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Assessing the cultural values of the geodiversity in a Brazilian city: The historical center of João Pessoa (Paraíba, NE Brazil), Mata da Aldeia chart

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The objective of this paper is to present a view of the geodiversity of the Historical Center of João Pessoa, located in Mata da Aldeia chart (scale 1:25.000), Paraíba State, northern Brazil, in order to insert sites in urban geotouristic routes. For this, a mapping of this geodiversity and its geoheritage was carried out through the inventory of sites with relevant value. Geologically, the chart is part of a sedimentary basin that developed on a faulted crystalline basement, whose Plio-Pleistocene reactivation resulted in a stepped substrate, and the terrain has geotouristic potential from the point of view of its geoheritage. It was necessary a detailed study of the geoscientific and historic literature of the area and a detailed field work, having a look about the physical substrate reflecting the importance of this as a heritage element of space. Tambiá fountain, Trincheiras fossil, Ireres doline, Stone Square, Santo Antônio fountain, Miracles fountain and Sanhauá fault were identified as geotouristic sites. It is therefore pertinent to interconnect this urban heritage to tourism in the area, so that more motivation arouses the interest of tourists, now turned to the bias of the lithosphere and hydrosphere.

1. Introduction

The theme about Natural Heritage is relatively new in geosciences and there is no unanimity in its definition and characterization. Since the United Nations Conference on the Human Environment, held in June 1972 in Stockholm, environmental problems began to be discussed on an enlarged scale and entered characters that had hitherto been seconded to this discussion agenda.

Thus, in October and November of the same year in Paris, the theme of environmentalism was inserted in the heritage view of space, through the Convention for the Protection of World Cultural and Natural Heritage, under the aegis of UNESCO, where aspects of nature and human-cultural were separated, at least in practice, since it is known that the recognition and protection of a national culture takes place through the "integration of natural elements and their processes with human actions, due to their identity, sensibility and meaning (religious, mythical, historical, symbolic, affective, among others)" (Pinto & Oliveira Filho, 2014:23), thus establishing a link between human beings and nature.

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Geodiversity, as the result of slow evolution since Earth's beginnings, refers a natural variety of geological (rocks, minerals and fossils), geomorphological (landforms, deposits and processes) and soil elements, including their relationships, correlations, interpretations, systems and properties (Gray, 2004). Are part of this diversity geological materials (rocks and their textural elements, structures, minerals and fossils, as well as the processes that generated or deform them, such as tectonics, generating folds, faults and cracks), geomorphological materials and forms (deposits, landform and the processes that gave rise to them), pedological (soil) and hydrological (surface or subsurface-sweet or salty); in situ (in the place of origin) or ex situ (collected and exposed elsewhere, in the case of rocks and their elements), analyzed at all scales (Pereira, 2019); the anthropic action plays a fundamental role in interfering with the characteristics of these elements.

Geoheritage refers to the set of values that represent the geodiversity of the territory, composed of abiotic natural elements existing in the surface (submerged or emerged) that must be preserved due to their patrimonial value (Rodrigues & Fonseca, 2008). Thus, in this work, it was dissociated from the geological heritage, which we consider to correspond to complementary but distinct concepts, both of which are framed in the abiotic natural heritage, together with the elements of the hydrological and pedological heritage.

The term 'site' was introduced in Geosciences by Grandgirard (1997), consisting of a portion of geoheritage that has a particular importance for the knowledge of Earth's evolution, climate and life history, thus possessing assigned values that give it an inheritance meaning as well the possibility of being inserted into a patrimonialisation context. It may be a geosite, geomorphosite, hydrosite or pedosite, depending on the patrimonial asset in question.

In a broader view, these values can be scientific, aesthetic, cultural, ecological and/or economic (Panizza & Piacente, 1993; Reynard, 2005). In addition, the identification, classification, evaluation, mapping, protection and promotion of this type of heritage add a value to tourism activities (i.e., geotourism) through the interaction between the cultural and natural aspects of the landscape (Panizza & Piacente, 2003). The study area of this paper, corresponding to Mata da Aldeia chart, southeastern quadrant, has an extremely interesting geodiversity that interweaves fluvial, continental and fluvio-marine elements associated with a sedimentary basin, considering, in the scope of this work, its geological and geomorphological aspects. Thus, when human perception values geological materials (rocky substratum and its elements - textures, structures, minerals, and fossils) with their geological structures (folds, faults, joints and breccias), as well as the set of landforms (and correlative deposits) with scientific, pedagogical, cultural or aesthetic interest, we have the definition of geoheritage (Reynard & Brilha, 2018; Reynard & Panizza, 2005), which, by its meaning, deserves to be studied, preserved and valued.

Previous studies have established in the theme of urban geoheritage, especially associated with the theme of urban geotourism. Urban geotourism manifests itself as an important area within geotourism. It presents a restricted conceptual aspect (strictu sensu) and a broad aspect (lato sensu). In a restricted sense, by knowing and mapping the cultural heritage, including churches, houses, cemeteries, monuments, paved roads, among others, in describing their architecture and history, identifying their lithologies, characterizing them petrographically and, if possible, identifying its origin, measures can be proposed that encourage and guarantee its geoconservation and disseminate its geodiversity (Pereira & Amaral, 2014; Pereira, Oliveira, & Vieira, 2013). The abiotic natural heritage inserted in the urban area, such as quarries, parks with freshwater springs, waterfalls, specific landforms, among others, can also be part of urban geotourism itineraries in this restricted sense.

In turn, the promotion of the understanding of landscape reading, the interpretation of the way the city was established in the physical substratum, the occupation of the urban space and the challenges imposed by the physical environment, allow the understanding of urban geotourism in a broad sense. It should be noted that urban geotourism becomes a complement to established itineraries, usually in the Historical Centers of the main tourist cities, by adding this new information.

After all, the rocks have minerals, textures and structures that make it possible to tell the history of the planet, besides being sources of information about the technological, social and economic past of people who used these georecourses in the construction of these constructions (Stern, Riccomini, Fambrini, & Chamani, 2006). Landforms, water and pedological resources are other elements of geodiversity that are conditions for settlement and urban sprawl and as such can also be used in the context of urban geotourism.

Discussions about urban geotourism are quite recent, especially since the mid-2000s, and to an extremely smaller extent compared to non-urban areas. In Geoscience literature, urban itineraries that mainly insert geological and geomorphological aspects are very common in the scientific environment, such as London (Robinson, 1982), Zaragoza (Carrillo & Glisbert, 1993), the dissemination of ex situ paleontological sites in Lisbon. (Silva, 2009), Segovia (Díez-Herrero et al., 2011), Lisbon (Rodrigues, Freire, & Machado, 2010; Rodrigues, Machado, & Freire, 2011), México City (Palácio-Prieto, 2015), Shiraz, in Iran (Habibi, Ponedelnik, Yashalova, & Ruban, 2018), Ljubljana (Ticar, Komac, Zorn, Ferk, & Hrvatin, 2017), among others. The dissemination of these itineraries to tourists would insert the activity of urban geotourism in these cities.

In Brazil, there are several proposals to study geodiversity in urban environments, either in the form of geological itineraries for urban geotourism purposes or for pure scientific knowledge, when studying details such as stonework or lithological pathologies in buildings. As examples, we have the city of Natal (Carvalho, 2010); São Paulo (Del Lama, Bacci, Martin, Garcia, & Dehira, 2015); Belo Horizonte (Fernandes, Conrado, Vivas, & Marciano, 2007); the historical municipalities of the Gold Cycle in Minas Gerais (Costa, 2014); Porto Alegre (Phillipp, Vargas, & Benedetti, 2009); Salvador (Pinto, 2015); João Pessoa (Pereira, 2019), among others.

The objective of this work is to present a view of the geoheritage of the historical center of João Pessoa, located in Mata da Aldeia chart, in its relation with cultural (urban) heritage. The production of these informations, taken to a wide range of researchers, scientists, students and tourists, among others, is an important piece for the construction of a culture that is able to understand that the region in which we live is much more complex than the our ancestors and that geoheritage

plays an important role in understanding the complexity of the relationships between human societies and their abiotic environment.

2. Materials and methods

The present work involves three sequential phases. They are:

1. Bibliographical research: in this phase, all scientific production involving historical, geomorphological and geological studies of the area was analyzed to increase the knowledge that involves the genesis of the landscape, as well as the understanding of the cultural and functional value of geodiversity, when related to the urban settlement and evolution of the region;
2. Field work: at this stage, the sites were recognized in the field, in order to identify geotouristic values, taking as criterion the presence of cultural, functional, aesthetic, economic and scientific values.
3. Inventory: considering the analyzed scale, from outcrop (meter-scale) to landscape (kilometer-scale; Carvalho, 1999; Cunha & Vieira, 2004), a database was created with sites that have values, based on their scientific importance, scenic beauty, pedagogical-didactic value, among others, through the completion of evaluation files that contain a series of information from the sites, which were obtained in the second stage.

The inventory and qualitative assessment of the sites developed through the analysis of a number of resources present in heritage assets, whether they belong to the abiotic or cultural milieu.

The site was analyzed for its physical characteristics, depending on the type of good evaluated (geological, geomorphological, pedological or hydrological). In order to elaborate a database of the abiotic environment of the area, this information was summarized and inserted in a catalog form proposed in this study, partially based on Rodrigues (2009), which includes the necessary information about the site, its characteristics, values and threats.

3. Geological and geomorphological context of the area

The geology of the area is related to the Paraíba sedimentary basin. Such sediments were deposited as the South American continent withdrew from the African continent (Françolin & Szatmari, 1987), over a crystalline basement deformed by NE shear zones (Jardim de Sá, 1994). This basin can be subdivided into three sub-basins: Olinda, Alhandra and Miriri sub-basins.

The sedimentary events of the Paraíba Basin deposition date back to the end of the Turonian when terrains north and south of the Pernambuco Shear Zone were reactivated (Petri, 1987) as the South American continent moved away from Africa, beginning the subsidence of the Paraíba Basin (Barbosa & Lima Filho, 2006; Petri, 1987).

This clastic-carbonate package, belonging to the Paraíba Group, is represented at the base by the Beberibe Formation (sandstones and conglomerates) and the Itamaracá Formation (limestones), which do not outcrop in the study area; the Maria Farinha Formation limestone (not present) and Gramame, at the top, covered by the poorly selected Mio-Mliocene sediments of the Barreiras Formation and post-Barreiras sediments, this last being Quaternary in age (marine terraces, swampy deposits, fluvio-lagoonal deposits, eolian deposits, coral reefs, beach rocks, of transitional marine origin; and alluvial fans, fluvial deposits, eluvium-colluvial and colluvial coverings, of continental origin).

From the Pliocene, as a result of the establishment of a stress field in the South American plate, with compression oriented E-W and N-S extension, a series of faults that hit the overlapping sediments were reactivated, having a crucial role in coastal morphology and tracing of the hydrographic network (Bezerra, Amaro, Vita Finzi, & Saadi, 2001).

This reactivation plays a fundamental role in the geomorphology of the area. We can identify two geomorphic subunits in the south coast of Paraíba state: the low coastal upland ('Coastal Tablelands') and the floodplains, this last being subdivided into fluvial and fluvial-marine floodplains. The top of the tablelands is linked to the plains in relatively steep slopes, where numerous fountains emerge.

4. Results - a view of the geodiversity of the area

The Mata da Aldeia chart, in its southeast quadrant, presents the Historic Center of João Pessoa, capital of Paraíba State, where the sites in this work were selected. The city of João Pessoa is known worldwide as the 'eastern extreme of the Americas', which in itself already has a tourist potential. Its geographical coordinates are 7° 7′ S and 34° 53′ W, and its proximity to equator gives it plenty of sunshine and high temperatures all along the year. It has an area of 211.5 km^2 and a population of 723.515 inhabitants (IBGE, 2010), resulting in a demographic density of 3421 inhab/km^2, the highest in the state.

It is bathed in the west by the Paraíba River, the main river of the state. According to the aesthetic, cultural, scientific, economic and ecological values, seven sites belonging to the urban geoheritage were selected (Fig. 1). They are:

Site 1: Tambiá Fountain

It corresponds to a hydrosite located in the Arruda Câmara Park, popularly known as 'Bica', with 245 ha area, managed by the City Hall and easily accessible by several bus lines. It is a place of rest and leisure for residents and tourist, with a zoo, a lake with pedal boats, leafy trees and a centuries-old history (Fig. 2).

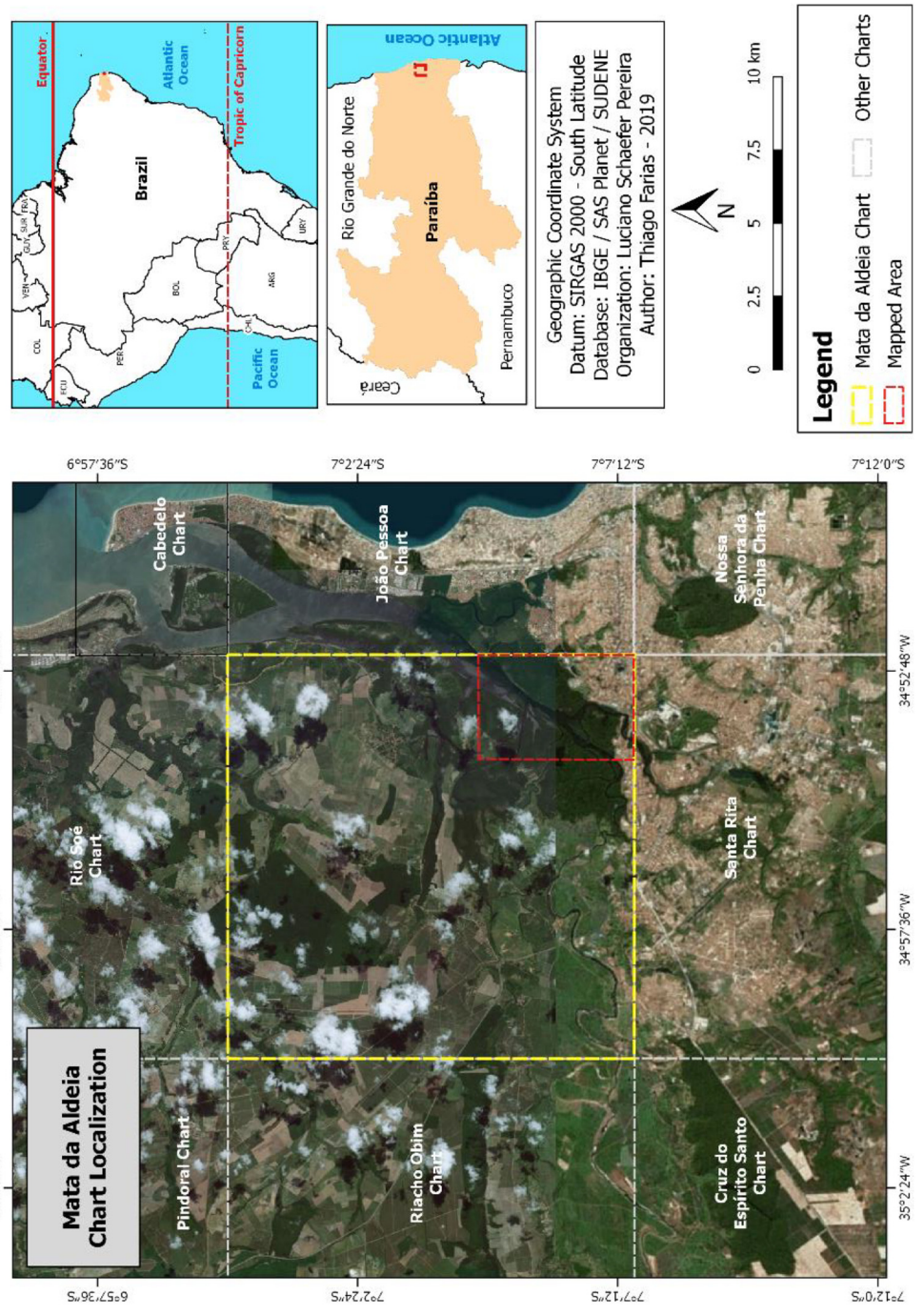

Fig. 1. Location of the mapped area in the Mata da Aldeia chart, Paraíba State and Brazil.

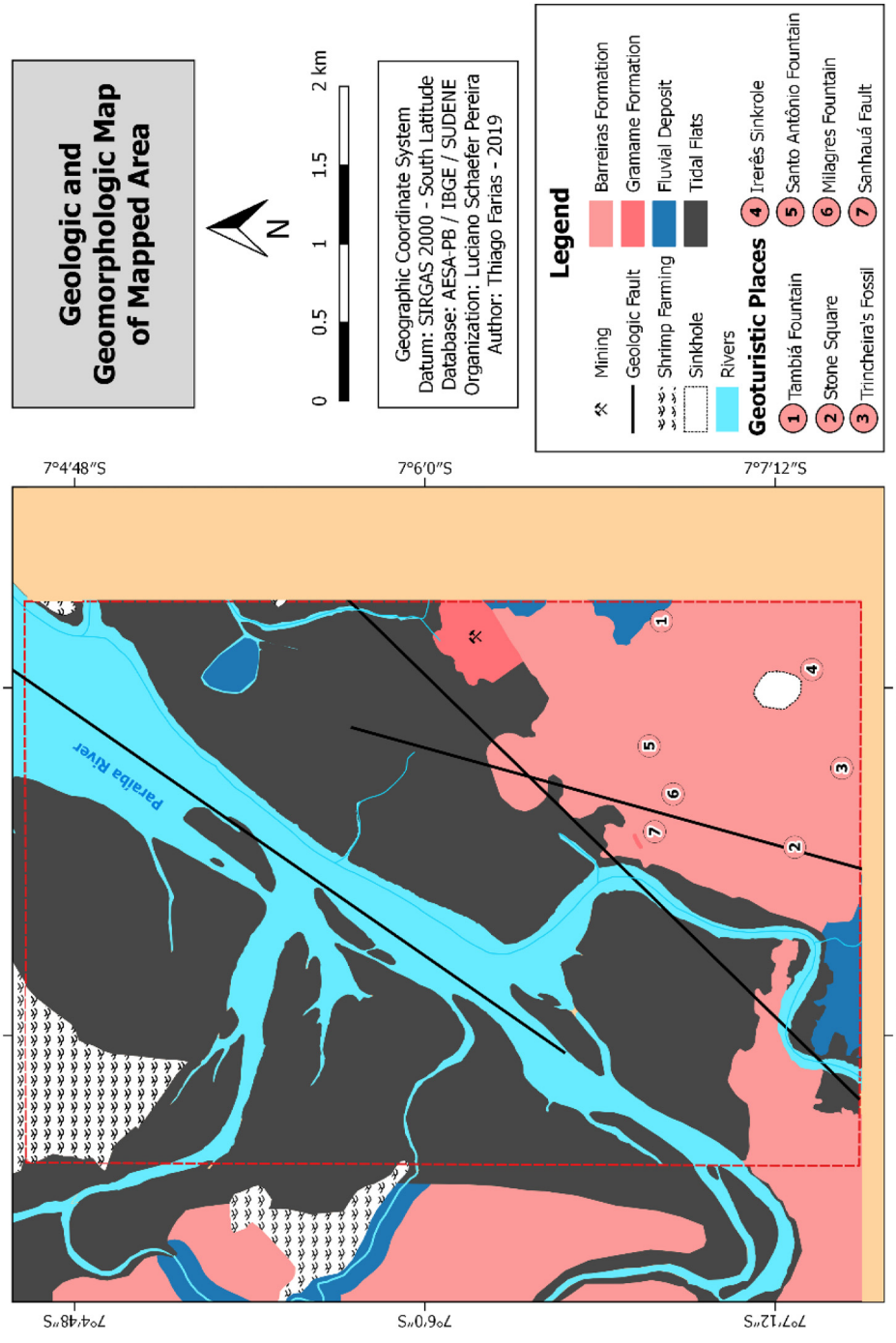

Fig. 2. Geological-geomorphological map of Mata da Aldeia chart.

Fig. 3. Degrading situation of the front built in the eighteenth century to identify the Tambiá Fountain, richly carved in limestone with baroque elements. Photo: the authors.

While piped water did not reach the city, the role of this fountain was crucial, especially in the nineteenth century, because of its good flow and quality. The date of approval for the construction of the Tambiá Fountain is March 1782 (Pinto, 1977), under the administration of Governor Jeronymo de Castro e Melo. However, since the 1730s there have been documents exchanged between the provider of the Royal Treasury and King D. João V about the need for reconstruction of a fountain in Tambiá, which allows us to infer that some type of building had been in place before.[1]

The name of this font is associated with a local legend, denoting the folk aspect of its cultural value. According to Rodriguez (1962), a young virgin indigenous named Aipré, of the Potiguara tribe, would had fallen in love with a Cariri warrior, an enemy of his tribe, called Tambiá. After his death by his relatives, the girl wept for 50 moons over the tomb, and her weeping gave rise to the waters of the spring. This is the legend best known and spread by the times. However, there is another where a Tabajara Indian begs her mother for water so that her love, the Tambia Indian, will not go away. On the day of his departure, the Indian is stung by a centipede and crushes it. Mother Earth is thus torn, and from its crevices spring the waters that gave rise to the spring (Medeiros, 1994).

Its bad current conditions, such as cracks and inclination, forced the City Hall to put a wooden screen (Fig. 3). According to Araújo (2012), it flows from the Barreiras Formation, about 7 m above the Gramame limestone, with an approximate altitude of 19 m above sea level. The author proposes that the northeast sector, where this fountain springs, has a depth of limestone greater than the west slope and which are springs from the upper-middle portion of the Barreiras Aquifer (Fig. 4).

Its exceptional cultural value, combined with the very high economic and scientific values, make it possible to infer that it is a geoheritage example in the area.

Site 2: Stone Square

It refers to a geosite represented by a monolith inside a square (Fig. 5), located in the southernmost portion of the historical center. Despite the xerosere vegetation, the rock can be identified as a porphyritical granodianite, with centimetric phenocrysts of K-feldspar and an abundant presence of biotite. In fact, this monolith, according to 'A União' Journal (10.07.1931), was brought to

[1] A.H.U.-ACL_CU_014, Cx 10, doc. 791, fl 3 e A.H.U.-ACL_CU_014, Cx 13, doc. 1085, fl 2.

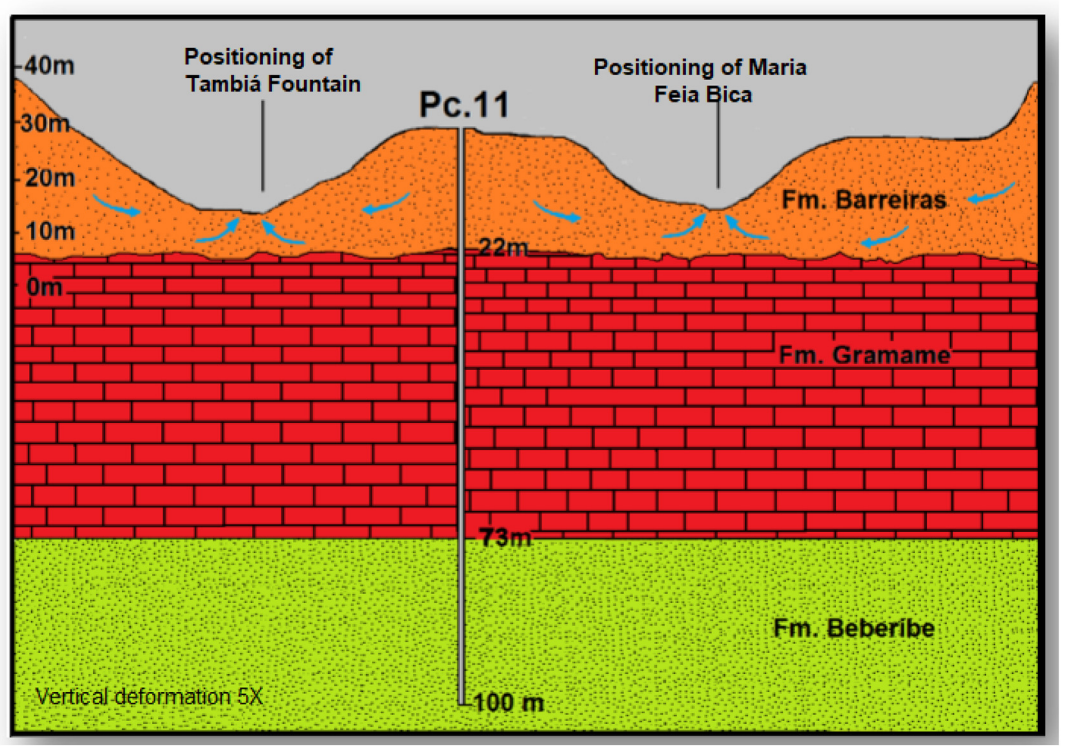

Fig. 4. Profile elaborated from drill cores (Pc.11) with the location of the Tambiá Fountain. (Source: Araújo (2012, p. 220).)

the site on July 12, 1931, from the Borborema Region. In informal conversations with the residents, two versions of the place of provenance were reached. In the first, the rock would have been brought from the municipality of Cruz do Espirito Santo (25 km from the capital) to the Sanhauá River by train and by carriages to the square. The problem with this version is that this type of granite does not outcrop in the municipality, which sits on a sedimentary basin.

The second version is that the monolith, located in the municipality of Bananeiras, 130 km from the capital, was brought in honor of the death of President João Pessoa, who at one point in his wanderings inland would have rested in its shadows. The municipality of Bananeiras records the presence of granodioritic rocks similar to that of Praça da Pedra, in outcrops along the PB-105 highway, which would corroborate this version (Pereira et al., 2013). The 1:500,000 geological mapping (Brasil, 2002) positions the region's rocks in the medium to high Potassium Itaporanga Granitic Calcialcaline Suite, represented by diorite associated with porphyritic granites and granodiorites, dating from 584 Ma by the U-Pb in zircons method by Brito Neves, Passareli, Basei, and Santos (2003). Fig. 6 shows Itaporanga Granodiorite (on the left, in hand) and Stone Square Granodiorite (on the right).

Interestingly, this site refers to one of the rare presence of a granitoid rock on the Paraiba coast, geologically associated with the Paraíba sedimentary basin, which denotes its high scientific value. Moreover, it represents a classic example of the historical aspect inserted in the cultural value of geodiversity and can be classified as an ex situ geodiversity element of the geological (petrographic) type.

Site 3: Tricheiras Fossil

It corresponds to a laminated limestone floor, located at Rua das Trincheiras, in the João Pessoa Historic Center, with the presence of a fish fossil of the genus *Dastilbe* (*Dastilbe elongatus* Santos), with the dimensions of 7 cm × 2 cm (Fig. 7).

This ornamental rock is known as 'Cariri Stone', which is widely sold in the city's building materials used for wall, floor and sidewalk coverings. The quarries are located in Ceará State, in the municipalities of Porteiras, Barbalha, Crato, Nova Olinda and Santana do Cariri, within the Araripe Geopark, in the Pedra Cariri Geosite, associated with the Crato Member, Santana Formation, eastern sector of the Araripe Basin. The Crato Member corresponds to laminated micrite limestones and clay-carbonate rhythmites interspersed with Cretaceous (112 Ma) shales and fine sandstones, associated with a carbonated lacustrine environment, with calm and swampy waters, whose abundant and diverse fossil records are explained by the intense local biodiversity (insects, arachnids, fish, algae, among others) in good fossilization state (Viana & Neuman, 2002).

A fossiliferous object is rare in the rocks, even ornamental, present in the historic center of João Pessoa. This characteristic per se gives it importance as an element of geodiversity of geological (paleontological) character.

Site 4: Irerês Doline

Fig. 5. Stone Square, in the Historic Center of João Pessoa.

Fig. 6. Comparison of the minero-textural characteristics of Itaporanga Granite (left, in hand) and the Stone Square monolith. (Photo: the authors.)

Fig. 7. Fossil located on the floor in Trincheiras Street.

Irerês Doline is one of the main postcards of the city. It is located in the heart of the Historic Center, being a convergence point of streets and avenues that radiate to all regions of the city (Fig. 8). Since the seventeenth century appears in virtually all the iconography of the capital, especially the Dutch one. There was the so-called Lagoon Farm, owned by the Jesuits, later called Irerês Lagoon, due to a very common mallards that swam in its waters. Only in the early 1920s the area passed into the management of the state.

Thus, at the beginning of the twentieth century, its landscape remained practically intact: a large lagoon, surrounded by leafy trees of the Atlantic Forest biome that collaborated to maintain its perpetuity, forming a marshy scenery and some farms that denoted the human presence in the area. For a long time it was an obstacle to the advancement of urbanization, especially towards the beach.

From the geomorphological point of view, the lagoon corresponds to a doline, a form that is very common throughout the study area, but most often without the presence of a body of water. Thus, the permanence of this mirror makes it very special, representing a natural recharge zone of the aquifer, in this case suspended, being at a height of about 35 m. Its body of water measures 750 m in perimeter, with about 4.5 ha of area, belonging to a centripetal basin with dimensions that reach 1.0 km^2 of total area (Barbosa, 2015). It is relatively symmetrical and is infiltrated in the Pleistocene porous sandstones of the Barreiras Formation.

It may be classified as a shelled doline, generated by the slow subsidence of the limestone of the Gramame Formation (Maastrichtian) above, about 3 to 4 m below the water depth (Araújo, 2012) that does not rise at this altitude because it is covered by the Plio-Pleistocene sediments of the Barreiras Formation. Vital (2015) correlated this doline and others in the region to a series of discontinuities present in Gramame limestone. The water mirror shows its connection to the suspended water aquifer (Fig. 9), which is limited at the base by an impermeable layer of fragipan.

This karstic geomorphosite can be considered a geoheritage asset in the area due to the exceptional aesthetic value, coupled with the very high scientific, cultural and economic values.

Site 5: Santo Antônio Fountain

It corresponds to a hydrosite located on the land of the Franciscans, inside the gardens, on the northwestern side of the tablelands, which can only be accessed with the permission of the friars. From the beginning of the conquest of the captaincy its

Fig. 8. Solon de Lucena Park in two moments. a) In the early 1930s. Photo: Walfredo Rodriguez Collection; b) current Solon Park of Lucena. Photo: PMJP collection.

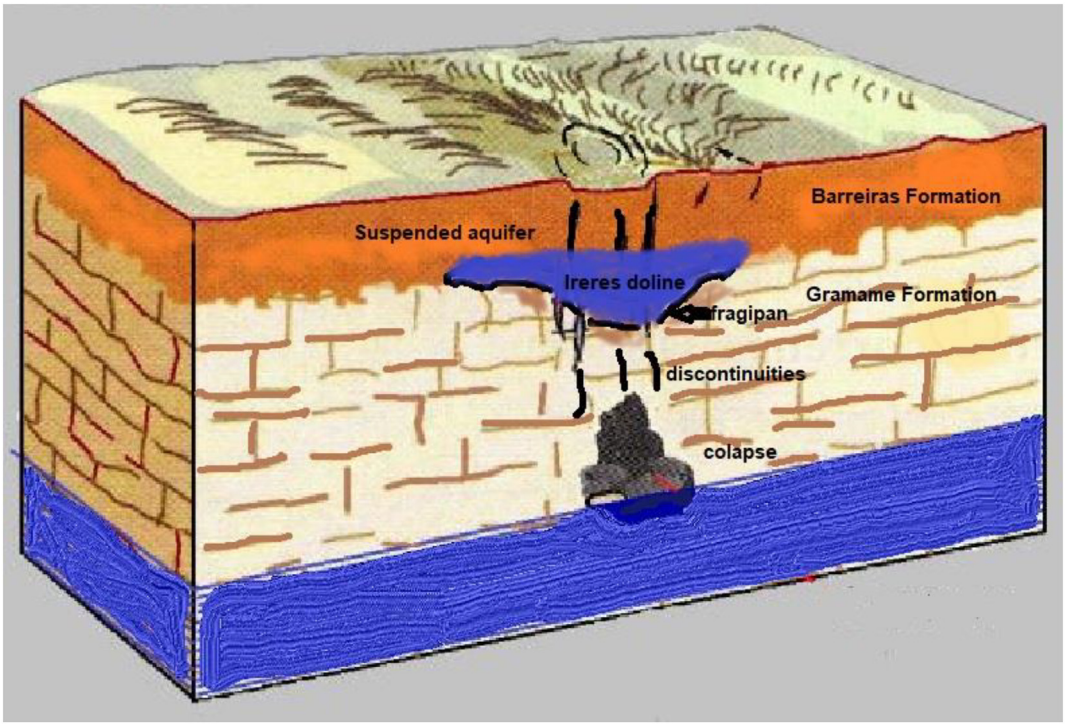

Fig. 9. Early stages of Irerês Doline formation from the collapse generated by the dissolution of the limestone. (Source: the authors.)

waters supplied the population. In Dutch iconography, the size with which it was portrayed seemed to be large, with a stream flowing towards the Sanhauá River.

The symmetrical limestone facade retains its original Baroque features (Fig. 10) and several small letters features with Latin sentences, including '`S. Antoni` Ora Pro Nobis' ("St. Anthony pray for us"). The base consists of a tank, 1.8 m long and 40 cm high, parallel to the retaining wall extending to the sides of the frontispiece assembly. This one is formed by blocks of limestone of 50 cm long by 30 cm high. According to old photos, water gushed from the pediment to the tank through a limestone-carved dolphin. However, this piece is lost, leaving only the nearest part of the wall.

What remains of the dolphin sculpture is surrounded by four narrow columns, about 10 cm wide, forming a lower floor, with two jaws, about half a meter high, at the ends. The narrower upper floor is more adorned, reducing the size of the jaws at the ends and adding small frowns and acanthus that make up two narrow columns. In the center, there is the niche where was located the image of St. Anthony that was lost over time.

Fig. 10. Frontispiece of the Santo Antônio Fountain.

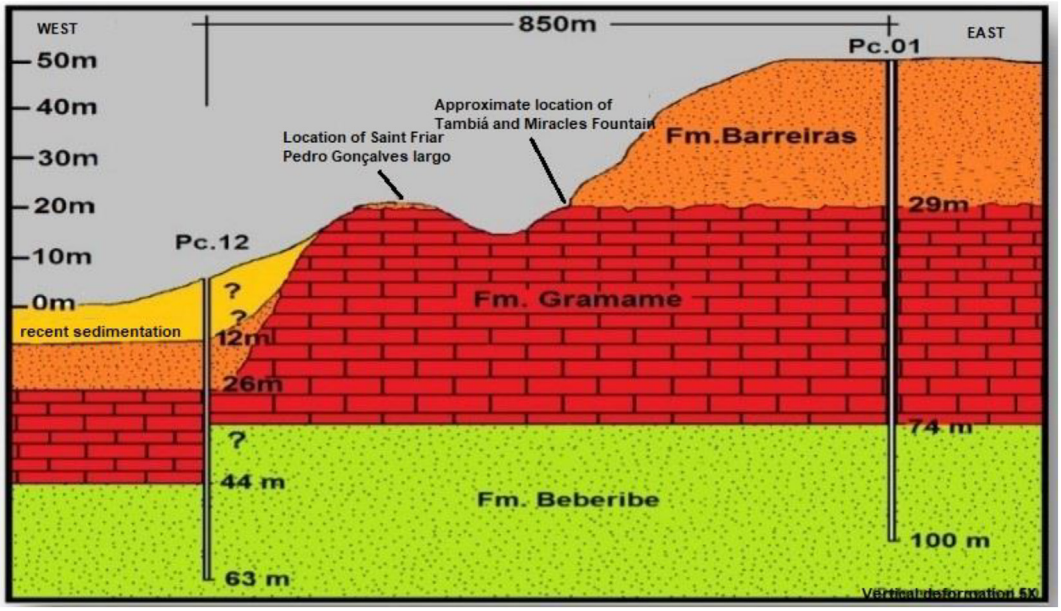

Fig. 11. Profile elaborated from drill core testimonies (Pc.01 and Pc.11) with the location of the Santo Antônio and Miracles Fountains. (Source: Araújo (2012, p. 221).)

From a geomorphological point of view, it is located on the west-facing slopes of the tablelands, at an altitude of about 22 m, in a great depression, sitting directly on the limestone (Fig. 11), which poured abundantly on the Franciscan ground. Thus it can be classified as a 'fountain of geological contact'. According to Araújo (2012), these slopes are complex, with differentiated segment profiles. In the upper and lower portions, the straight profile has a high slope that decreases in the intermediate portion, where the fountain is located, in contact with Barreiras (top) sandstone and Gramame limestone (base). This zone consists of the drainage headland amphitheater, which tends to slow the flow of water and even retain it, forming small streams and ponds.

It was listed, along with the entire São Francisco Complex, by the National Institute of Historical and Architectural Heritage (IPHAN) on October 16, 1952. For its very high aesthetic, scientific, economic and cultural value, the fountain is an important hydrosite representative of the geodiversity of the area.

Site 6: Miracles Fountain

It corresponds to a hydrosite of great importance in the initial period of the formation of the city, being located near the first streets of the upper city, where a large part of the population lived, in Slope do Saint Francis, which connected the upper and lower city, on the terrain of the first vicar of the Mother Church.

Fig. 12. Fountain of Miracles.

The name 'of the Miracles' is related to a local legend, from which comes the name of the Alley. According to Aguiar (1992), it was from this source that, in 1801, the Franciscan Friar Jose de Jesus Maria Lopes would have murdered barbarously, impaled, his mestizo lover Tereza, after luring her to a bath in the moonlight. Considering that there is no 'miracle' in this fact, Araújo (2012) proposed another origin for the name: miraculous medicinal properties of its waters, reported in the "Book that gives reason of the State of Brazil" (Livro, 1968).

In 1849 the facade of the fountain would have been built, according to historical documents cited by Araújo (2012), to improve the distribution of water to the population, without having to resort to the Tambiá Fountain, but which was not very successful due to the small size of its accumulation tank and low water flow. According to Rodriguez (1962), it had two bronze taps and limestone pilasters with capitals topped by a semicircle cornice, with a symbol of imperial weapons on the top, which was removed after the Proclamation of the Republic (1889).

What remains of this fountain, incorporated into a wall without spilling any more water, is the limestone pilasters, the holes where the two taps were, and, in high relief, the indication of the year of construction, all plastered with lime and white ink, which demonstrates the little importance given to the natural and cultural heritage of the city (Fig. 12).

It has the same characteristics as the Santo Antônio Fountain. About 17 m high, located at the contact of Barreiras sandstone and Gramame limestone, it is a 'fountain of geological contact', as well as a 'fountain of fault' as it is located on the slope representing a fault plane (Fig. 11).

It was selected as an important element of local geodiversity for its high scientific value as a representative of the Barreiras aquifer and for being part of the city's supply history. Its name is a classic example of the cultural value of geodiversity in its mythological bias.

Site 7: Sanhauá Fault

It corresponds to a tectonic geosite, whose panoramic viewpoint is located on a small hill, about 15 m high, between the upper city and the old port of Varadouro (Fig. 13).

The square sits directly on the limestone, which rises just below the Hotel Globo's retaining wall on the west side that connects to the port, along the train tracks.

In ancient times, before the conquest and consolidation of the urban network, the Sanhauá River and its tributaries probably sculpted the slope where the limestone outcrops. With the urbanization and subsequent deforestation, exposing the west slope of the tablelands, weathering caused the siltation of the area of the Porto do Capim, in Varadouro, "pushing" the Sanhauá River further west.

The handshake between the indigenous leader Piragibe and João Tavares, representing the Portuguese Crown, which sealed the peace agreement and subsequently provided the foundation of the city of Nossa Senhora das Neves, was on the banks of the river Sanhauá, hence its importance is not only ecological-environmental, but also historical-cultural.

This river is relatively linear, with predominantly SW-NW flow direction and low winding cliffs. According to Araújo (2012), the configuration of the terrain of the Upper and lower historic center is the result of a normal fault that crosses the western sector of the tablelands, with northeast direction. This failure, proposed after studies using a geological map made from SRTM images, drill cores and fieldwork, would dovetail the Marés and Sanhauá rivers, as well as the intermediate portion of the Gramame River as represented in Fig. 14, which justifies the outcropping of the (Maastrichtian) Gramame limestone along these fault lines (point A in Fig. 14, for example). The outcrop of these limestones was responsible for the punctual emergence of a series of springs at a certain level of this slope that served as water supply for the spring Nossa Senhora das Neves, first

Fig. 13. Aerial view of São Frei Pedro Gonçalves square.
(Source: modified from Google Earth (May/2016).)

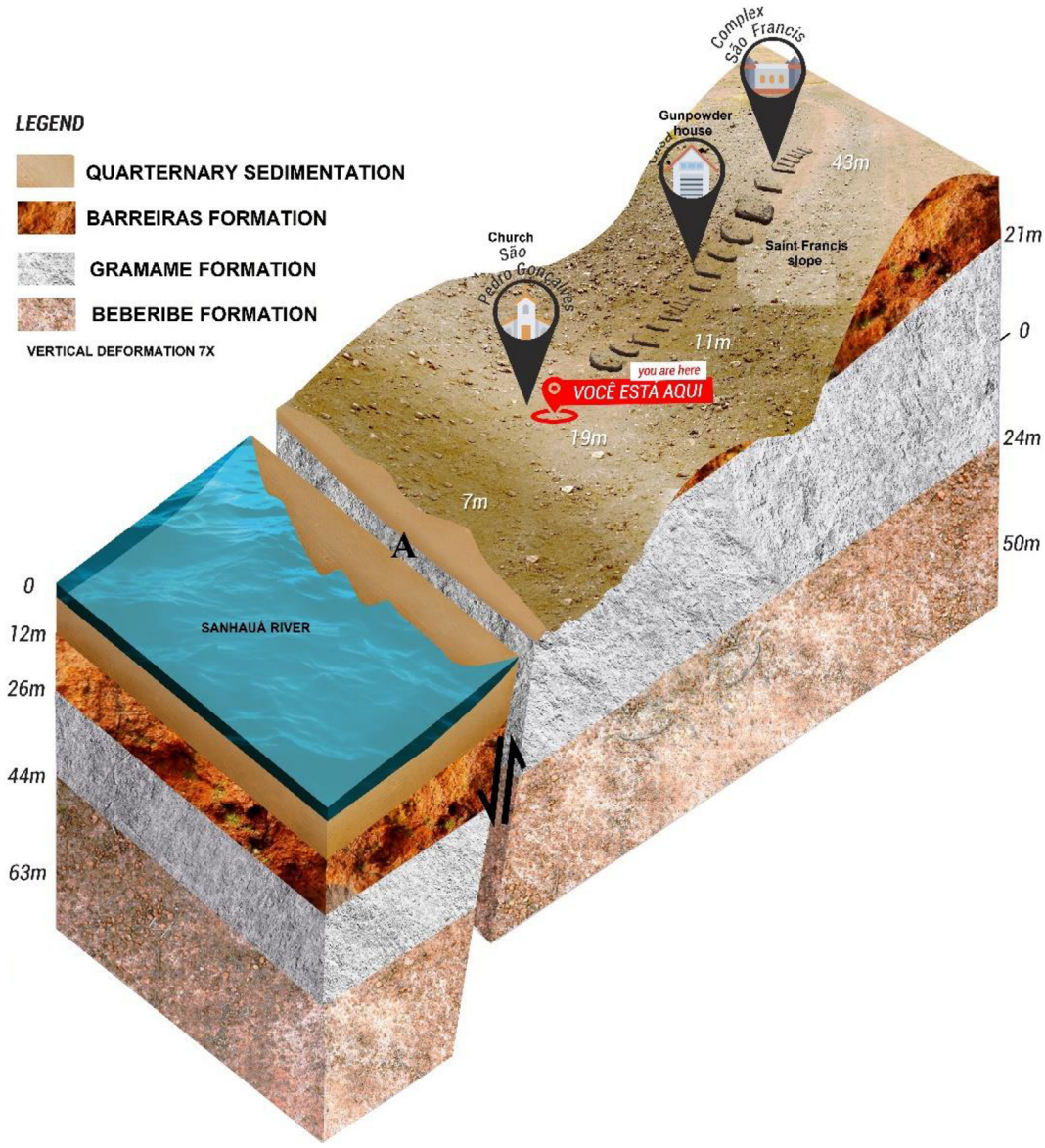

Fig. 14. Representative block diagram of the 'Sanhauá Fault', showing limestone outcrop along the fault plane (point A) and lithostratigraphic units, as well as some elements of Cultural Heritage.
(Source: the author.)

name given to the municipality of João Pessoa, on 08/05/1585. Andrades Filho (2010) studied the Sanhauá sub-basin by remote sensing techniques and suggested that this region was affected by neotectonic faults of Quaternary age.

The exceptional aesthetic and scientific values, coupled with the very high functional value, justify considering the Sanhauá Fault as a representative of the geoheritage of the area due to tectonic bias.

5. Discussions

All elements of geodiversity that are important for the dissemination of geosciences, with particular economic, pedagogical, scientific and cultural interest, among others, that have values that make them unique, configure the geoheritage of a place (Rodrigues & Fonseca, 2008). Especially in urban areas, places of greater demographic density, this geoheritage tends to present traces of a geological and geomorphological history that have an intrinsic relationship with the anthropic environment, becoming the substrate for the consolidation of the site or its georesources be used for the construction of buildings, such as churches, houses, paving the streets, among others.

In the geoheritage of the area, in the form of rocky outcrops, with their minerals, fossils, structures and textures, in the soils, in the bodies of water, as well as in the great landforms or in the cultural heritage of the Historic Center, are inserted information that helps to tell the history of this place, its geodiversity and how the georesources were used, at a given historical time, from a cultural point of view. Thus, the Geosciences, culture and history of the place where this information is inserted are combined.

It is clear that there is an interaction between various elements that play an important role in all urban systems, which are physical, economic, social and cultural elements. The geographical position of the cities was the result of planning, and the strategy of consolidation and expansion of João Pessoa, at the end of the 16th century, was no different.

Factors such as the threat of the French invasion and the need to guard against contact-resistant indigenous settlements marked their position on the top of the hill, overlooking the river plain, and the expansion towards the coast took place later, only in the first mid-twentieth century, when functionality diversified, including as a national tourist destination

The touristic itineraries through the Historic Center, which focus their attention, basically, on the history and architecture of the buildings, forget the cultural landscape and the associated geodiversity elements. Thus, those who visit such places have a visual perception of the incomplete site, dissociated from a geoheritage discussion, since they are often unaware of the geological and geomorphological features that attracted them to the region.

Geotourism is a niche tourism that seeks to rescue for future generations those destinations that are not traditional or give a new look to conventional tourism, as a new product and a new tourism experience. Through the association of geodiversity-geoheritage elements with cultural elements, it seeks to insert them in the tourism context (Arouca Declaration, 2011), which may happen in the 'cultural tourism' of the Historic Center, aimed at disseminating geodiversity and, in particular, its geoheritage, respecting local culture and traditions and striving to increase the quality of visits. This will preserve not only habitats and ecosystems, but also the cultural elements that are embedded in local identity by diversifying and complementing its tourism offer.

The depredation of nature due to the increase in consumption and inadequate economic and social practices forces some sectors of the economy to adapt to conservationist activities, both biotic and abiotic.

João Pessoa has a beautiful landscape, which interlaces these natural elements with a very rich history, whose beginnings are directly linked to this geoheritage, it becomes necessary to link nature, history and culture to tourism, as this is the basis for environmental knowledge, the historical ties between nature and society are strengthened and the local economy is enhanced through an already ingrained practice, inserting new characters that were indirectly part of the system. In addition, sustainability is rooted in geotouristic practices and the participation of a local community aware of this situation can generate an increase in income, whose abiotic heritage will serve as a new tourist attraction, and can boost areas with stagnant economy.

It is of utmost importance to recognize certain elements of geodiversity and geoheritage for the consolidation and urban expansion of João Pessoa, as well as to map the abiotic environment and cultural heritage of the area, in order to add value to the already traditional cultural tourist activity developed in the region.

The inventory, with qualitative assessment, of the sites presented in this paper proposed to disclose the abiotic environment associated to cultural heritage, a trigger for the development of a geoconservationist consciousness and a dynamizer of the local economy, necessary for the role that the abiotic environment has as a record of current and past geoenvironments, influenced by many elements and influencer of many others.

6. Conclusions

Tectonics played a key role in the configuration of the local relief, while exogenous agents, such as marine regressions and transgressions, present and past climates, biological and anthropogenic agents, among others, modeled and formed the beautiful landforms and landscapes. At the moment when human beings value places of interest, these sites have a heritage value, deserving to be safeguarded for future generations, which is one of the principles of geoconservation.

Based on previous studies on the geology and geomorphology of the area and on pre-established criteria such as scientific, cultural, aesthetic, ecological and economic value, a number of sites were identified at various scales. The region is a tourist destination known in Brazil from the point of view of sun and sea tourism.

It is therefore pertinent to interweave this heritage to tourism in the area, so that more motivation arouses the interest of tourists, now turned to the bias of the lithosphere and hydrosphere. It can be concluded that the Historical Center of João Pessoa, located in Mata da Aldeia Chart, have geotouristic potential. This practice still remains incipient, and the inventory of this heritage with the intention of disseminating the geosciences, is necessary and is of crucial importance for urban management and planning.

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