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POTENTIAL GEOMORPHOSITES AS LOCALS OF GEOTOURISTIC INTEREST: CASE OF MUNICIPALITY OF JOÃO PESSOA, PARAÍBA STATE (BRAZILIAN NE)

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Abstract: The objective of this paper is to present a view of the geomorphological heritage of the municipality of João Pessoa, northern Brazil, in order to insert potential geomorphosites in urban geotouristic routes. This city is part of a sedimentary basin that developed on a failed crystalline basement, whose Plio-Pleistocene reactivation resulted in a stepped substrate, and the terrain has urban geotouristic potential from the point of view of its geomorphological heritage. The relief was fragmented into three major morphosculptural units: coastal plains and tablelands, limited by the slopes, all with their potential geomorphosites, developed at various scales and presented here in.

Keywords: Geomorphological Heritage, Potential Geomorphosites, Locals of Geotouristic Interest, João Pessoa, Urban Geotourism.

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INTRODUCTION

Valuing natural diversity has been commonly and more evidently accepted in Biology, where concerns about the extinction of species and habitat loss have led scientists, public administrators, NGOs and others to conduct conferences and environmental policy agreements. In this light, the municipality of Joao Pessoa, capital of Paraiba state, stands out with a unique natural biotic heritage, like one of the largest tropical forests in the planet's urban area with 535 ha, the Botanical Gardens Benjamin Maranhão, known as 'Mata do Buraquinho'. However, its abiotic heritage, as support of biodiversity, has been relegated to the background, especially taking into account the bias of conservation or, in this case, geoconservation and even geotourism. The municipality of João Pessoa has an extremely interesting geodiversity, interlacing river elements, marine and fluvio-marine elements as well, seated on a sedimentary basin, considering, as part of this work, its geomorphological aspects, namely its landforms and deposits at different scales. Thus, when the human perception values a set of landforms (and correlative deposits), or geomorphosites, with scientific, ecological, economic, cultural or aesthetic interest, have the definition of geomorphological heritage (Panizza & Piacente, 1993; Panizza, 2001; Reynard, 2005; Reynard & Panizza, 2005) which, by its meaning, deserves

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to be studied, preserved and valued. It should be noted that in this work, geomorphological heritage was dissociated from the geological heritage, we consider complementary concepts but distinct both belonging to the abiotic Natural Heritage.

Furthermore, the identification, classification, evaluation, mapping, protection and promotion (Panizza, 2001; 2003; Pereira et al., 2007) of this type of heritage adds an asset for tourism activities in the scope of geotourism, through interaction between cultural and natural aspects of the landscape (Panizza & Piacente, 2003, Rodrigues et al., 2011). The goal of this paper is to present a vision of geomorphological heritage of João Pessoa, northestearn Brazil, in order to insert potential geomorphosites in geotouristic routes. The production of this information, brought to a wide range of researchers, scientists, students, tourists, among others, is important for the construction of an urban culture that is able to understand that the city we live in is a much more complex piece than that of our ancestors, and that the geomorphological heritage have an important role in consolidating this achievement, serving as a builder element of the dialectical relationship between natural history and human history of the municipality of João Pessoa.

METHODOLOGY

The proposed work involves seven sequential stages. They are:

1. Bibliographical Reference: at this stage, any scientific studies involving history, geomorphology and geology, including tectonics, of the municipality of João Pessoa will be analyzed, to increase the knowledge involving the genesis of the landscape, as well as the understanding of cultural and functional value of geodiversity, when related to the setting and urban development of the municipality;

2. Field Work: to recognize up to potential sites of geomorphological interest in the field, in order to identify geotouristic use values, which will help in the selection of those to be inserted in later stages of the project. To this end, topographic maps were used, such as João Pessoa chart, scale 1: 100.000 and the Joao Pessoa chart SB.25-YC-III-1-NE, scale 1: 25.000, as well as aerial photographs, scale 1: 8000 and satellite images, as images of the sensor ASTER/ TERRA, VNIR bands, spatial resolution 15m;

3. Inventory: a database is created with potential geomorphosites that have geotouristic use value, due to its logistic facilities, scenic beauty, cultural value, among others, by filling out assessment files that include the absolute and relative location, photography, access ways, description of the physical characteristics, etc., based partially in Rodrigues (2009), considering the analyzed scale, from the outcrop (meters) to landscape (km; according Carvalho, 1999).

2. Semiquantitative Assessment: in this stage, the potential geomorphosite has to be re-assessed, in order to define the sites of greater or lesser geotouristic interest and, according Pereira & Nogueira (2015).

3. Conservation: at this stage, it analyzes the potential risk, inserted by natural or human activities, in the assessed geomorphological site. So, according to the relevance in this matter, sites that should be preserved, either from contact with humans or the nature of the dynamics of action in the case of certain outcrops, will be preserved, for example, significant elements as fossils or minerals that can be destroyed by erosion. This level of vulnerability and risks of degradation will be assessed of the semiquantitative point of view, through a methodology proposed by Pereira & Nogueira (op. cit.).

4. Regulation: since by knowing the most vulnerable locations of geotouristic interest, this step consists in the insertion of the potential geomorphosite into the current environmental legislation, with the transfer to the government of information about the level of protection that each site requires, aiming geoconservation strategies, since geotouristic activities increase human pressure on the natural environment.

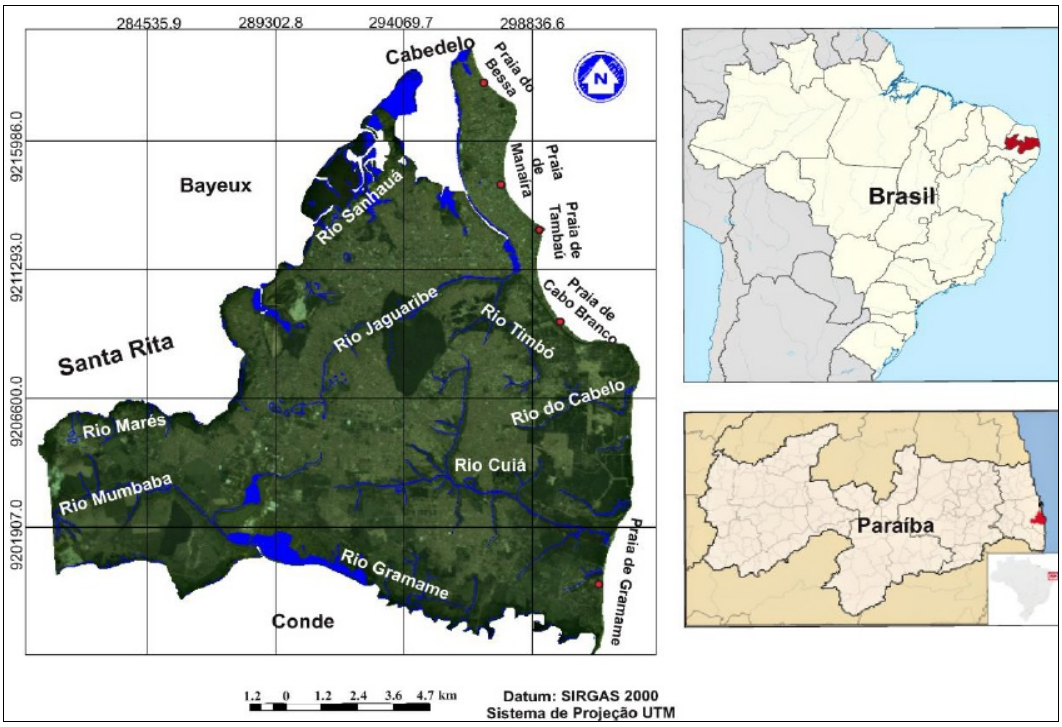

Figure 1. Location of João Pessoa, Paraíba, Brazil NE (Source: Barbosa, 2015)

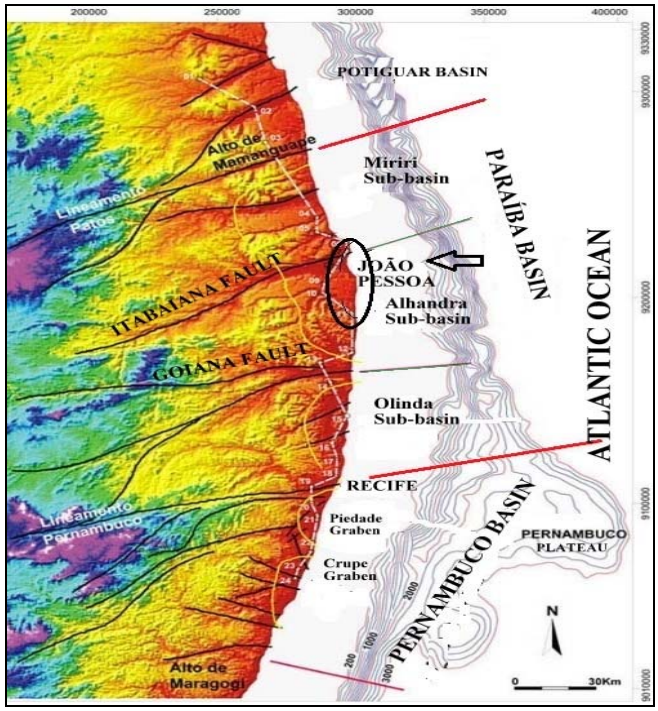

Figure 2. Location Area (circle) of the sedimentary basins of the Northeast
(Source: modified from Barbosa & Lima Filho, 2005)

5. Disclosure: will be done by preparing a Geotouristic Guide of João Pessoa, which will enable to propose guided geotrails. Furthermore, it proposes the development of panels in those places of greatest geotouristic value, concerning its formation and carachteristics, richly illustrated. Thus, the sites will be valued and exposed, as well as the local geodiversity and, indirectly, the geosciences.

This project is part of a geoheritage mapping to be developed in the long term, culminating with the publication of the Geotouristic Guide. Thus, it is presented in a stage, in which the sites are being identified by their culture, ecologic, scientific and, mainly aesthetic values, and inventoried to future geoutouristic use.

Geological and geomorphological context of the area

The municipality of João Pessoa is located in the topographic chart of João Pessoa plane (SB-25-YC-3), scale 1: 100,000 (Figure 1), elaborated by the Army Ministry. The geology of the research area is associated with 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 shear zones (Jardim de Sá, 1994). This basin can be subdivided into three sub-basins (Figure 2): Olinda, Alhandra and Miriri sub-basins. The study area is part of the Alhandra sub-basin, border to the north by Itabaiana fault and to the south by Goiana fault.

The sedimentary deposit events of the Paraíba Basin are dated from the late Turonian, when the the lands both to the North and to the South of the Pernambuco Shear Zone were reactivated (Petri, 1987), as the South American continent moved away from Africa, starting the land subsidence of the Paraíba Basin, later regarding the basins to the north and to the south, Potiguar and Pernambuco, respectively, wich have already demonstrated sedimentary deposits from the Barremian/ Aptian (Petri, 1987; Barbosa & Lima Filho, 2006). In this period (between the Coniacian and lower Campanian), the basin's sedimentation has begun (Barbosa et al., 2003), even in continental conditions, depositing sandstones and conglomerates of Beberibe Formation, 360 m- thick (Barbosa et al., 2003), representative of a high-energy river environment (Barbosa & Lima Filho, 2006), resting unconformably on the bottom. This includes the Alto Moxotó Terrain, composed of granodioritic and granithic orthogneiss and metamorphosed volcanic rocks on amphibolite facies (biotite schist, biotite-gneisses and graywackes) of the Paleoproterozoic age (Brito Neves et al., 2004). The Paraíba Basin resisted the rifting process until the Late Cretaceous (Mabesoone & Alheiros, 1988), being the last link with Africa.

With this subsidence, forming a gentle slope inclined to the east-type homocline (Asmus, 1975) and subsequent disruption of the link between South America and Africa, the terrain begins to be invaded by the sea, gradually depositing marine carbonate sediments from the Itamaracá Formation, 70 m thick, dating from the Upper Campanian, indicative of a transgressive stage that will continue throughout the Maastrichtian, under hot and dry climatic conditions (Petri, 1987). The maximum drowning of the basin, whose marine waters hamper the deposition of clastic to its interior, is represented by a phosphatic level dating from the Campanian (Lima Filho & Souza, 2001), which limits the Itamaracá Formation of the posterior formation, 70 m-thick, representative of a tract of high sea already with calm and shallow water, whose carbonate deposition is represented by several facies of the limestone from the Gramame Formation, occurring initially in the Upper Campanian (Tinoco, 1971; Lima et al., 2006), and extending around all Maastrichtian. In João Pessoa, this formation outcrops on the Ilha do Bispo, on the right margin of the Sanhauá River, being exploited by a cement industry for almost 100 years. At the end of Maastrichtian, the ocean floor expands, starting a regressive marine event, meaning the marine platform begins to be exposed and weathered (Barbosa et al., 2003). During the Paleocene, this regressive stage is

characterized by highly fossilized carbonate deposition from the Maria Farinha Formation, representing a low and open marine environment (Tinoco, 1971; Cordoba et al., 2007; Barbosa et al., 2003) in more humid climatic condition (Petri, 1987). This formation outcrops abundantly in the form of dolomitic limestones on the southern coast of the area, especially in the municipality of Conde.

The Barreiras Formation, from the upper-Plio-Pleistocenic age, is considered a plataform coverage of the Paraíba Basin, which sediments are the result of weathering from the outcropping crystalline shield in Borborema Plateau (Gopinath et al., 1993), distant about 30 km from the coast and were deposited in a braided river environment (represented by gravel and coarse to fine sand) on alluvial fans (intercalated conglomerates intercalated a thinner silty-claye layer, according Alheiros et al., 1988), under an arid climate. Its average thickness is 40 m, reaching 80 m (Leal E Sá, 1998).

Above the Barreiras Formation were deposited quaternary sediments, representative of a marine/ transitional environment (Pleistocene and Holocene marine terraces, rocky and algalic-coralineous reefs, mangroves and beach sands named 'beachrocks') and of a continental environment (colluvial deposits, cones of dejection , inactive dunes and alluvial deposits), through new spaces created by faults reactivated in the Neogene and Quaternary ages (Bezerra & Vita-Finzi, 2000; Rossetti et al., 2008, among others). 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 et al., 2001), as it will be seen below. The study area belongs to the geomorphologic unit of Plains and Coastal Tablelands, according to Ross (1985), having direct relation with ancient tectonic movements, generated during the drift of the South American and African plates (Asmus, 1975), added to Cenozoic tectonic events (Bezerra et al., 2001; Bezerra & Vita Finzi, 2000, among others).

We can identify three subunits to the urban site of João Pessoa and the south coast: the coastal plain, low coastal upland ('Coastal Tablelands') and floodplains, which can be still subdivided into fluvial and fluvial-marine floodplains (Rodriguez, 2002). The top of the tablelands is linked to the plains in relatively steep slopes, in form of cleefs, with great scenic beauty, in the shore. The coastal lowlands are in direct contact with the sea, have altitudes between 0 and 10 m, which quaternary sedimentation of river, marine and rivermarine origin filled the coastal plain, resulting in numerous geomorphological features that can be considered potential geomorphosite for its scenic beauty and / or relevant geological/ geomorphological history.

On the margin of the Rio Paraiba, floodplains occur on higher altitudes, whose presence of mangroves, away up to 12 Km of the coastline denote its ecological importance. In the northern portion of the study area, the sandbank of Cabedelo ('Restinga de Cabedelo') separates the Paraíba River from the Atlantic Ocean. The low coastal uplands, also known as 'Coastal Tablelands', correspond to a higher, gently sloping portion of the land, with flat top, generally inclined to the east, result from the action of exogenous agents that carved the Barreiras Formation, including marine abrasion on cliffs, another outcrop form of this formation on the coast, at its eastern portion. Most of the urban site of João Pessoa sits on this geomorphological unit.

According Brito Neves et al., (2004), these low coastal uplands were results of large arching and a succession of steeped pediplains to inland, subordinated to paleoclimate, whose graben- horst type structure controlled its morphology. Reactivation of basement shear zones with E- W ansd NE- SW direction, from the Early Cretaceous (Nóbrega et al., 2005), reach the sediments of the Barreiras Formation, forming fault scarps that are capped by alluvial terraces, sandstone dunes, debris slopes, soil and vegetation, and which serve as

bounds of the river valleys, while the upraised portions were dissected (Lima et al.,1990). Thus, the altimetric quotes of the urban compartment of tablelands show uplifted portions (west, whose elevations reach 70 m) and lowered portions (between Mumbaba River and Sanhauá River, a tributary of the Rio Paraiba, where altitudes do not exceed 40 m), rising again (in the upper course of the Rio Cuiá), decreasing toward the east, and denoting the structural behavior of the graben-horst type, bounded by normal faults (Bezerra et al., 2001). The substrate of municipality is represented by a Graben, called Gráben da Grande João Pessoa, according Brito Neves et al., (2004, 2009), whose sediments reach 300 m thick, when they reach the basement (Figure 3).

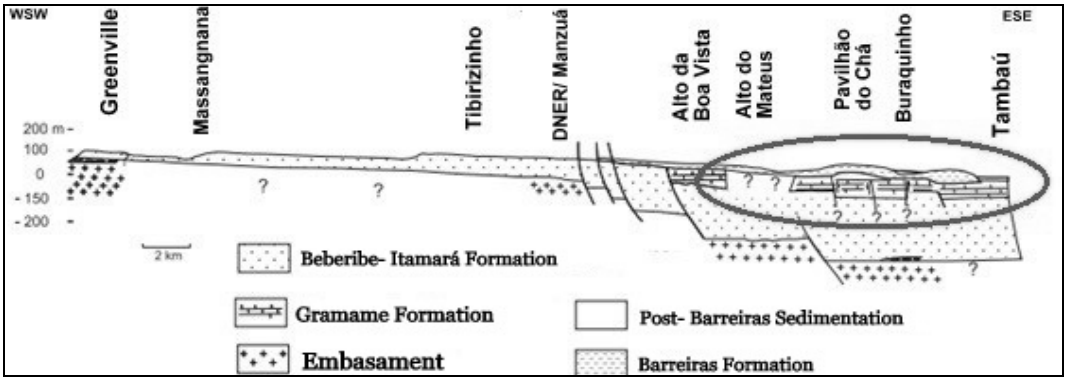

Figure 3. ESE- WSW profile showing the behavior of basement, forming the Graben of Grande João Pessoa, on east and their overlapping sediments, drawn from dozens of pit datas, with the delimitation of João Pessoa area in circle area (Source: modified from Brito Neves et al., 2009)

Away from the urban area grew the sugar production in the presence of fertile black clay soil, named 'massapê', extending away dozens of miles from shoreline. The limit of the coastal plain can be viewed along the San José Comunity, a district with serious infrastructural problems, which sat at the feet of a dead Cliff, tangent the lower course of the Rio Jaguaribe and through a wide range of inactive cliffs, further south where, on the other hand, the Altiplano District formed, with a concentration of high-income population (Figure 4). In this figure, the Lagoa dos Irerês, a doline near the historical center of the city, represents the exhumation of the Barreiras Formation sediments and the outcrop of the juxtaposed limestone; in the lower portion, the Cabo Branco Lighthouse and Ponta do Seixas, representing the eastern tip of the Americas and to the northwest, the mangroves of the Paraíba River and its tributaries; in the western sector, Intercement's quarry, that exploits the limestone of Gramame Formation for decades; in the central inferior portion, the Botanical Garden Benjamin Maranhão, known as Mata do Buraquinho, one of the biggest urban forests in the world, with 535 ha of Atlantic Rainforest biota; in the higher portion, the Holocene terraces that originated the Restinga- sandbank- of Cabedelo. In the marine portion, algalic-coralineous reefs that originated Picãozinho, known point of tourist attraction of the capital.

Geomorphological sites of geotouristic use interest

The geomorphosites of geoturistic use interest proposed here, as referenced above, are the result of a thorough literature that deals with the issue not only in the municipality of João Pessoa, but in the Paraiba Basin as a whole. These geomorphosites are inserted in one of three morphosculptural compartments, named coastal plains, flood plains and low coastal uplands, besides the slopes that limit the low plains of the coastal plains, and can be seen in Figure 5.

Figure 4. Satellite photo showing some geomorphological, geological and biotic elements of the coast of João Pessoa: the contact of the coastal plain (delimited with the dashed black line) with the coastal tablelands, bounded by a range of dead- or inactive- cliffs (dashed red line) and the Rio Jaguaribe (Source: modified from Google Earth)

Figura 5. Orbital image of the municipality of João Pessoa, circumcised in the red line, with the location of potential geomorphosites of geotouristic interest (Source: modified from Google Earth)

1) Coastal Plain (PC):

* Restinga of Cabedelo (PC01, in Figure 5): coastal landform representing the extreme northeast of the study area of the Holocene marine terraces that extend

throughout the Paraiba coast. Corresponds to a sandbank, parallel to the coastline, which separates the sea to the east from the Paraiba River in the west. These sand deposits, with no more than four meters above the current high tide, were formed during the marine regression subsequent to the Last Trans-gression. In the portion exposed to the effect of waves and tides is given the name of the 'beach', with variable width in the Paraíba coastline. The Holocene terraces, with average variable widths between 0.5 and 1 Km, and may or may not have crests of coastal ridges on the surface, depending on the level of urban occupation, being more extensive and continuous that the Pleistocene ones, that outcrop on the south coast, out of this research area.

The Holocene terraces are represented by unconsolidated quartz sands, light-colored, medium to coarse grain and medium selected (Alheiros et al., 1990), with parallel- plan stratification. In the C-14 dating method, which occurred in lagoon sediments on the northern coast of Sergipe state, resulted in 7.2 ± 200 ka years BP age (Bittencourt et al., 1983), while shells included in these terraces resulted, in Alagoas coast, resulted in ages between 2.57 ± 170 ka years BP and 3.69 ± 180 ka years BP (Barbosa et al., 1986).

* Headland bay beaches of Tambaú/ Cabo Branco and Manaíra/ Cabo (PC02, in Figure 5): coastal landform with arc-shaped, in which sandy spit, that separates the Tambaú- Cabo Branco Beach from Manaíra Beach was built the Hotel Tambaú, in 1971, who has served as a gigantic jetty, depositing beachy sediments from landshore drifting in the southern portion and facilitating erosion in the northern portion. In the field work was conducted beach profiles along the area, concluding that the Tambau- Cabo Branco beach not recorded evidence of coastal erosion, with a relatively wide beach and backshore, the latter covered by berm vegetation. On the beach of Manaíra, this backshore is narrow, and at high tide the waves undermine the wall that separates the beach from the boardwalk, near the Hotel Tambaú.

* Marine abrasion on the Beach of Bessa (PC03, in Figure 5): with double headland bay shape, separated by a sandy cusp, the Beach of Bessa is a northern continuation of Beach of Manaíra, whose limit is the beginning of 'Restinga of Cabedelo'. In this cusp, there is an intense marine erosion that caused the demolition of several residences located there. It is the last north urban beach of João Pessoa, whose boundary with the municipality of Cabedelo corresponds to a 'maceió', regional name given to small lagoons that have become isolated by sand bars deposited by marine action. This 'maceió' corresponds to the former mouth of the Jaguaribe River, that in the 1940s, was deviated towards the Rio Mandacarú. From this deviation, about 4 km lenght, remains a channel passing under and next to the shopping district of the Bessa, represented by Shopping Manaíra, Hiperbompreço and Carrefour, channel that plays a key role to drain the Bessa neighborhood and serves like natural border between the municipalities of João Pessoa and Cabedelo.

* Stone blocks at the foot of the cliff (PC04, in Figure 5): at the foot of the active beach cliffs of Jacarapé occurs blocks of rock from 'rock falls'. This fall is a result of chemical weathering along the weak zones of the cliffs, associated with the marine undermining at its base, which ultimately break down huge portions of boulders, which are deposited by gravity at the foot of the cliffs, forming talus deposits talus.

* Ponta do Seixas (PC05, in Figure 5): located at the Beach of Seixas, corresponds to a sandy cord, with metric dimensions, which is the easternmost point of the Americas, that is, the point at Brazil closer to Africa, which gave it a tourist value of undeniable importance (Figure 6).

* Cones of dejection (PC06, in Figure 5): synonymous of 'alluvial fans', they are at the foot of the inactive cliffs at the Beach of Gramame, being predominantly sandy to

conglomeratic, poorly selected, and they are witnessing a period of drought. They have altitudes between 10 and 20 m, with the slightly sloped surface to the coastal plain. Bittencourt et al., (1983, p. 95) suggests that these deposits have been previously deposited the Penultimate Transgression, since the Pleistocene marine terraces on the south coast of the state and outside the area of this project, lean on these deposits and were the last to suffer erosion at the refered transgressive event.

* Reefs: it appears as algalicos- coralinous and rocky reefs, can be seen in Figure 4. The algalic- coralinous reefs, along the city's coast, present elongated and discontinuous shapes, parallel to the coastline, and can reach to 4 Km. The elongated bodies have tens of meters wide while the irregular can reach hundreds of meters. The main example of this kind of deposit is Picãozinho (PC07, in Figure 5), visited daily by hundreds of tourists. They settled and grew on banks of submerged sandstones (Laborel, 1969). The rocky reefs, named 'beach rocks', outcrop along the coast, in front of the Restinga of Cabedelo (PC08, in Figure 5), sometimes directly on the beach, forming continuously or not linear features, for up to several kilometers, commonly parallel to the coast. Normally submerged, may outcrop at low tide or, keeps emerged the average sea level, when has larger proportions.

2) Flood plains (FP):

* Basin of Paraíba River- lower course (FP01, in Figure 5): Paraiba River, also known as North Paraíba River, is the main river of the homonymous basin and the longest river totally located in Paraíba State. It is the second largest basin of Paraiba State, lower than the Piranhas River Basin, being composed by the sub-basin of the Rio Taperoá and geographically subdivided into Upper, Middle and Lower Course[1]. It is your lower course which bathes the municipality of João Pessoa, inserted in the area of this article. Thus, by also bathe the municipality of Campina Grande, the second most populous city in the state, this basin has the highest population density of the state, entering more than half the population of Paraiba.

As it approaches its mouth, the Paraiba River widens, forming an estuarine complex with a valley bottom that gives rise to fluviomarine plain of the Paraiba River, with its river terraces and extending up to 12 km river inside, filled by a dense network of anastomosing drainage that flows into the river. This accumulation of sediment, especially fine one, plus the action of periodic tidal, formed a large mangrove ecosystem, reaching almost most of the tributaries of the river Paraíba. Moreover, the high population density in its estuary is generating a mischaracterization of your landscape by human occupation and the works necessary for their attachment, the shrimp farming and emission of daily tons of pollution in its waters and mangroves, whose contamination can become irreversible.

The linearity of the Paraiba River, along its upper and middle course mainly, allows us to infer that its evolution is indicative of structural expression, where it valley is embedded in Itabaiana Fault, which crosses the municipality of João Pessoa, in a SW- NE direction. However, when approaching the shore, the channel suffers a sharp inflection to north, when it reaches the Atlantic Ocean. Whereas there is no lithological variation to justify this deviation, it may be related to the valley groove in a normal type faulting, corrobored by the abundant outcrops of limestones from the Gramame Formation, especially those faced to the Paraíba River. The east land portion of this fault plane uplifted, which is located the upper town's João Pessoa historic downtown.

* Sub-basin of Jaguaribe River (FP02, in Figure 5): Jaguaribe River is the main river inserted in the urban area of the city of João Pessoa. Its springs located in the southern portion of the municipality, near the Conjunto Esplanada district, in a lake currently

[1] AESA. Comitê Rio Paraíba. Extracted from http://www.aesa.pb.gov.br/comites/paraiba/ Acess at 15 feb 2015

grounded, associated with a set of ponds with Karst origin called Açude das Três Lagoas de Oitizieiro (TL03), at an altitude of about 22 m. Its initial length was 21 kilometers to disembogue into the Atlantic Ocean. However, in the 1940s, promoted by former DNOS (National Department of Sanitation Works), it was diverted, as mentioned earlier, near of where is currently the Shopping Manaíra, eventually disemboguing into the Mandacarú River (Christiano, 2007), like referred before. It bathes 25 districts, having like the main tributary of the right margin, the Timbo River and the left margin, the Riacho dos Macacos, and practically disappeared with the real estate expansion of Torre and Jaguaribe districts, as well resurgences in its upper course and the dam in the Mata do Buraquinho (PAC, 2007). Both the Jaguaribe River and the Timbo River exhume the Barreiras Formation sediments, which in the urban area of Joao Pessoa are slightly inclined. In the upper course, Jaguaribe River carves the tablelands deeply, generating large amphitheaters, though, in general, tablelands are relatively soft and low slopes in urban area of João Pessoa (Furrier, 2007). Upon reaching the line of retreated inactive cliffs, it sharply deflects to the north (Figure 5), tangential to the inactive cliff Joao Agripino district.

At this point, probably, was the mouth of the river, before the deposition of holocene sedimentation that formed the marine terrace, aged approximately between 3 and 7 Ka years BP (FP03, in Figure 5). This typological difference between the sandstone barriers and beachy sediments, combined with the low slope in the newly formed coastal plain is the justification for the deviation that occurs, so the river breaks through inactive cliffs line.

3) Tablelands (TL)

* Inactive dunes of Altiplane District (TL01, in Figure 5): the aeolian deposits extend over the entire Paraíba basin in the form of mobile (active) dunes and fixed (inactive) dunes, being important paleogeographic and paleoclimatic Quaternary indicators. The supply of sediment from the dunes, which contributes to extending or shortening the beach range, makes important the activity of this dune sediment budget. The mobile dunes are more recent, overlapping the sediment of the Holocene marine terraces, so have later ages to 5.1 ka years BP. The fixed ones, also called paleodunes, can be internal or external dunes, are covered by vegetation that prevent their progradation.

The inner dunes, older, are found on the tablelands of the Barreiras Formation, and were formed by sediments of own coastal plain, while the outer dunes are on the Pleistocene marine terraces (Bittencourt et al., 1983; Furrier, 2007), occurring in Jacarapé Beach (PC05, in Figure 5). Much of the vegetation covering the dunes inactive in João Pessoa were removen for further urbanization, as is the case with the proposed site of geomorphological interest area in the Altiplano District, where lives a population of high income. On the north coast of the Paraiba State, Barreto et al., (2002) dated sediment samples collected in inactive dunes at different levels of depth, resulting in ages between 27.2 ka years BP, for the most shallow (1.8 m) to 61.6 ka years BP to the deeper ones (3.8 m). The authors suggest, considering the height of the dunes around 30 meters, that the eustatic level was much lower than the current when the dunes were fixed.

* Karstic features: in various portions of the study area, karst landforms are present, being most common the dissolution features, such as sinkholes and karren. The latter outcrops on the western side of the tablelands, associated with the slopes, therefore will be described in another morphoscultural compartiment. Regarding the sinkholes, based on aerial photographs analysis and planaltimetrics charts, we can identify various portions of the city of João Pessoa who own the land subsidence by dissolving limestone of Gramame Formation, along fault planes that serve as a conduit for percolation of surface water, such as the Dolina of Irerês (TL02), renamed to Solon de Lucena Park, in the city's Historical Center and Açude das Três Lagoas do Oitizeiro (TL03), with the depression of Barreiras sediments and subsequent occupation of the latter by the low income population and, as a

topographically depressed area, is susceptible to flooding in heavy rains seasons. Furrier & Vital (2011), through field and office work, with SRTM radar images, produced a Digital Model of Terrain of Cruz das Armas district, confirming the existence of a closed and circular depression, soft feature on local, a landscape like sinkhole (TL04, in Figure 5).

* CIMPOR quarry (TL05, in Figure 5): since 1933, the limestone of Gramame Formation has been exploited for a cement factory at Ilha do Bispo, where today a huge scar marks the ground in the form of a quarry, located in an drain bedside amphitheater that exhumed the sediments of Barreiras Formation. This quarry, which partly formed a pond, has cultural importance because in its limits would be the place where settled at the time the city was founded, the village of the Indian Piragibe and later was erected the Engenho da Graça Chapel, in the late seventeenth or eighteenth century probably, currently only remnants. In the nineteenth century, the place was transformed into a farm, and new elements were built as a large house and slave quarters, currently ruined as well. The entire collection was listed by IPHAN (Heritage Institute) in 1938.

* Cave of Onça (TL06, in Figure 5): the cave is a form of pseudokarstic relief, which probably was originated by percolation of water into the subsurface in the bedding planes of the Barreiras Formation sediments. The sediments representing the tablelands representing interfluves and slopes of the Mumbaba river valley and Mussuré river valley and its tributaries. The water weathers and transports the sediments to form galleries along the stratification layers. In the area, the temporary runoff became underground one after the formation of a sink due to good porosity of the rock, associated with greater resistance sandy-loamy soil, at the bottom, hardened by a cementation process, called fragipan by the soil scientists, of which has formed fractures by plants.

The flow was responsible for the formation of an underground valley on the surface, temporarily flooded in the rainy winter, through which flows the water to rise in surface as waterfall, with a height of 18 meters. It has a wide entrance with 9 meters square, whose interior, with 302 meters long, is divided into several small galleries, some with less than a meter high, whose roof has openings ranging from a few centimeters to several meters, enabling serve as entrance to a human. The presence of blocks inside the cave configures its situation of instability, with the possible rupture of the walls and the ceiling collapse. The existence of lateral cavities further worsens the situation, consequence of the collapse and expansion of fractures.

4) Slopes (S)

* Upper/ Lower Downtown (S01): according Araújo (2012), this setting of the historic center ground is the result of a normal fault that crosses the western sector of tablelands, with northeastern direction, as previously reported. This faulting, proposed after studies using a geological map prepared from SRTM images and field work, embbebed the lower course of the Paraíba river and, further south, its tributary Marés river and Sanhauá river, as the intermediate portion of the Gramame river. The karren outcrops on the western side of the tableland along this fault plane, which are faced the plain of Sanhauá river. The outcrop of these limestones of Gramame Formation was responsible for the punctual appearence of a number of exsurgencies at a certain level this slope who served as sources of supply for the population of nascent Nossa Senhora das Neves, the first name given to the municipality Joao Pessoa, the date of its inauguration (August 5, 1585).

* Cleefs: as already mentioned, the cliffs are landforms that represent the face of the horst ending abruptly towards the sea, which may or may not have contact with the ocean, and are bordering of tablelands with the coastal plain. A line of inactive cliffs, with colluvium deposits at the base, are good examples of geomorphosites as they represent the paleogeography of the area with regard to the former coastline position in past times (Figure 4 and s02, in Figure 5).

The most famous active cleef is the 'Cabo Branco Cliff' (S03, in Figure 5), about 40 meters high, with its lighthouse demarcation of 'most eastern point of the Americas' (Figure 6). In fact, besides a beautiful view of the city from the belvedere in the top of this cliff, we can see the Ponta do Seixas, a sandy strand entering the ocean in Praia do Seixas, south of the cliff, which is, rather the extreme easterly point. Recently, in 2008, a Science Station was built, near the Cabo Branco lighthouse, a center for science, culture and arts. The design, signed by renowned architect Oscar Niemeyer, was a reason for intense controversy for environmental problems, due to the proximity of the cliff, which suffers constant marine abrasion. In the beginning of 2015, the cliff collapsed.

Figure 6. Aerial view of Cabo Branco Lighthouse Area, with Ponta do Seixas in the background and the Science Station in the foreground (Source: Felipe Gesteira)

At the foot of Cabo Branco cliff, as occurs intense process of coastal erosion, there is the presence of a darker material and a few blocks of the same color detached meters ahead of the cliff, showing the distance the same retreated. Furrier (2007) explains that it is very common in this area, the precipitation of iron and aluminum oxy-hydroxide in the sediments of the Barreiras Formation, commonly observed on the cliffs. These concentrations form hard ferricretes levels (concretions of iron) at various levels and, especially, at the base thereof. The ferricretes, because they have greater resistance to erosion, in some cases, form marine terraces of abrasion and rocky banks, witness to the erosive retreat of the cliffs by wave action.

Many of these sites are currently affected by various tour packages, but without a connection, systematization or even an interpretation that properly explores its geoheritage importance. For example, every day, dozens of buggies, depart for the south coast taking eager tourists for landscape appreciation, but at the return ride, eight hours later, with the full mind and camera of gorgeous images, they do not have the scientific understanding on how this landscape connects to the Earth's formation.

With this, one realizes the importance of mapping the sites of the area that, when inserted into a geotouristic guide designed to be covered in one or two days- a weekend, for example, result in the disclosure of this basin's geodiversity and geosciences as a whole, adding value to tourism, generating direct and indirect jobs, boosting the economy and promoting other positive consequences, without forgetting that, in the end, the sites' geoconservation must be the main focus.

CONCLUSION

The relief forms the northeastern coast are the result of the action of endogenous and exogenous agents who acted together but with different proportions. The tectonic and especially the neotectonics played a key role in the coastal relief configuration, while the exogenous agents, such as regressions and sea transgressions, wind, current and past climates, rivers, biological and anthropogenic agents, etc., shaped and formed the beautiful existing forms of relief. By the time the human being evaluates geomorphosites of geotouristic use interest, these sites now have heritage value and deserves to be safeguarded for future generations, which is one of the principles of geoconservation.

From previous studies about the history, geomorphology and geology of the area and pre-established criteria, such as scientific, educational, aesthetic values, among others, and especially tourism value, a number of geomorphosites were identified at various scales, inserted into morphosculptural units of land. This work aimed a disclosure of this geomorphological heritage, which will be subsequently added other geoheritage elements, such as geological, hydrological and pedological, besides the Cultural Heritage of Historical Center, with regard to geomaterials that built, in order to insert them in urban geotouristic routes. João Pessoa is a known tourist destination in Brazil, from the sun and sea tourism's point of view. It is pertinent, therefore, interlacing this abiotic heritage to tourism in João Pessoa, to awake another motivation to the interest of tourists.

Thus, if the role of geotourism is promoting geodiversity and its geoheritage through the geomorphosites, the implementation of projects it is necessary for scientific, educational and interpretive purposes to promote tourism in the area. The alliance between public-private partners is necessary in order to minimize conflicts, solve problems and capacitate the processes that enable the insertion of geotouristic activity in the study area and the popularization of the term. Although not the scope of this project, to its effectiveness is maximized, it is suggested the fulfillment of certain conditions, the State responsibility and / or academia, through a collaborative alliance that results in consensual agreements on common goals that legitimizes policy decisions.

We conclude that the municipality has geomorphological heritage potential, and the following phases of the project will enable the development of a urban geotouristic map of João Pessoa. The development of urban tourism in João Pessoa is a dynamic way to publicize this geoheritage to a maximum number of people, whether tourists or not, for its geoconservation. This practice still keeps incipient, and the inventory this heritage, first step in a long process, with the intention to disclose the geosciences, it is necessary and it is important to the management and urban planning.

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