areas permitted by environmental legislation.

4.3. Geoenvironmental Unit DCfl_Dflco

The fluvial-lacustrine environment, which comprises the Geoenvironmental Unit DCfl_Dflco, consists of flat areas suitable for short-cycle agriculture, flood mitigation, and environmental preservation (Figure 7A). Due to their flood-prone nature, whether seasonal or permanent, these areas are not recommended for urban occupation because of their low load-bearing capacity, resulting from flooding and ground settlement due to the presence of compressible clays and peat (Figure 7B). If these areas are drained, there is a risk of spontaneous combustion of the peat. There is a predominance of poorly drained soils with excess salts or sulfur, rendering the soils unsuitable for agriculture and exhibiting high corrosivity for buried structures.

4.4. Geoenvironmental Unit DCmc_Dmar

The Geoenvironmental Unit DCmc_Cmar in a coastal marine environment is characterized by predominantly unconsolidated sandy sediments, such as beach sands, which have low load-bearing capacity and are subject to erosion (Figure 8A). It contains landscapes of great scenic beauty and geotourism potential. However, due to the daily effects of tides and waves, engineering works located in these areas exhibit high susceptibility to erosion, making these locations unsuitable for urban occupation.

The sandy sediments have high permeability, resulting in significant vulnerability to the contamination of underground water sources due to the percolation of pollutants, as well as having low retention capacity. The soil exhibits low natural fertility, and since these are beach areas, they are subject to strict environmental legislation, which restricts mineral exploitation (Figure 8B).

4.5. Geoenvironmental Unit DCm_Dm

The mixed environment (marine/continental) of the Geoenvironmental Unit DCm_Dm features irregular intercalations of sandy and clayey sediments, generally rich in organic matter (mangroves), deposited in the daily tidal fluctuation zone, which is rich in animal and plant life (mangroves). The channels and islands covered by mangroves are ideal spots for geotourism and environmental protection (Figure 9A). Due to periodic flooding by seawater, being situated in an intertidal zone, it features soil rich in organic clay (indiscriminate mangrove soils), which are muddy, deep, and partially or permanently submerged. Thus, the land located in these areas has very low load-bearing capacity and layers with high concentrations of organic matter, which release corrosive acids and methane gas (highly flammable), imposing several restrictions on engineering works, potentially causing significant settlement in fill and constructions, as well as provoking corrosion in pipelines and equipment buried in the sediments (Figure 9B).

This unit features areas unsuitable for groundwater extraction due to the clayey substrate and high concentrations of salts. Mangroves act as barriers against erosion caused by wave action, protecting certain sections of the coastline. Similarly, they provide protection against flooding along the rivers, reducing the force of floods and retaining transported sediments, thereby helping to extend the coastline.

4.6. Geoenvironmental Unit DCT

The Geoenvironmental Unit DCT consists of irregular alternation between layers of sediments with diverse compositions (sandstone, siltstone, claystone, and gravel). Most areas of the unit (Figure 10A) feature soils with low natural fertility and flat terrain, which is favorable for the use of agricultural machinery. The flat areas are also suitable for urban occupation with good load-bearing capacity. However, the slopes of the plateaus are not recommended for housing due to the risk of landslides caused by slope gradients and the high susceptibility of these materials to erosion. The sediments in this unit are widely used for borrow materials, gravel, sand, and clay extraction for civil construction due to their granulometric characteristics and ease of excavation. However, they are very friable and quite prone to erosion and landslides, especially near the cliffs along the coastline (Figure 10B).

Although it is not considered a good aquifer due to low flow rates in silty and clayey sediments, and moderate rates in sandy and conglomerate sediments, and sometimes water with high iron content, exploitation in this unit is well-developed due to the significant area it occupies in the coastal zone and the ease of drilling wells, which are generally shallow.

The implementation of any project that may produce waste with the potential to contaminate the soil or aquifers must be carefully planned.

4.7. Geoenvironmental Unit DSMc

In the Geoenvironmental Unit DSMc (Figure 11A), limestone and silty-clayey sediments predominate, exhibiting reasonable load-bearing capacity and low shear strength and penetration resistance. These sediments are poorly permeable but have a high capacity to retain and eliminate pollutants. The alteration of limestone provides soils with good natural fertility for agriculture, while the altered soils of the clayey sediments tend to be thick, impermeable, and possess good capacity for retaining and eliminating pollutants.

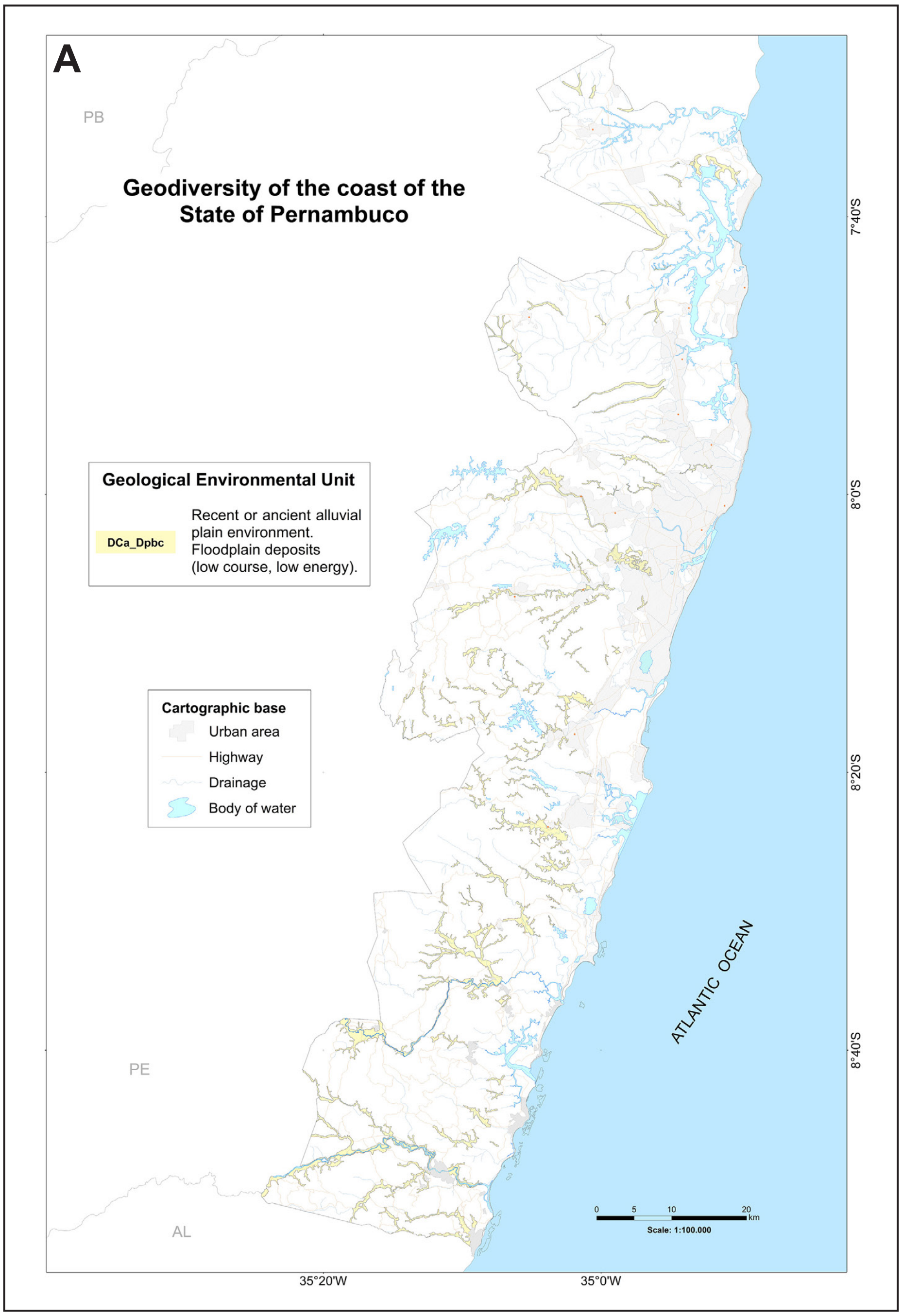


Figure 6. A - Location of the Geoenvironmental Unit DCa_Dpbc along the coast of Pernambuco; B - Alluvial plain - Botafogo River, municipality of Igarassu (Pfaltzgraff and Torres (2020).

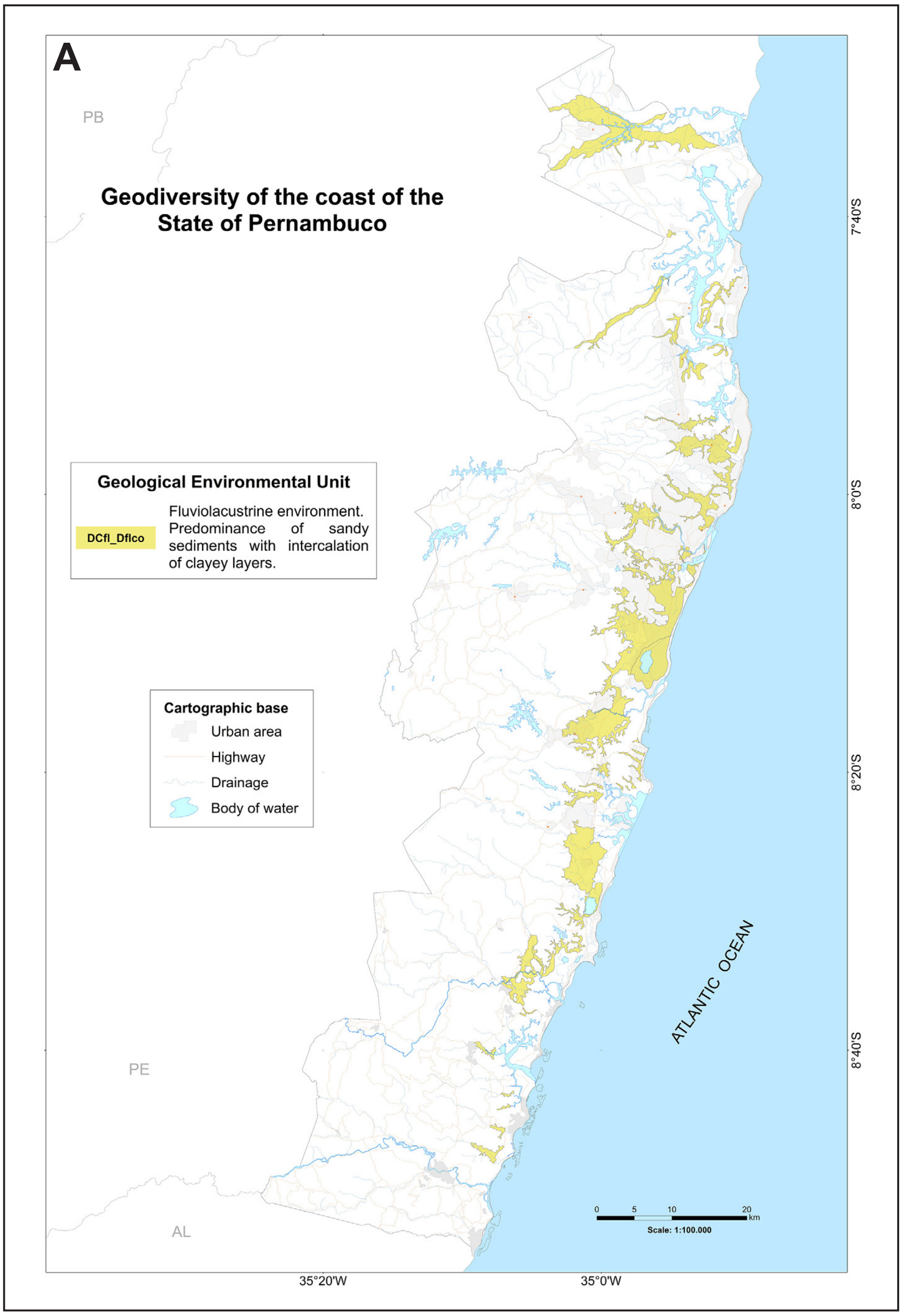


Figure 7. A - Location of the Geoenvironmental Unit DCfl_Dflco along the coast of Pernambuco; B - Inter-dune wetlands with mangroves and hydrophilic floodplain fields (bulrushes), municipality of São José da Coroa Grande (Pfaltzgraff and Torres 2021).

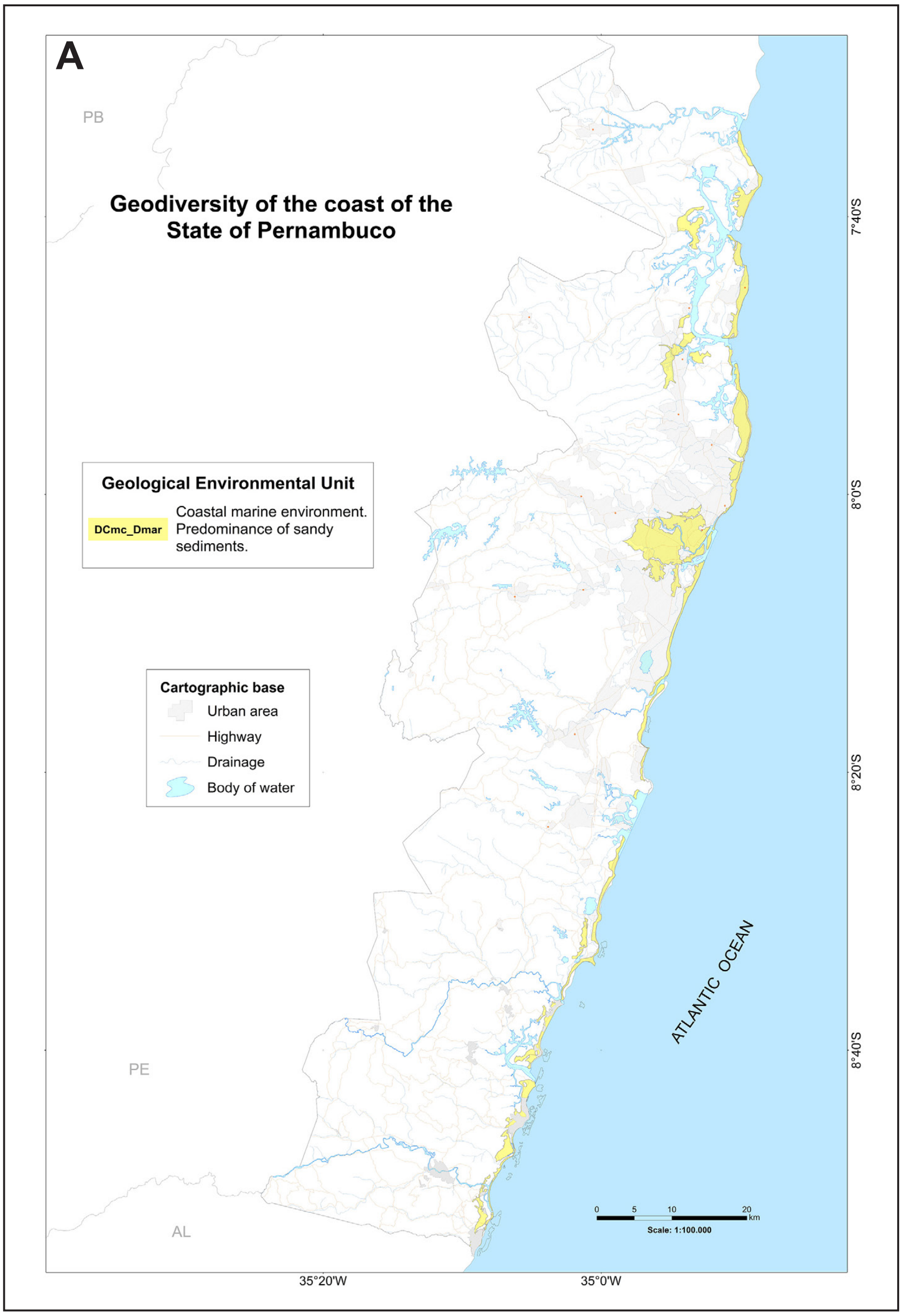


Figure 8. A - Location of the Geoenvironmental Unit DCmc_Dmar along the coast of Pernambuco, characterized by predominantly sandy sediments; B - Marine terrace at Barra de Sirinhaém beach, municipality of Sirinhaém (Pfaltzgraff and Torres 2021).

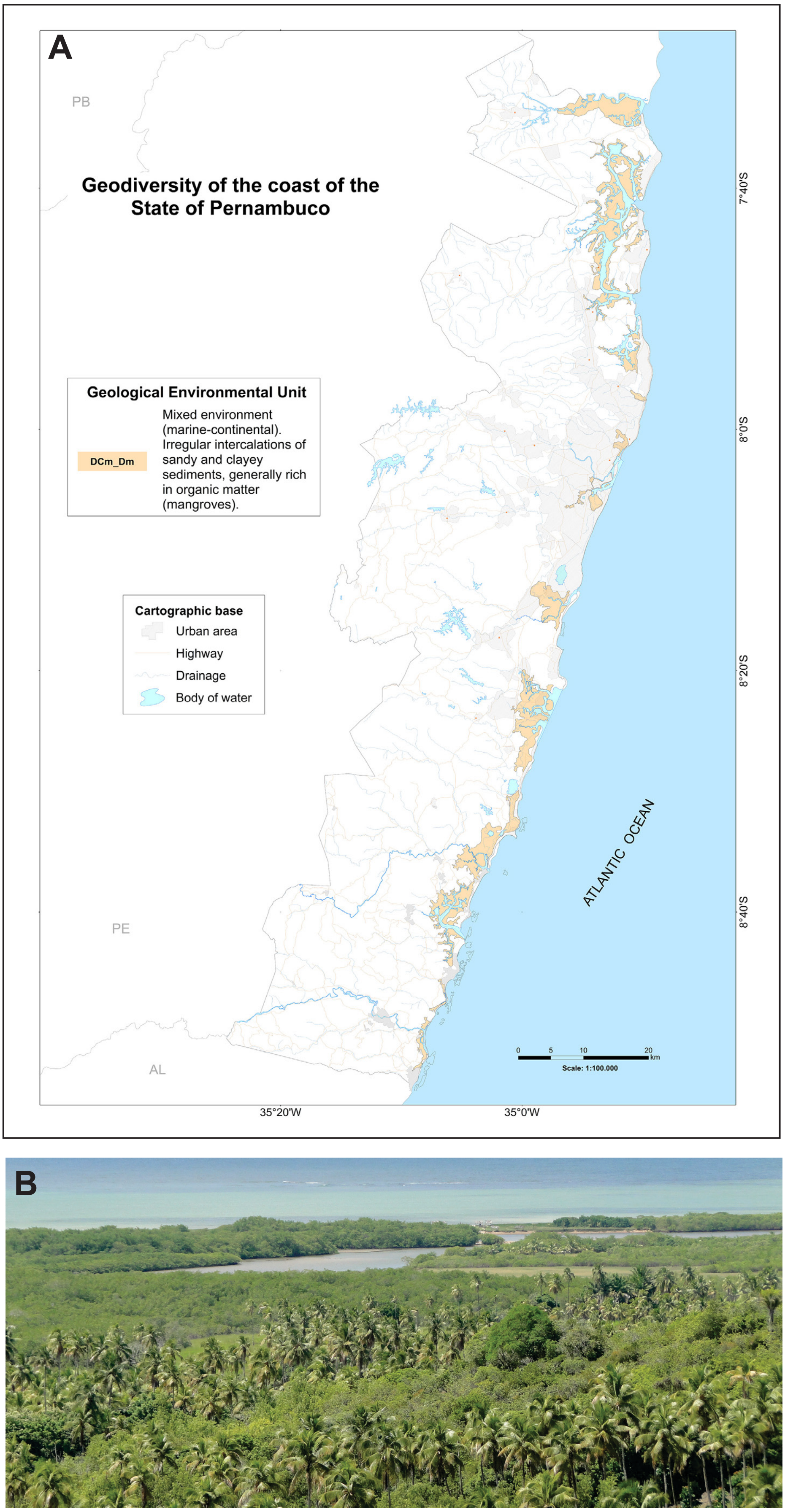


Figure 9. A - Location of the Geoenvironmental Unit DCm_Dm along the coast of Pernambuco; B - Fluvio-marsh plain with mangrove vegetation in the estuary of the Una River, municipality of Barreiros (Pfaltzgraff and Torres 2021).

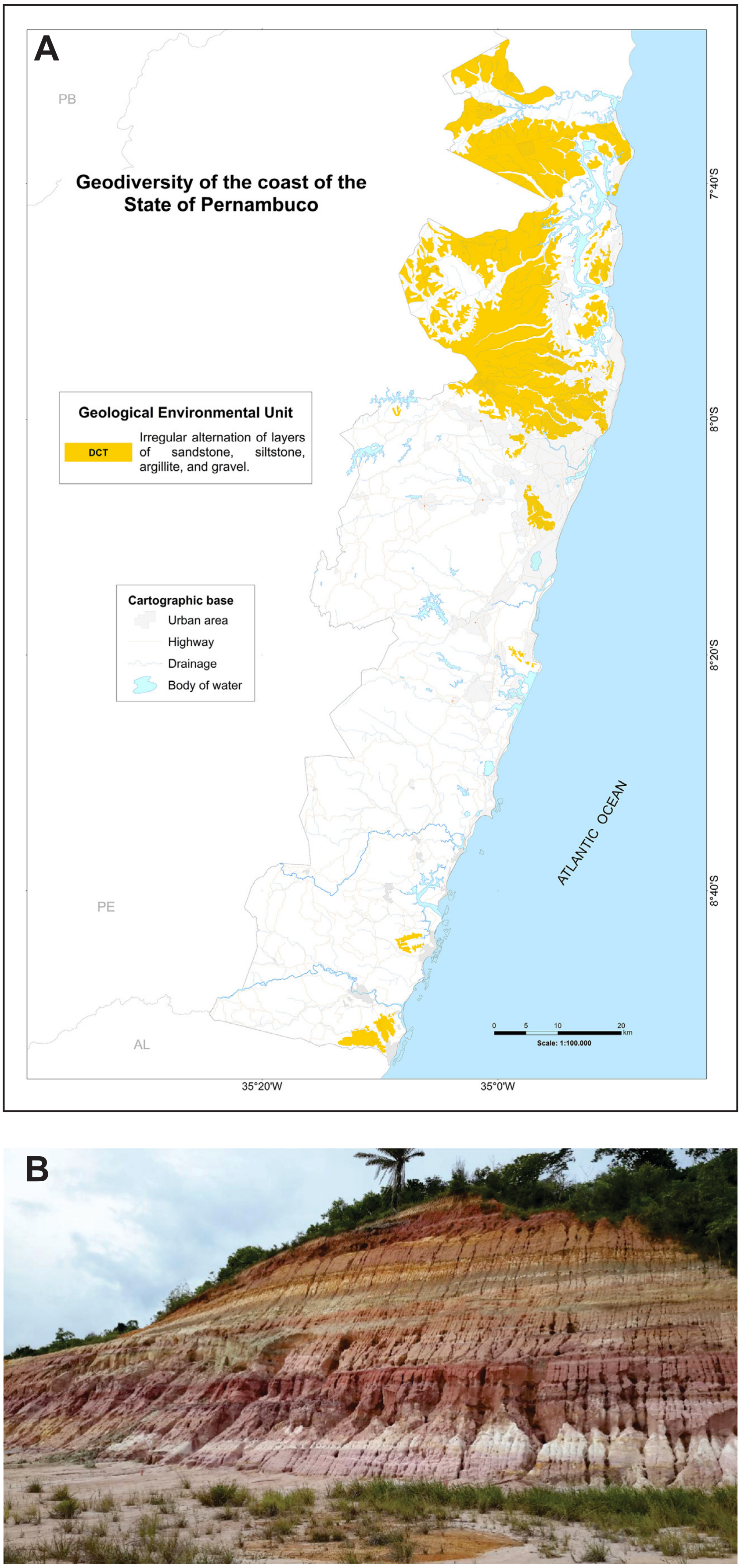


Figure 10. A - Location of the Geoenvironmental Unit DCT along the coast of Pernambuco; B - Stratified sedimentary package of the Barreiras Group exhibiting intense erosive processes, municipality of São José da Coroa Grande (Pfaltzgraff and Torres 2021).

This unit contains aquifers with low flow rates and potential for water exploitation, both in volume and quality, due to the high amount of calcium carbonate (hard water), which can compromise its quality, with such aquifers being primarily recharged through fractures. In areas with karst features, the vulnerability to aquifer contamination is very high. The implementation of roadway works in these areas requires careful consideration, as locations with limestone can form cavities due to dissolution, making them susceptible to underground collapses, causing subsidence and surface collapses. Thus, the execution of engineering works must be preceded by geological and geotechnical investigations to identify the existence of such features (Figure 11B).

4.8. Geoenvironmental Unit DSMqcg

In the Geoenvironmental Unit DSMqcg (Figure 12A), there are interesting relief forms and erosive features that create scenic and tourist attractions. Predominantly, quartzose and conglomeratic sediments are present, with intercalations of silty-clayey and/or calcareous sediments. The soils are predominantly of low natural fertility, slightly better where calcareous levels occur, with gentler slopes and water availability. These areas are susceptible to erosion and landslides due to the stratification of the layers. The materials forming this unit exhibit low to moderate resistance to cutting and drilling (they are quite abrasive to cutting and drilling with machinery), and in some locations, the material has favorable characteristics for use as borrow material.

The high permeability of this unit allows for the occurrence of granular/porous aquifers with good exploitation capacity. However, the predominance of highly permeable sediments and soils makes these lands highly vulnerable to the percolation of contaminating agents into the groundwater. They have a high recharge potential, especially on the flat surfaces of plateaus and table tops. Areas with less varied relief present good conditions for the construction of roadworks and urban occupation. Caution is required with road cut slopes, where the alternation of stratified layers can complicate stability, causing severe erosion, necessitating the reinforcement of these slopes against erosion (Figure 12B).

4.9. Geoenvironmental Unit DVMdaba

The Geoenvironmental Unit DVMdaba (Figure 13A) is composed of intermediate volcanic rocks (dacites, andesites, and/or andesitic basalts). These rocks have high compressive strength, a high degree of coherence, and resistance to cutting and drilling. They also have permeability ranging from low to moderate, which is unfavorable for the recharge of groundwater. The soils are quite fertile, porous, and have good water-holding capacity, maintaining a good availability of water for plants over an extended period. They exhibit low natural erosivity and a high capacity to retain and fix nutrients and assimilate organic matter, responding well to fertilization. However, due to the high density of open fissures, especially near the surface, they allow the percolation of contaminants into the groundwater when not covered by a thick layer of alteration (soil). In areas where the soils are deep, this risk is low. The aquifer is fissure, with highly irregular storage capacity. Rock outcrops can also be observed through the Island of Santo Aleixo (Figure 13B).

4.10. Geoenvironmental Unit DSVP2pbu

In the Geoenvironmental Unit DSVP2pbu, there is a predominance of metapelites with intercalations of metabasic and/or metaultramafic rocks. The different metasedimentary lithologies have good load-bearing capacity and medium to high resistance to cutting and penetration. The flatter areas where this unit occurs (Figures 14A and 14B) are favorable for urban occupation and the implementation of mechanized agriculture (when water is available), as well as being more conducive to the recharge of underground aquifers.

The aquifers are of the fissure type, with highly variable productivity and storage capacity. In areas with thicker soils, there is good protection of the aquifers against contamination due to the more clayey and less permeable soil. When the degree of fracturing is high, both recharge and percolation are also high, with wells showing high flow rates. However, this also facilitates the infiltration and percolation of polluting fluids that can reach the aquifer. The presence of thicker layers of clayey soil provides a relative protection for the groundwater against potential pollutants.

4.11. Geoenvironmental Unit DSP2q

The Geoenvironmental Unit DSP2q (Figure 15A) features quartzites as the predominant rocks, which have high resistance to cutting and penetration and good load-bearing capacity. Thus, they can be used as material for cladding, flooring, and stone masonry. The soils are of low natural fertility, highly erodible, acidic, and permeable, with their alteration mantle being usable as gravel and for sand extraction. Due to the fracturing of this unit, cut slopes may experience issues with rock falls or instability (Figure 15B). The aquifers are of the fissure type. The presence of faults and fractures facilitates water circulation for recharge. These faults and highly permeable soils enhance the percolation of polluting fluids, which can contaminate groundwater.

4.12. Geoenvironmental Unit DCGR2salc

In the Geoenvironmental Unit DCGR2salc (Figure 16A), rocks from subalkaline granitic series are present: calc-alkaline (low, medium, and high-K) and tholeiitic. Areas with gentler relief can be used for urban occupation and transportation infrastructure construction, provided that technical standards are respected. However, in areas with more rugged terrain, rock outcrops may be susceptible to block falls and rock fragments. The subalkaline granitic rocks contain several diagnostic minerals: hornblende, biotite, titanite, and epidote. They provide high load-bearing capacity and resistance to cutting and drilling, requiring explosives for blasting and can be used as ornamental stone (Figure 16B). Various types of soils can be found in the form of thin layers that are highly susceptible to erosion, including Argissols, Humiluvic Spodosol, and Yellow Latosol. The unit features a fissure aquifer with low storage and exploitation capacity. Thus, only shallow wells and pits are found in the regolith.

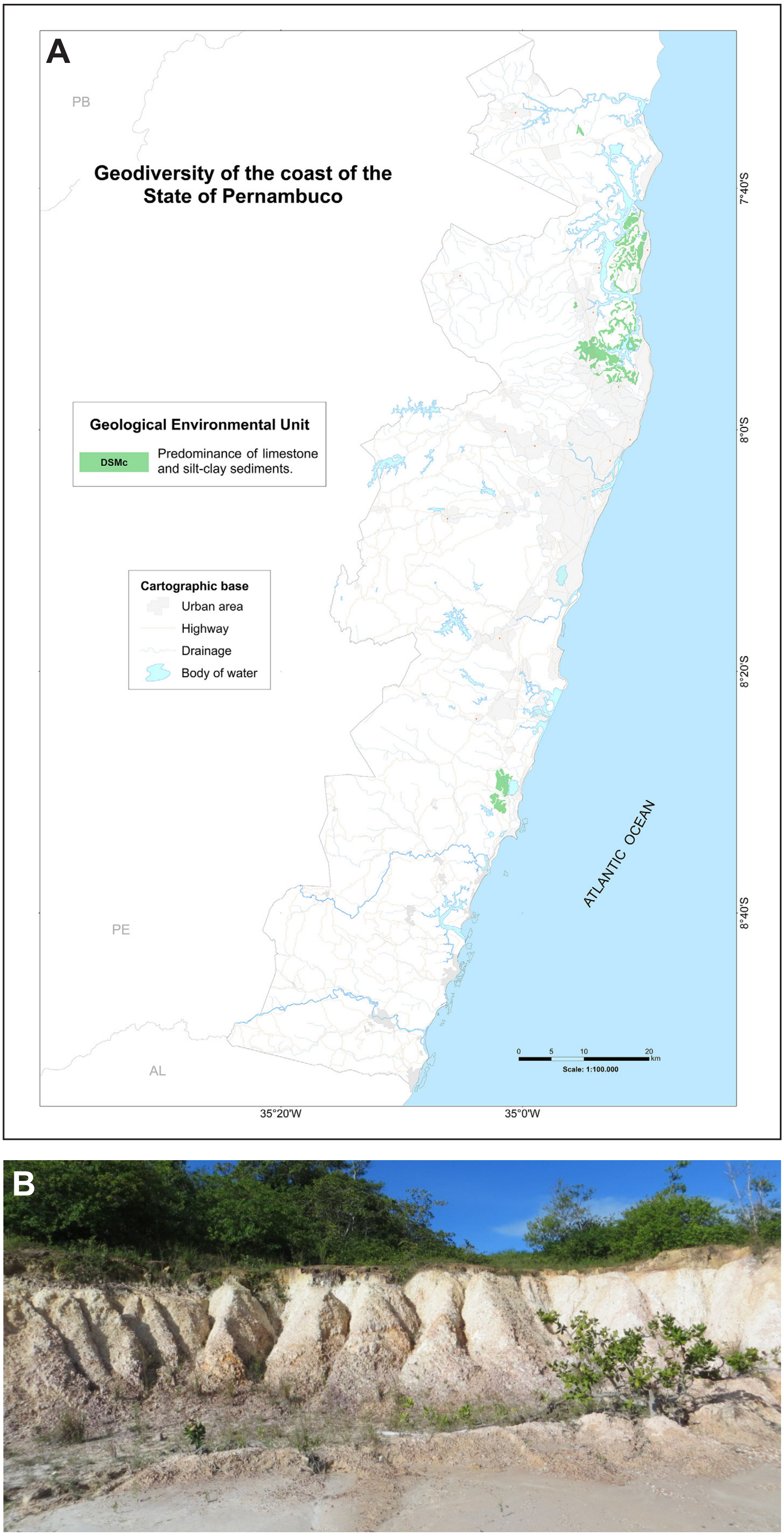


Figure 11. A - Location of the Geoenvironmental Unit DSMc along the coast of Pernambuco; B - Hills and slope - Heavily eroded road cut, municipality of Ipojuca (Pfaltzgraff and Torres 2020).

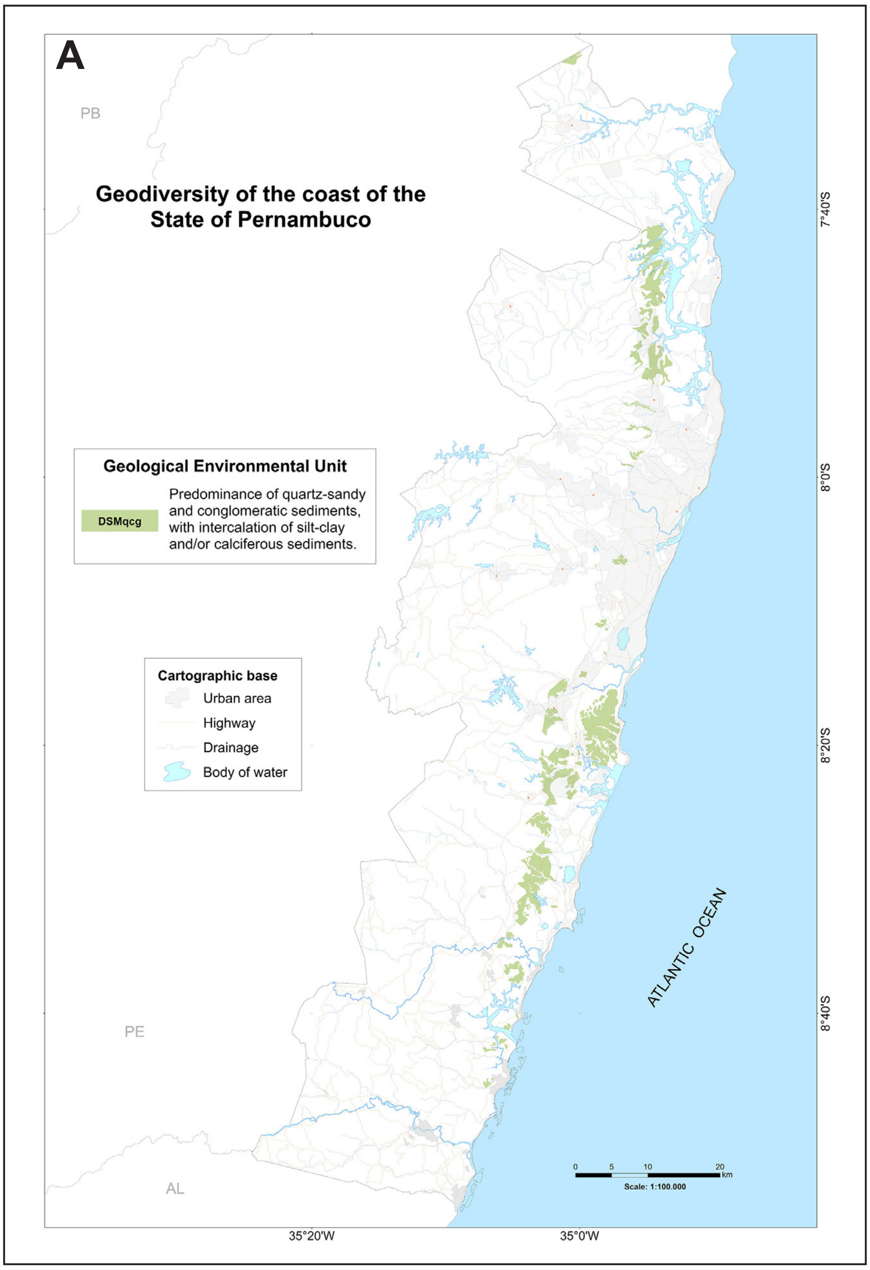


Figure 12. A - Location of the Geoenvironmental Unit DSMqcg along the coast of Pernambuco; B - Road cut slope exhibiting a stratified sedimentary package of the Cabo Formation with severe erosion, municipality of Tamandaré (Pfaltzgraff and Torres 2021).

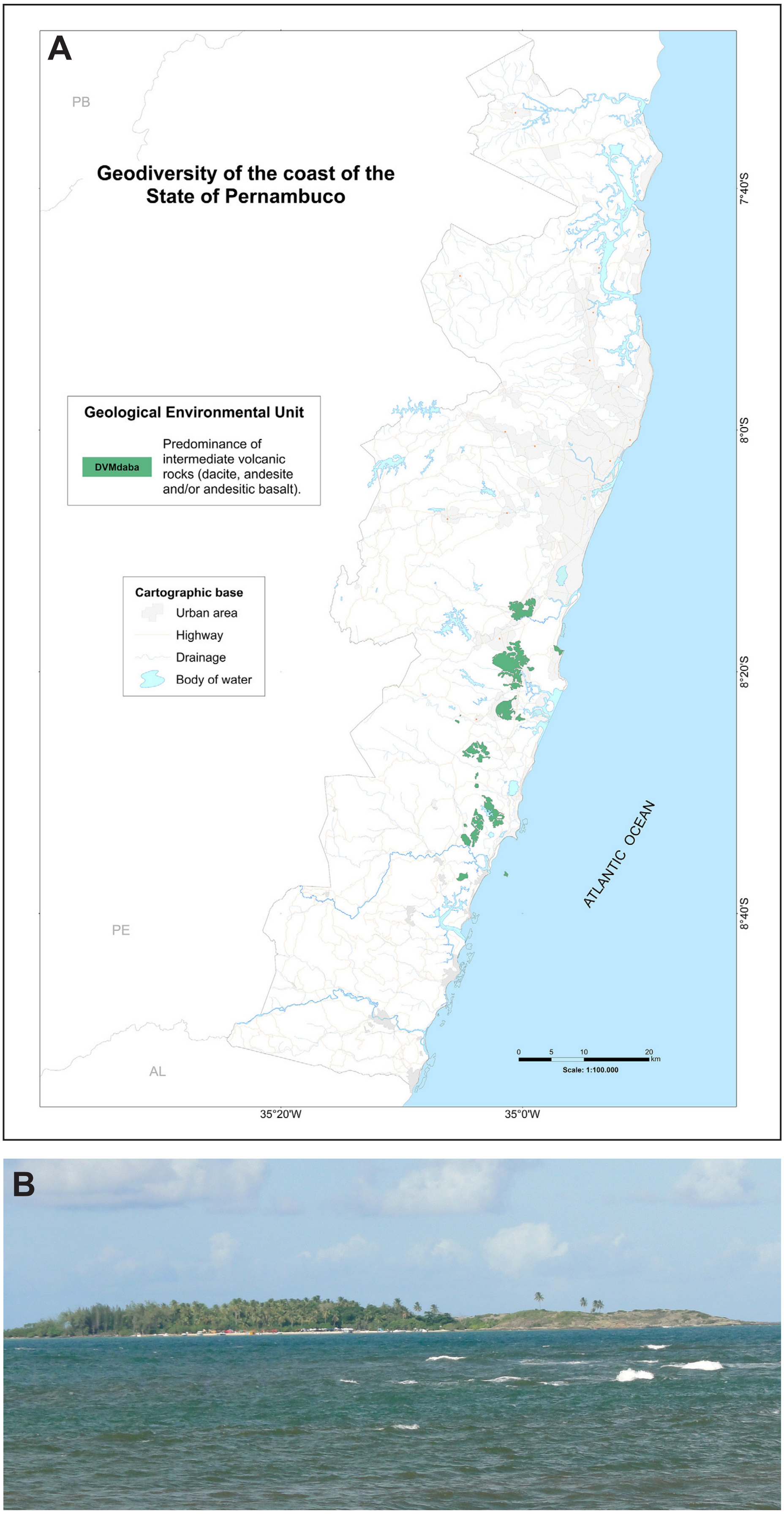


Figure 13. A - Location of the Geoenvironmental Unit DVMdaba along the coast of Pernambuco; B - Santo Aleixo Island composed of volcanic rocks from the Ipojuca Formation, municipality of Sirinhaém (Pfaltzgraff and Torres 2021).

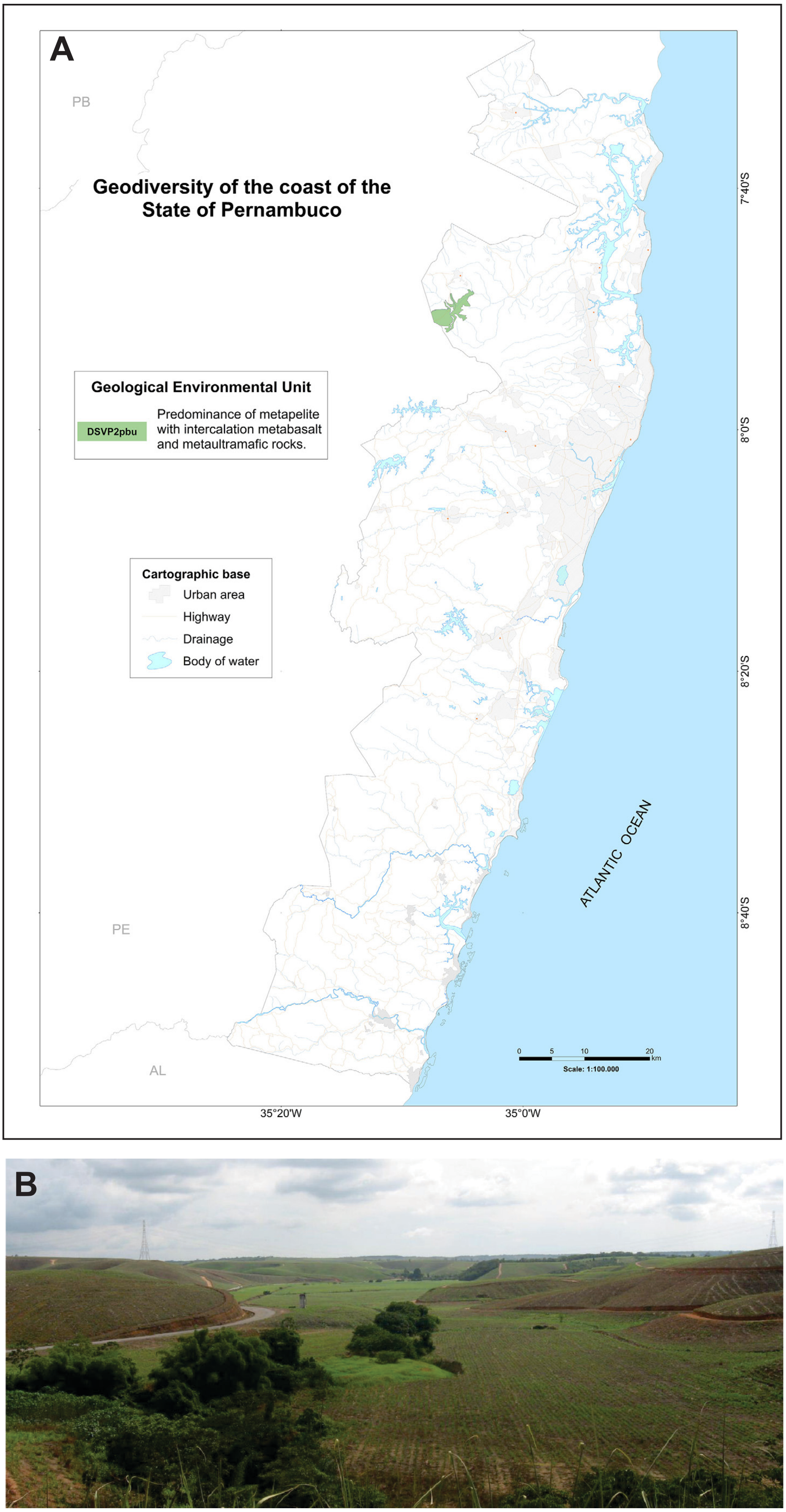


Figure 14. A - Location of the Geoenvironmental Unit DSVP2pbu along the coast of Pernambuco; B - Botafogo River Valley amidst dissected plateaus, municipality of Araçoiaba (Pfaltzgraff and Torres 2020).

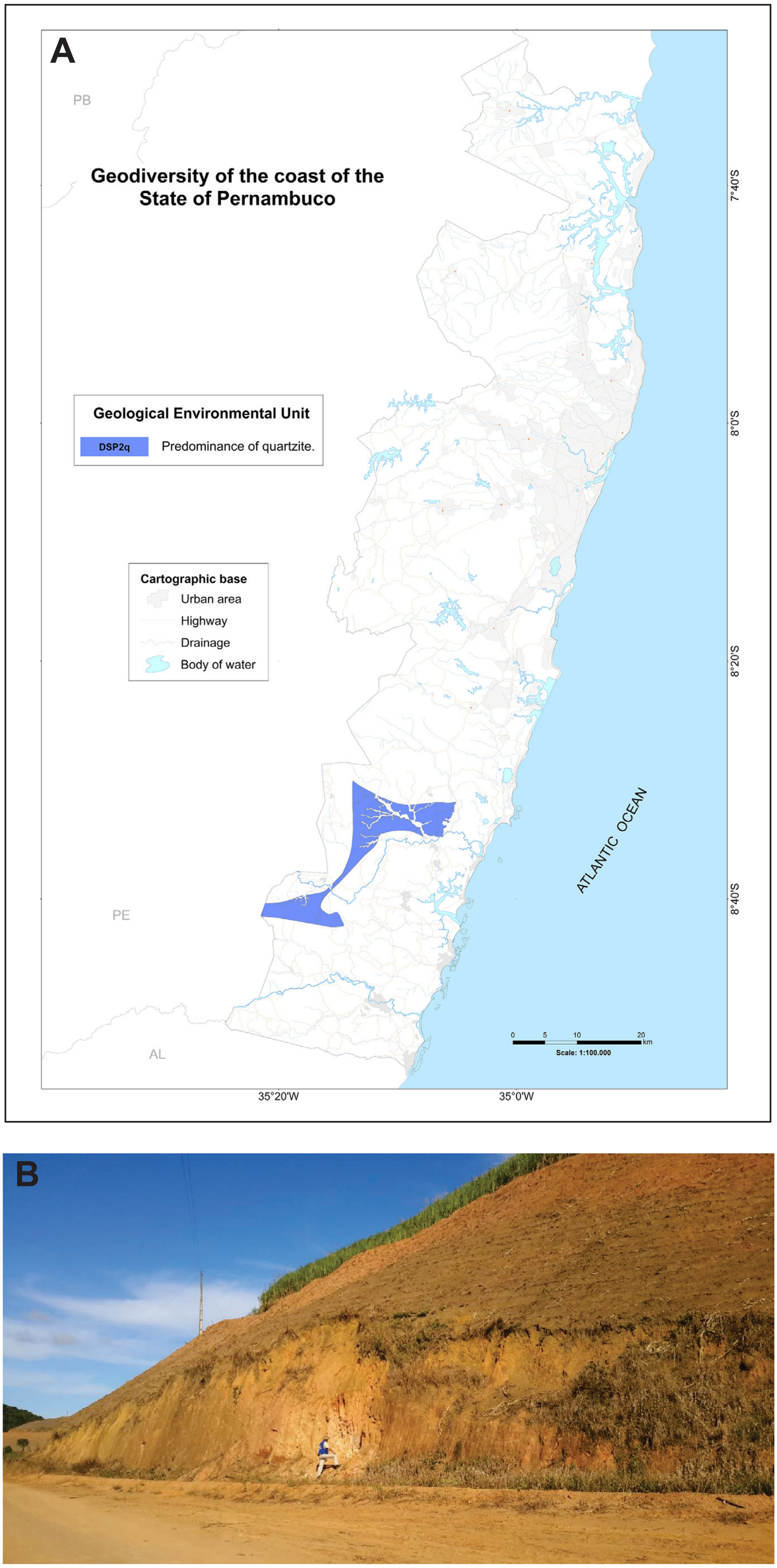


Figure 15. A - Location of the Geoenvironmental Unit DSP2q along the coast of Pernambuco; B - Heavily eroded road cut slope, municipality of Sirinhaém (Pfaltzgraff and Torres 2021).

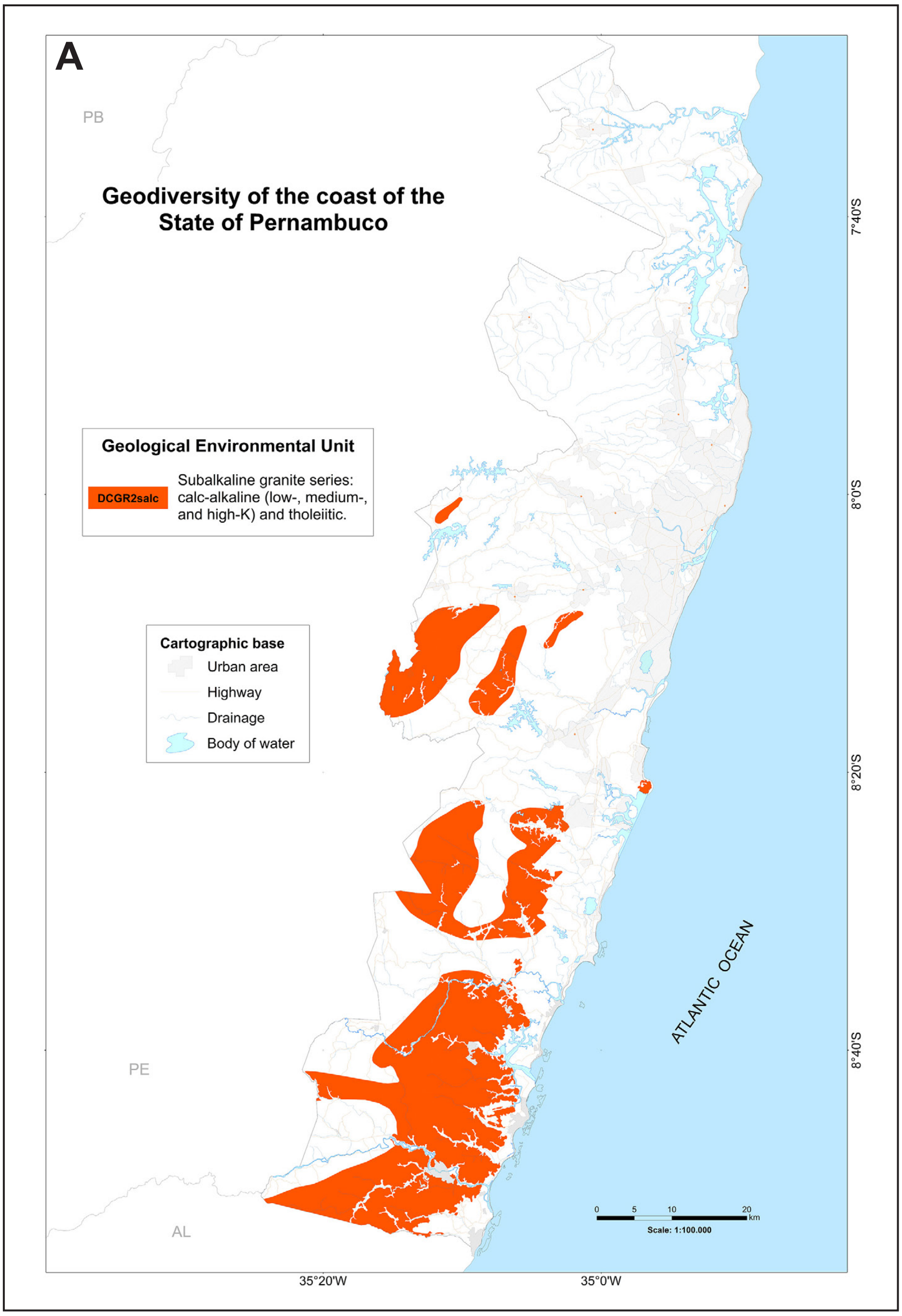


Figure 16. A - Location of the Geoenvironmental Unit DCGR2salc along the coast of Pernambuco; B - Herval Quarry - extraction of granitic rock, municipality of Barreiros (Pfaltzgraff and Torres 2021).

4.13. Geoenvironmental Unit DCGR2pal

The Geoenvironmental Unit DCGR2pal (Figure 17A) is composed of rocks supersaturated in Al_2O_3, where the sum of sodium, potassium, and calcium oxides is less than the amount of aluminum oxide present ($Al_2O_3 > Na_2O + K_2O + CaO$). These are peraluminous granitoids composed of the diagnostic minerals: muscovite, garnet, cordierite, sillimanite, monazite, and xenotime. This unit features a fissure aquifer with low storage and exploitation capacity, which explains the existence of few wells (only surface wells and shallow pits in the regolith).

These granitic rocks exhibit high load-bearing capacity and resistance to cutting and drilling, requiring explosives for blasting. They can be used as gravel or railway ballast (Figure 17B). When altered, the rocks in this unit give rise to a thick layer of soil with low fertility, which is highly susceptible to erosion. In areas where this unit occurs with rugged terrain, rock outcrops may be susceptible to block and fragment falls.

4.14. Geoenvironmental Unit DCGMGLgnp

The Geoenvironmental Unit DCGMGLgnp (Figure 18A) is characterized by a predominance of paragneisses (which may contain migmatitic portions), which are rocks with high load-bearing capacity and high resistance to cutting and penetration, requiring explosives for blasting (class 3). The intercalation with lenses of mafic rocks can lead to soils with greater fertility, while quartzitic lithologies can be used for the extraction of quartz sands, including industrial; gravel, stone for cladding, and carbonate rocks (marbles and limestones).

The flatter areas are suitable for residential, industrial, and mechanized agricultural developments (Figure 18B). However, underground engineering works and roads, in particular, require careful planning and construction. In steeper areas, there is a risk of block and fragment falls on the slopes.

The aquifers are of the fissure type and exhibit significant variation in the quantity and quality of the extracted water. The few shallow wells and pits that exist over the unit draw water from the regolith layer that covers the intact rocks. The large number of fractures, combined with areas where the soil thickness is minimal, allows for the percolation of water and surface pollutants, contaminating the aquifer.

4.15. Unidade Geoambietnal DCGMGLgno

Among the lithologies of the Geoenvironmental Unit DCGMGLgno (Figure 19A), there is a predominance of ortho-derived gneisses (which may contain migmatitic portions). These rocks exhibit significant differences in geomechanical and hydraulic behavior and, in flatter areas, are suitable for residential, industrial, and mechanized agricultural developments (Figure 19B). In steeper areas, there is a possibility of block and fragment falls.

They exhibit high load-bearing capacity, high resistance to cutting and penetration, requiring explosives for blasting these rocks. While the resistance to physical weathering is high, the resistance to chemical weathering is conditioned by the amount of quartz in the rock. They can be used as ornamental stone, railway ballast, or rock aggregate. However, when heavily fractured, they can cause destabilization in underground works and on cut slopes.

The aquifers are of the fissure type and show significant variation in the quantity and quality of the extracted water. The large number of fractures in the rocks of this unit, in areas where the soil thickness is minimal, allows for the percolation of water and surface pollutants, contaminating the aquifer.

5. Conclusion

When analyzing the distribution of geoenvironmental units, we can suggest that the physical characteristics of the region have likely been influenced by geological distribution. The information obtained from the Geodiversity projects of the Recife Metropolitan Region (RMR) and the Southern Coast of Pernambuco, mentioned in the work, shows that the oldest rocks of the crystalline basement are located in the western part of the coastal municipalities of the state. In the crystalline basement, the relief is characterized by hills and low and high hills, where erosion and landslides may occur; hydrogeological potential is very low; and the greatest concentration of agricultural land is found in two predominant soil types (Latosol and Yellow Argisol).

Recent sediments are found at the northern extremity, extending along the coastline to the border with the state of Alagoas (AL), with sediments in the southern portion having a predominantly more carbonaceous composition, while in the northern portion, the sediments are sandier.

These sediments feature a relief composed of marine, fluvio-marsh, and lagoon plains, with hydrogeological potential varying from very high to non-aquifer; the most prominent soil type observed is Argisol. Various types of geological and geotechnical events may occur, with erosion being the predominant one, followed by flooding along the rivers. Most urban areas are used for residential and commercial purposes, with paved streets and little vegetation cover. The cities with the highest population concentration and/or building density are Olinda, Paulista, Camaragibe, Recife, and Jaboatão dos Guararapes, all located along the coastline. Most tourist attractions are along the coast, with the southern beaches being the most well-known, such as Porto de Galinhas and Carneiros.

This work provides an overview of the coastline of the state of Pernambuco, offering government and private managers basic information to assist in the development of public policies aimed at land use and occupation and better utilization of the physical environment.

The geological information available in the scientific community is often difficult for lay professionals in the field to understand. The variety of soils identified in this work can support a diversification of agricultural crops, contributing to the absorption of local labor.

Thus, the Geodiversity Map aims to present this data in a language that is easily understandable for the entire population, clearly and objectively showing high-quality technical content that is simple to comprehend. Therefore, its use and social value are evident, as it provides valuable resources for administrators responsible for societal development.

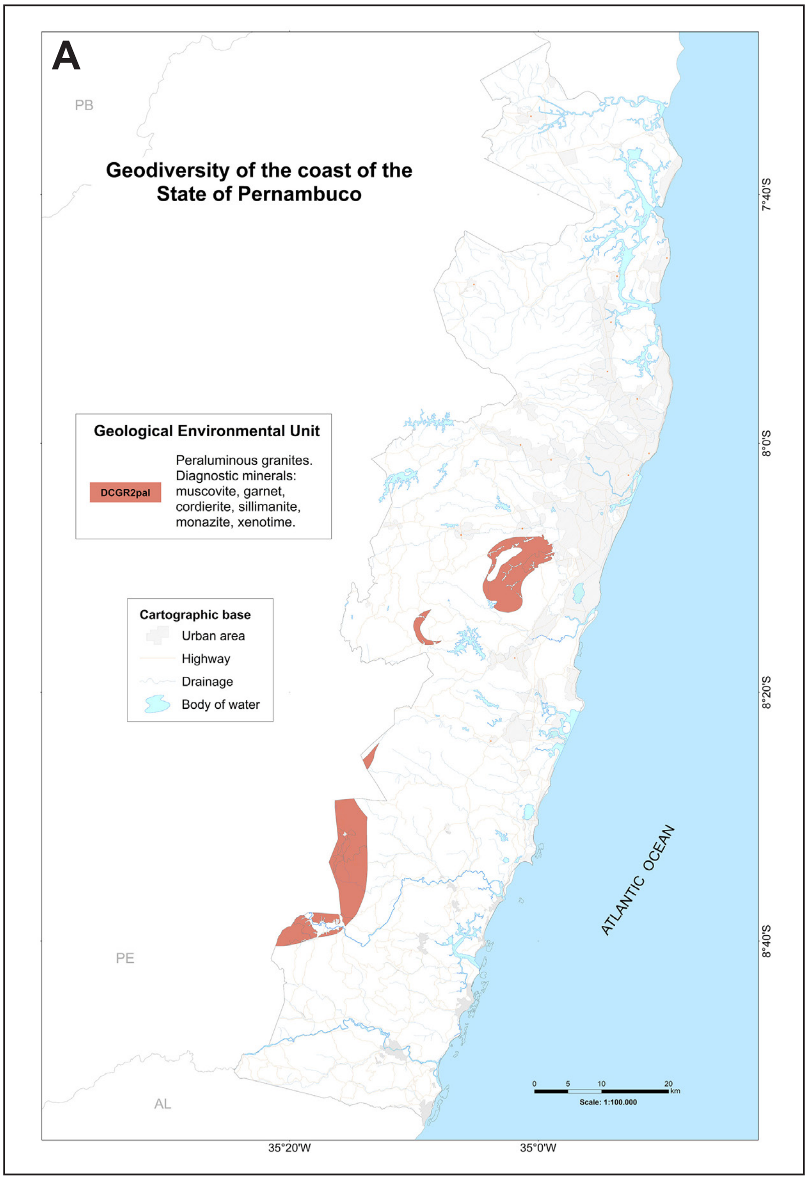
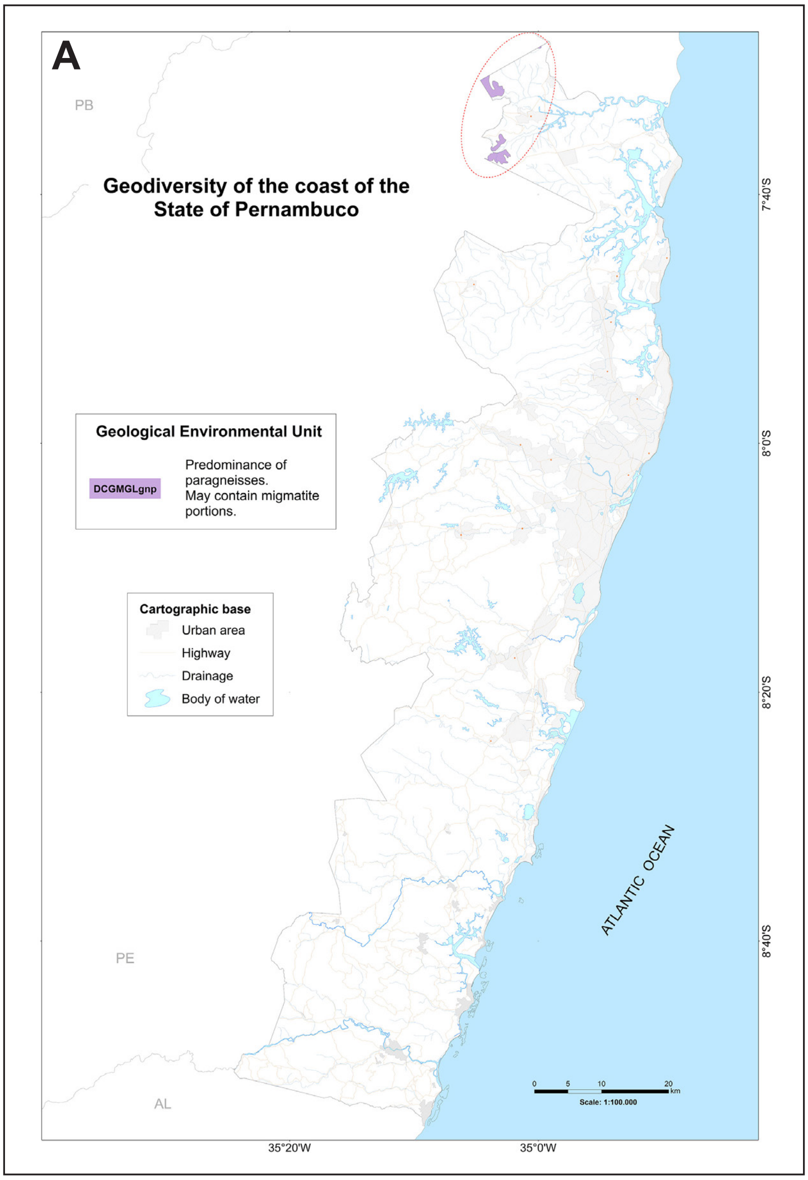


Figure 17. A - Location of the Geoenvironmental Unit DCGR2pal along the coast of Pernambuco; B - Outcrop of granitic rocks – Extraction for construction materials, municipality of Jaboatão dos Guararapes (Pfaltzgraff and Torres 2020).



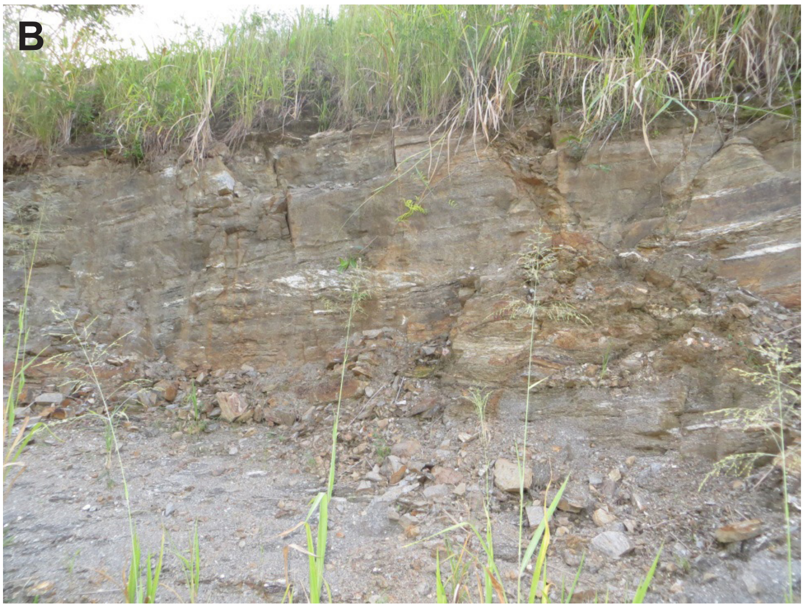


Figure 18. A - Location of the Geoenvironmental Unit DCGMGLgnp along the coast of Pernambuco; B - Saprolite of gneissic rock - Road cut, municipality of Cabo de Santo Agostinho (Pfaltzgraff and Torres 2020).

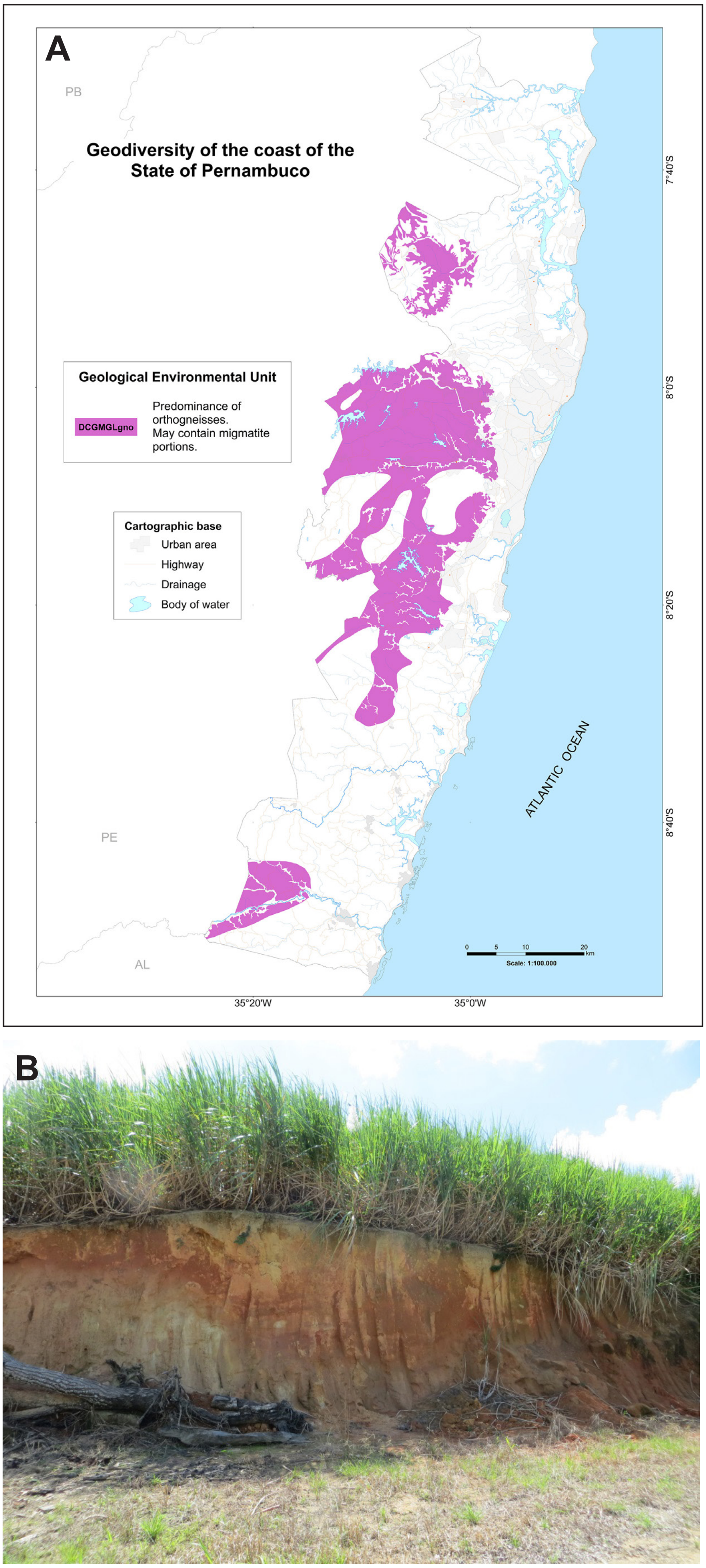


Figure 19. A - Location of the Geoenvironmental Unit DCGMGLgno along the coast of Pernambuco; B - Road cut in a heavily eroded sugarcane field, municipality of Cabo de Santo Agostinho (Pfaltzgraff and Torres 2020).

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Authorship credits

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A - Study design/ Conceptualization **B** - Investigation/ Data acquisition
C - Data Interpretation/ Validation **D** - Writing
E - Review/Editing **F** - Supervision/Project administration

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