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ECONOMIC POTENTIAL OF THE GOIANA CITY-PE: SANDY DEPOSITS EXAMPLE FOR CIVIL CONSTRUCTION

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Abstract

The Goiana City is located at the northern end of the Pernambuco coast, directly bordering the state of Paraíba. It is located to the north of the Pernambuco principal city (Recife) and inserted in the geological context of the Paraíba Basin where sedimentary coverings predominate from the Upper Cretaceous to the recent age. The Barreiras Formation covers a considerable portion of the city. This unit is related to the existence of alluvial fans and fluvial systems that possibly were graded to deltaic systems and, they present a facies variation from clay to conglomerates. The action of weathering and associated leaching on the sandy-clay layers of this unit led to the occurrence of sandy deposits with a high content of SiO_2 (> 95%) known as "white sands". The thickness of these deposits varies between 0.1 and 3 meters and the grains are well selected and subangular. The predominant particle size fraction is fine to medium according to the standards of the Brazilian Association of Technical Standards (ABNT). Considering all the characteristics of the ore, the deposits quality and composition, the "white sands" are considered to be of good quality for the construction industry, which is why studies and explorations have been intensifying in the region.

Keywords: White Sands, Coastal Boards, Paraíba Basin.

POTENCIAL ECONÔMICO DO MUNICÍPIO DE GOIANA-PE: EXEMPLOS DE DEPÓSITOS ARENOSOS PARA CONSTRUÇÃO CIVIL

Resumo

O município de Goiana está localizado no extremo norte do litoral pernambucano limitando-se diretamente com o estado da Paraíba. Está situado ao norte da capital pernambucana (Recife) e inserido no contexto geológico da Bacia Paraíba onde predominam coberturas sedimentares desde o Cretáceo Superior até o recente. A Formação Barreiras abrange consideravelmente uma porção territorial do município. Esta unidade está relacionada a existência de leques aluviais e sistemas fluviais que possivelmente gradavam para sistemas deltaicos e, apresentam uma variação faciológica desde argilitos até conglomerados. A ação do intemperismo e da lixiviação associada sobre as camadas areno-argilosas dessa unidade originou a ocorrência de depósitos arenosos com alto teor de SiO_2 (> 95%) conhecidos como “areias brancas”. A espessura destes depósitos varia entre 0,1 e 3 metros e os grãos são bem selecionados e subangulosos. A fração granulométrica predominante é fina a média de acordo com os padrões da Associação Brasileira de Normas Técnicas (ABNT). Considerando todos as características do bem mineral, a qualidade e a composição dos depósitos, as “areias brancas” são consideradas de boa qualidade para a indústria de construção, razão pela qual os estudos e as explorações vêm se intensificando na região.

Palavras-chave: Areias Brancas, Tabuleiros Costeiros, Bacia Paraíba.

POTENCIAL ECONÓMICO DE LA CIUDAD DE GOIANA-PE: EJEMPLO DE DEPÓSITOS ARENOSOS PARA CONSTRUCCIÓN CIVIL

Resumen

El municipio de Goiana está ubicado en el extremo norte de la costa de Pernambuco, limitándose directamente con el estado de Paraíba. Se ubica al norte de la capital de Pernambuco (Recife) y se inserta en el contexto geológico de la cuenca de Paraíba, donde predominan los revestimientos sedimentarios desde el Cretácico Superior hasta el reciente. La Formación Barreiras cubre una porción considerable del municipio. Esta unidad está relacionada con la existencia de abanicos aluviales y sistemas fluviales que posiblemente fueron clasificados para sistemas deltaicos y presentan una variación fisiológica de arcilla a conglomerados.

La acción de la meteorización y la lixiviación asociada en las capas arenosas-arcillosas de esta unidad condujeron a la aparición de depósitos arenosos con un alto contenido de SiO_2 (> 95%) conocidos como "arenas blancas". El grosor de estos depósitos varía entre 0,1 y 3 metros y los granos están bien seleccionados y son subangulares. La fracción de tamaño de partícula predominante es de fina a media según los estándares de la Asociación Brasileña de Estándares Técnicos (ABNT). Teniendo en cuenta todas las características del bien mineral, la calidad y la composición de los depósitos, las "arenas blancas" se consideran de buena calidad para la industria de la construcción, por lo que se han intensificado los estudios y exploraciones en la región.

Palabras-clave: Arenas Blancas, Tablas Costeras, Paraíba Cuenca.

1. INTRODUCTION

The term sand, designates a granular material, with a diameter in a defined range (2 to 0.06 mm), of silicatic composition, with quartz mineral predominance, or other minerals, shell fragments ($CaCO_3$) resulting from natural breakdown or comminution of rocks or shells of organisms, more or less cemented (DNPM, 2015).

Generally speaking, sand covers a wide range of granular materials (essentially quartz), with different specifications and uses, such as: aggregates for civil construction, foundry molds, transformation industries (glass, abrasives, chemicals, ceramics, steel, foundry, filters, cement, refractories), water and sewage treatment, ore with minerals of economic interest, such as: monazite (cerium and rare earth elements), ilmenite (titanium), gold, cassiterite and others (Quaresma, 2009).

Sand production is a basic sector in the construction industry chain, has significant revenues and generates many jobs. The economic activity of sand production is characterized by large volumes produced. Transport accounts for about 2/3 of the final price of products, which imposes the need to produce them as close as possible to the market, which are urban agglomerations (Quaresma, 2009).

The sand production for civil construction is widespread throughout the national territory. All states in the country have a sand mine for construction. In the 2007 survey “Universo da Mineração Brasileira”, based on the Annual Mining Reports, it listed 742 sand mines. The number of companies that produce sand is in the order of 2,000, according to ANEPAC (Quaresma, 2009).

The Goiana City (Pernambuco) has considerable economic potential for this mineral, popularly called "white sand". This potential is characterized by a sedimentary origin due to the weathering of the Barreiras Formation, concentrated on the coast of Pernambuco. Here, we present characteristics of these deposits considering the exploratory activity of this ore in the Goiana city.

2. METHODS

This work reflects the grouping of some information obtained in the field through the conduct of mineral surveys carried out in the Goiana city in order to identify reserves of the referred mineral resource, sand for civil construction, as well as obtaining public data located on the National Mining Association website (ANM).

In addition to the geological mapping carried out in the region, the intervals that contain the ore were separated and sampled for a better classification. These intervals were submitted to granulometric (granulometric separator) and chemical (X-ray fluorescence) analyzes.

Some of these informations are of a confidential nature (such as, for example, the exact location of reserves and drilling), so that the disclosure of these by the technical responsible is prohibited.

3. GOIANA CITY CHARACTERIZATION

The Goiana City is located in the Mata mesoregion and in the Northern Microregion of the State of Pernambuco, bordering on the north with the Paraíba State, on the south with Itaquitinga, Igarassu, Itapissuma and Itamaracá cities, on the east with the Atlantic Ocean and on the west with Condado and Itambé (Figure 1), approximately 65 km to the north of the capital, accessed by the highway BR-101.

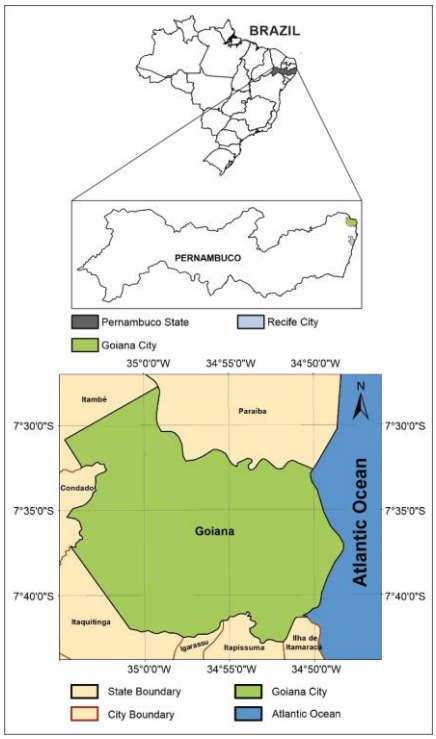

Figure 1 – Location of the Goiana City in the Pernambuco State and reference to its municipal limits and the Paraíba State. Source: author (2019).

The municipal area occupies approximately 500 km^2 and represents 0.50% of the Pernambuco State and is inserted in the SUDENE Itamaracá (SB-25-X-C-VI) and Limoeiro (SB-24-Y-C-V) sheets in the 1:100,000 scale.

Among the physiographic aspects, the following stand out: the Tropical Rainy climate; the subperennial forest type

vegetation, with portions of subcaduciferous forest and cerrado; the surface waters inserted in the Hydrographic Basin of the Goiana River, having several distributional channels, streams and dams; and the relief is predominantly part of the Coastal Tabuleiros unit (CPRM, 2005).

4. GEOMORPHOLOGY E REGIONAL GEOLOGY

The genesis of the Paraíba Basin, as well as the marginal sedimentary basins of the South Atlantic, is related to the opening of the South Atlantic Ocean, which occurred from the fragmentation of the Gondwana continent. The evolution of this rifting process has resulted in the formation of passive margin basins, which currently represent the main oil exploration targets on Brazil's Atlantic margin. The basin is inserted in the regional context of the Borborema Province. Almeida *et al.* (1977) defined the name for the folding region in the northeast of Brito Neves (1975), located north of the São Francisco Craton and affected by the Brasiliana Orogenesis.

Oliveira & Santos (1993) and Santos (1995, 1996), based on the evolutionary model of the tectonic bonding type, implemented the concept of "terrains" or the process of bonding distinct tectonic-stratigraphic terrains in which the lands of the Borborema Province, in the Precambrian evolution, would have been glued during orogenic events: Cariris Velhos (Greenville age) and Brasiliana (Pan-African). The latter would have been responsible for the juxtaposition and dispersion of the land (Figure 2).

The Paraíba Basin was implanted under three distinct terrains of the Borborema Province: **1) Rio Capibaribe Terrain** - represented by paleoproterozoic orthogneisses (1.97 to 2.12 Ga, NEVES *et al.*, 2006), and by Taquaritinga orthogneiss, Mesoproterozoic (1, 5 Ga, SÁ *et al.*, 2002). The cover, meta-sedimentary, is composed of the Surubim Complex, represented by shales and pelitic gneisses with garnet and / or sillimanite, marbles, quartzites and calcisilitic rocks; **2) Alto Moxotó Terrain** - represented by metavolcanosedimetal supracrustal sequences of the Lagoa das Contendas complexes (1.012 ± 18 Ma, SANTOS *et al.*, 1994 and 1995a) and Sertânia, Caroalina sequence; **3) Alto Pajeú Terrain** - main representative of the geological event Cariris Velhos, is represented by a metasedimentary association interspersed with metavolcanic and metavolcanoclastic rocks belonging to the São Caetano Group. These domains are part of the Transverse Zone of the Borborema Province, which is limited by the two main Shear zones in the region, the Pernambuco Shear Zone (PESZ), to the south, and the Patos Shear Zone (PASZ), to the north.

Figure 2 – Subdivisão das bacias marginais da porção oriental do nordeste do Brasil. Em destaque, os terrenos pré-cambrianos que compõem o embasamento da Bacia Paraíba, cujos domínios coincidem com a Zona Transversal do Nordeste, limitada pelas grandes Zonas de Cisalhamento Pernambuco e Patos. Fonte: modificado de Barbosa (2007).

The Paraíba Basin has six lithostratigraphic units deposited in different evolutionary stages of the South Atlantic rift (Figure 3). The Beberibe Formation, a basal unit, corresponds to fluvio-lake sandstones of Santonian - Campanian age (BEURLEN, 1967a, 1967b, 1967c; MABESOONE; ALHEIROS, 1988; FEIJÓ, 1994; SOUZA, 1998); the Itamaracá Formation, which represents a transitional sequence, is represented by calcareous sandstones, marl and siliciclastic limestone of Meso-Campanian-Neo-Maastrichtian age (KEGEL, 1955; LIMA FILHO *et al.*, 1998; BARBOSA *et al.*, 2003; SOUZA 1998, 2006; MOURA, 2007); covering the transitional deposits, shallow platform carbonates of the Gramame Formation of Maastrichtian age occur (MAURY, 1930; BEURLEN, 1967a, 1967b, 1967c; TINOCO, 1971; MUNIZ, 1993; LIMA & KOUTSOUKOS, 2002) that form a narrow roof, coastal zone, practically the entire coastal strip (BARBOSA, 2007), and the Maria Farinha Formation of Daniana age, which is restricted to the coastline in the Olinda Sub-basin (BEURLEN, 1967a, 1967, 1967c; MUNIZ, 1993), also occurring, the reef limestone of the Eocenic age of the Tambaba Formation (CORREIA FILHO *et al.*, 2015), deposited on a narrow strip of the coast in the Alhandra Sub-Basin; and there are also deposits of a continental nature of the Barreiras Formation, which is of Miocene-Pleistocene age (ARAI *et al*., 1988, 1994, 1997; LEITE *et al.*, 1997a, b; BEZERRA, 2014; ROSSETI, 2006).

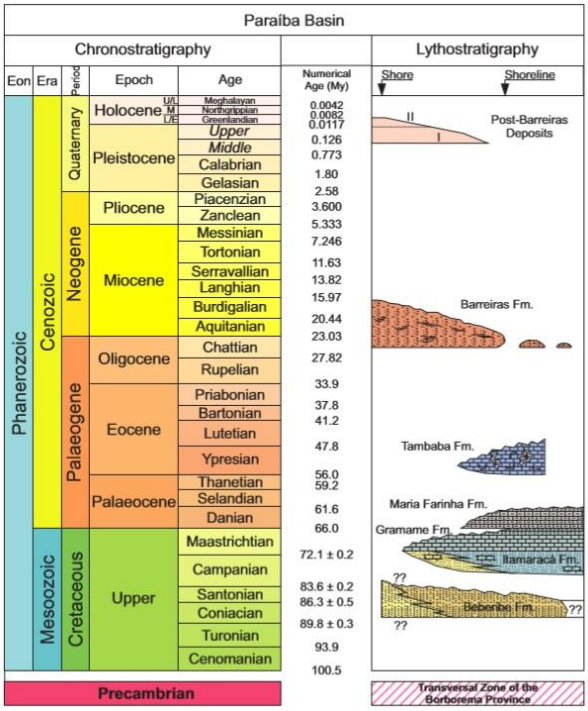

Figura 3 – Carta estratigráfica para a porção emersa da Bacia Paraíba, considerando o registro das unidades nas duas sub-bacias (norte-sul). Fonte: Correia Filho et al (2015).

In the coastal strip of the Pernambuco State, the coastal plateaus constitute the plateaus located, predominantly, on the north coast of the state, between the Baixada Litorânea and the areas of the crystalline basement. They present tabular surfaces dissected by valleys, such as that of the Goiana River and small coastal rivers, with an average altitude of 50 to 150 m above sea level (TORRES & PFALTZGRAFF, 2014).

5. RESULTS AND DISCUSSIONS

This ore occurs predominantly in the valleys of the main existing rivers of the city, as well as in colluvial coverings, resulting from weathering and erosion of metamorphic rocks, with sands still occurring in eluvial coverings resulting from weathering of granite rocks, and also, weathering of sedimentary rocks.

The region is mostly covered by sugar cane plantation, with small stretches of vegetation in the initial development stage, pasture, grasses, fruit trees (Figure 4A; Figure 4B). The coastal boards are the most pronounced geomorphological features and are evident in the relief of the region, which are formed due to the deposition and erosion of the Barreiras Formation, and provide the formation of these mineral reserves.

Figure 04 - Photos of the studied region. A) Physiography of boards and characteristic vegetation formed by the cultivation of sugar cane, grasses and fruit trees; B) Access from the region, favored by the federal highway BR-101; C) and D) Occurrence of the ore ("white sands") on the surface; E) and F) Open pit ore exploration method. Source: author (2019).

Com base nas informações obtidas em campo, a ocorrência dos níveis arenosos, conhecidos como *"areias brancas"*, do município de Goiana foram formados, em sua grande maioria, sobre as camadas areno-argilosas da Formação Barreiras (Figura 5), em decorrência do processo de intemperismo químico regional e da lixiviação associada (Figura 4C; Figura 4D). Após esses processos, a Formação Barreiras proporcionou a formação de pequenas bacias (Figura 4E; Figura 4F), as quais são responsáveis por conter tal bem mineral.

Based on information obtained in the field, the occurrence of sandy levels, known as "white sands", in the Goiana city were formed, mostly, on the sandy-clay layers of the Barreiras Formation (Figure 5), as a result of the regional chemical weathering process and associated leaching (Figure 4C; Figure 4D). After these processes, the Barreiras Formation provided the formation of small basins (Figure 4E; Figure 4F), which are responsible for containing such ore.

These basins refer to sandy layers - sometimes with capping, which may be soil or sand with the same texture and composition as the ore, but with a much higher organic matter content - predominantly quartzose, with well-selected, subangular grains, with thickness ranging from 0.10 to 3.00 meters (Figure 7), horizontal and preferably arranged on flat boards in the region.

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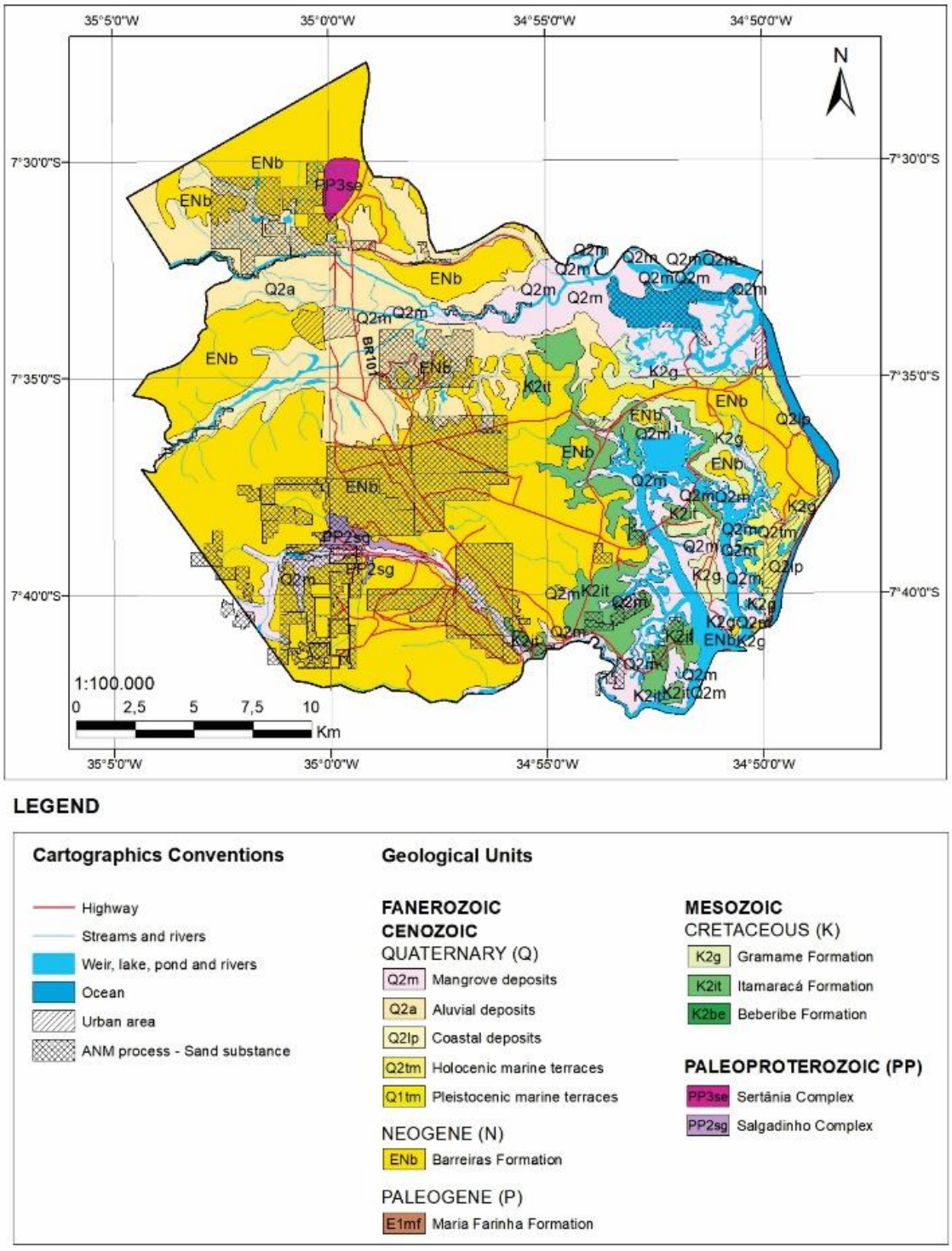

Figure 05 – Geological map of the Goiana city showing the different lithologies occurring in the municipality. Noteworthy are the areas that have legal title (ANM) for sand ore. Source: modified from CPRM, 1990 and 2017.

According to the standards of the Brazilian Association of Technical Standards (ABNT), the predominant granulometry is fine to medium, concentrating only 0.26% in the No. 08 sieve (2.4 mm), and accumulating a percentage higher than 84% in the sieve No. 100, with meshes corresponding to 0.15 mm (Figure 6). In addition, the results of chemical analysis (Table 2) identify a percentage higher than 97% for silica (SiO_2), reflecting the predominance of the quartz mineral and characterizing the ore as free of impurities (clay minerals), due to the other percentages analyzed below 1%.

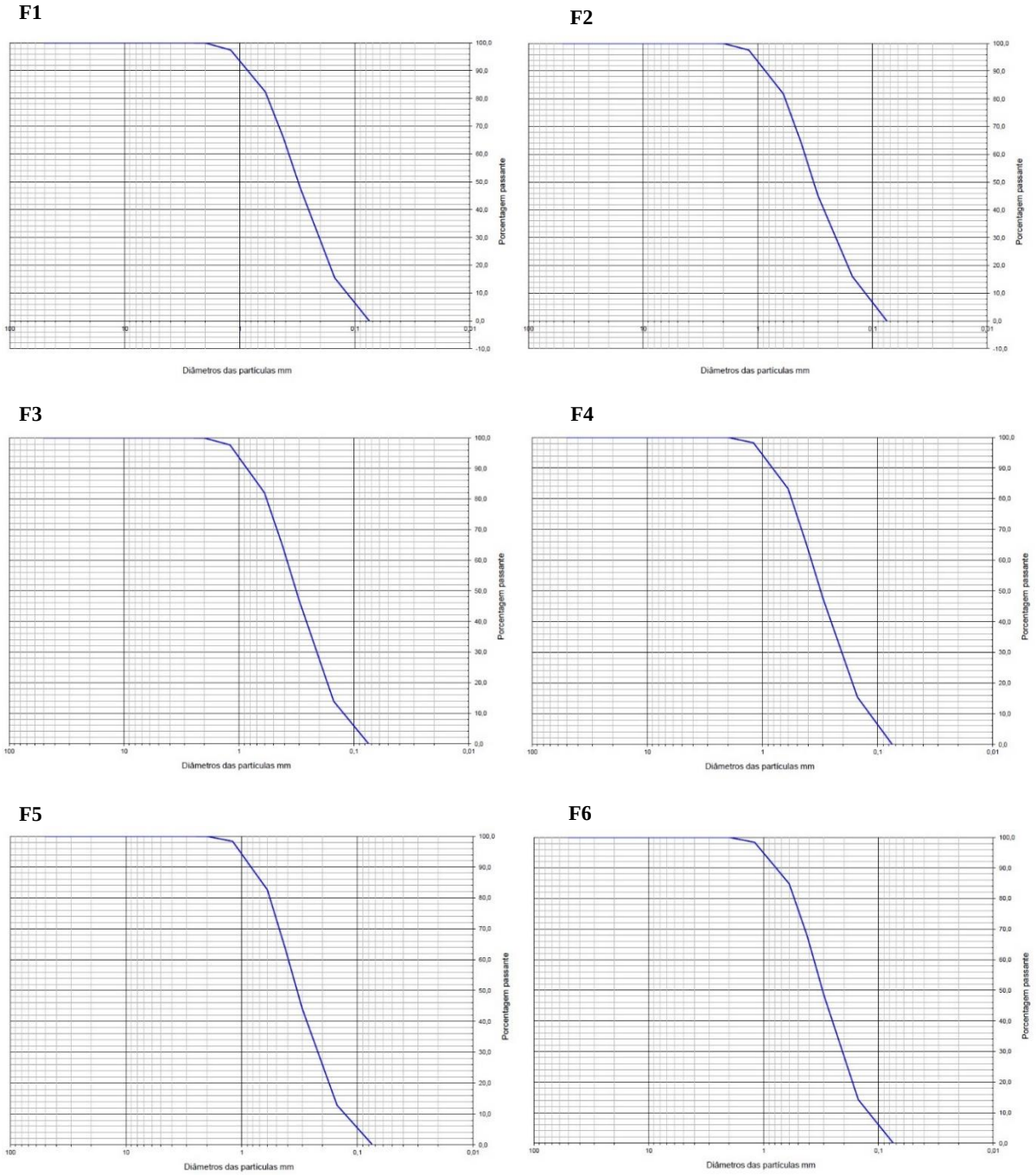

Figure 06 – Granulometric curves of the intervals of the respective holes studied according to NBR 7181/2016: HOLE 1 (F1), HOLE 2 (F2), HOLE 3 (F3), HOLE 4 (F4), HOLE 5 (F5), HOLE 6 (F6). Source: author (2019).

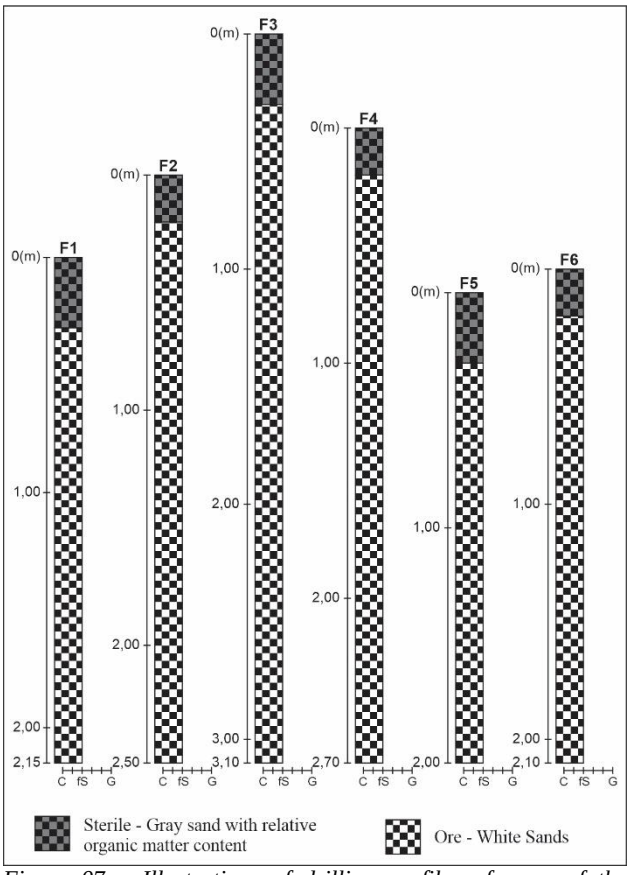

Figure 07 – Illustrations of drilling profiles of some of the perforations carried out. Note the predominance of the ore in relation to the sterile. Source: author (2019).

The development of the mining process is carried out using the open-pit method, in strips, which contain the smallest possible area and with sufficient reserve to meet consumption according to production, in order to enable an immediate recovery of this strip to be mined.

The sterile materials and organic soil are deposited in areas previously defined for this purpose, and will be used for the recovery of the degraded area, providing an immediate restoration of the area, to enable agricultural cultivation or the development of flora, as the case may be.

The environmental impacts to be generated with the dust and noise of the equipment in operation, vehicle traffic, deforestation and possible spillage of lubricants and oils, are all mitigated during the development of the mine, through specific environmental control programs.

As an additional benefit to the recovery process of the degraded area, there is the prospect that, with the removal of sand, the soil will become more apt for agriculture than it is currently, as it will become predominantly clayey, by exposing the clay to the substrate, thus becoming richer in nutrients and much less acid.

Table 1 – Result of chemical analyzes carried out for the ore found. Note the high SiO_2 content in all the holes and their respective analyzed intervals. Source: author (2019).

Chemical analysis						
Hole	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
(1)	0,30	0,20	0,30	0,20	0,30	0,20
(2)	2,15	2,50	3,10	2,70	2,00	2,10
(3)	1,85	2,30	2,80	2,50	1,70	1,90
P.F.	0,00	0,02	0,00	0,01	0,00	0,01
SiO_2	97,37	96,52	97,64	97,81	97,41	97,59
Al_2O_3	0,70	0,85	0,53	0,53	0,91	0,64
Fe_2O_3	0,69	0,77	0,72	0,68	0,65	0,68
CaO	0,10	0,18	0,12	0,12	0,13	0,13
MgO	0,28	0,40	0,16	0,19	0,22	0,18
Na_2O	0,42	0,50	0,41	0,42	0,50	0,44
K_2O	0,00	0,00	0,00	0,00	0,00	0,00

(1) Depth of ore start at the hole (in meters);

(2) Total hole depth (in meters);

(3) Thickness of the ore (in meters).

6. FINAL CONSIDERATIONS

Sand mining activities in the region are intensifying with the increase in civil construction activity, notably in the large urban centers of the region, mainly in the Recife Metropolitan Region.

Considering all aspects and characteristics of the ore to be produced, taking into its economic viability, existing support structure and its geological reserves, the region in question has a good commercial condition for exploration, in addition to the prospect of growth in civil construction.

The quality and granulometric composition of the sand are considered to be of good quality for the purpose for which they are proposed, which is why studies and explorations have been intensifying in the region.

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