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Geohistorical evolution and the new geological map of the city of Vitoria, ES, Brazil

Giseli Modolo Vieira Machado[a,*], Pablo Medeiros Jabor[b], André Luiz Nascentes Coelho[c], Jacqueline Albino[d]

[a] Post-Graduate Program in Geography, Department of Geography, Federal University of Espírito Santo, 514, Fernando Ferrari Av., Goiabeiras, 29060-900, Vitoria, ES, Brazil

[b] Jones dos Santos Neves Institute, 2524, Marechal Mascarenhas de Moraes Av., Jesus de Nazareth, 29052-015, Vitoria, ES, Brazil

[c] Laboratory of Geographical Cartography and Geotechnology, Departament of Geography, Federal University of Espírito Santo, 514, Fernando Ferrari Av., Goiabeiras, 29060-900, Vitoria, ES, Brazil

[d] Department of Oceanography and Ecology, Federal University of Espírito Santo, 514, Fernando Ferrari Av., Goiabeiras, 29060-900, Vitoria, ES, Brazil

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IBGE
Brazilian Institute of Geography and Statistics
IEMA
State Institute for the Environment and Water Resources
IJSN
Jones dos Santos Neves Institute
PMV
Prefeitura Municipal de Vitória
USGS
United States Geological Survey
IDAF
Institute of Agricultural Protection and Forestry

ABSTRACT

The economic growth over the last century, driven by port activities, promoted an artificial territorial expansion since urban growth was limited by the weak development of the coastal plains and the predominance of crystalline hills in Vitoria, Espírito Santo, Brazil. This paper summarizes the geo-historical evolution of Vitoria, the main transformations of the urban area and their relationship with the current landscape while introducing a new geological map of the city produced from the identification and delineation of technogenic deposits. Bibliographical, cartographic and field surveys were done using the Geographic Information System integrated with Remote Sensing products and techniques to produce the maps. The results show that, currently, Vitória has 10 km^2 of technogenic deposits, corresponding to about 12% of its geological coverage while 61% of the shoreline perimeter is artificialized. Urban roads, recreational areas, and residential neighborhoods were settled over landfills, 52% of which covered either water depths or mangrove forest. It is concluded that the topography was the greatest obstacle to the occupation and development of Vitoria earlier. Almost the whole perimeter of Vitoria Island and mainland have been altered by landfill. However, these "new" spaces remained as the limiting factor to any re-adaptation attempt of the coastal ecosystems, especially mangroves, in a future scenario of sea-level oscillations.

1. Introduction

The change of geomorphological and soil shapes in urban areas, especially by construction and engineering works, produces surface anomalies that constitute environment changes such as solid waste deposits, landfills, rectifications and excavations (Machado, 2013). The accumulation of different shape and composition materials, resulting from the disposal of human activities and/or urban growth in landfills, is known as technogenic deposits, from the geological viewpoint.

The technogenic deposits result from the human interventions in the physical environment and its effects, and man is considered as the geological agent (Oliveira and Pelogia, 2014; Campos and Oliveira, 2014; Machado, 2013; Oliveira et al., 2005), such as, shell mound deposits produced by indigenous populations. Geologically, it has been proposed that the term Technogenic should represent a time of transition and/or beginning of man activities in geology that started about 10,000 years ago characterized by a fully Quaternary situation (Peloggia, 1997). However, Peloggia and Oliveira (2005) highlight that man played a determinant role in the recent and contemporary construction processes of these deposits.

These deposits are not testimonies of landscapes that once existed, but essentially, of those that would not have occurred if not for the action, direct or indirect, of humanity (Oliveira, 2005). The concept of historical time allows researchers to identify and learn the genesis of evolution of technogenic deposits, and to recognize the historical phases of the local landscape transformation through the records impregnated in the layers (Miyazaki, 2014).

Technogenic is driven by anthropogenic events such as landfills,

* Corresponding author.
E-mail addresses: giselimodolo@gmail.com (G.M.V. Machado), pablo.jabor@ijsn.es.gov.br (P.M. Jabor), alnc.ufes@gmail.com (A.L.N. Coelho), albino.jacqueline@gmail.com (J. Albino).

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construction of breakwaters, expansion works of ports (Pedrosa, 2007), agricultural and mining activities (Oliveira, 2005), gold digging (Miyazaki, 2014), among others, that are, mostly, locally materialized in the urban environment. Coastal areas are being increased by landfills due to high urban pressure resulting from increasing building density (Pires et al., 2012). These deposits are subjected to the addition and removal of material by wave action and, sometimes, subsidence is observed to result from the accommodation of material due to underground water (Machado, 2013). Goudie (2006) highlights that cities such as Hong Kong, Dubai, and Tokyo are advancing over the sea to expand their economic territories, by moving tons of discarded construction materials, soil, and solid waste in marine waters causing imbalance in the aquatic ecosystems.

Fanning and Fanning (1989) classified the materials used in landfills. The urban materials consist of urban waste such as demolition materials (brick, stone, glass, plastic, etc.) and earth materials. The garbage materials consist of detrital materials with predominantly organic waste under anaerobic conditions - dumps and sanitary landfills. The spoil materials consist of excavated earth materials that are redeposited in landfills with a small amount of debris that originate from the earthwork. Last, dredged materials result from the dredging of waterways or seabed.

It is in this context of coastal landscape transformation, especially estuaries, in which incorporating or converting mangroves into urban areas is favored due to the possibility of easy dumping of industrial and agricultural waste, pressure from the real estate market, proximity to ports and marine construction (Schaeffer-Novelli, 1995). As an example, in the estuarine zone of Suape (PE), northeastern Brazil, the construction of a port and infrastructure for an industrial complex led to landfills, dredging and damming that drastically modified the estuarine landscape and local hydrology (Braga et al., 1989). The emergence of urban mangroves from landfills in the estuarine complex, diagnosed by Brandão et al. (2009) in Recife and Olinda (PE) is another example of landscape transformation.

Although mangrove ecosystems are vulnerable, the anthropogenic damage inflicted on their forests can be reversed over a relatively short time period if environmental conditions are stimulant (Sakho et al., 2011). Similarly, Schaeffer-Novelli (1995) and Brandão et al. (2009) stated that after removing the causes of environmental degradation (in this case, finalization of landfills), the mangrove showed a natural tendency towards original recomposition and restructuring. However, this is not a pattern and tends to be suppressed especially in port areas (Braga et al., 1989).

Nevertheless, the capacity of each coastal environment (plains, estuaries, lagoons, bays ...) to revert to the natural environment and/or to adjust to changes at the base level when incorporated by technological reservoirs is not yet known.

Most of the large Brazilian coastal cities result from the initial settlements built by the Portuguese as Vitoria, one of the oldest state capitals of the country. The city occupation started in the island portion, represented by the Precambrian crystalline hills and surrounded by the estuarine portion of Vitoria Bay.

Vitoria became an important port city that resulted from the intensification and diversification of economic activities in Espírio Santo driven mostly by the coffee culture in the late nineteenth century (Bittencourt, 1987). Subsequently, the incipient industrialization of the mid-twentieth century, contributed greatly to the population concentration in the capital, incorporating new areas to the dynamics of the city.

Except for the geological records left by the indigenous people, the technogenic deposits on the Vitoria island, driven by landfills, began in the second decade of the nineteenth century (1812–1819) to meet the port and health demands of the small urban population concentrated in the city center (Faria, 2010). According to Costa (1998), a significant part of the perimeter shoreline of Vitoria Island in the early twentieth century to the present day has undergone expressive construction of landfills all around. Landfills have changed the physical space and the city boundary, especially by suppressing and occupying the coastal, estuarine and mangrove areas, adding new elements to the landscape and creating new spaces (Faria, 2010).

According to Santos (1988), man can modify the aspects of the natural frame, creating a second nature more suited to his interests. Thus, these “new spaces” begin to compose the newest geological record.

This work presents (a) the geo-historical evolution of Vitoria showing the main transformations of the urban area and its relationship with the current landscape that resulted from the creation and/or modification of area coverage by landfills, and proposes (b) an updated geological map including technogenic deposits as a stratigraphic unit.

2. Materials and methods

2.1. Study site

Vitoria, the state capital of Espirito Santo, is located partially in the continent (Camburi plain) and on an island (Vitoria Island) with several smaller islands, covering a territory of 86.63 km^2 divided in two bays. The first, Espirito Santo Bay, is characterized by a semi-closed body of water connected to the sea, with large industries such as Vale and two major ports, Tubarao and Praia Mole located to the north (Fig. 1). The second, Vitoria Bay is an extremely sheltered estuarine system that surrounds Vitoria Island with two channels to the sea, Passagem and Porto, and the latter houses the old ports of Vitoria and Capuaba (Fig. 1).

The study area is characterized by a very jagged and irregular relief, a massif in the center of the main island, hills, and islands of Pre-Cambrian rocky headlands (granite/gneiss) of the Paraiba do Sul Complex, which alternates with the Tertiary tablelands (Neogene) of the Barreiras Formation (Martin et al., 1996, 1997). The coastal plains are spatially limited while their sedimentary evolution is associated with sea level fluctuations and the availability of river sediments (Albino et al., 2006). The Quaternary records are characterized by fluvial-marine sands with mangrove areas limited by the relief (Machado et al., 2016).

In a broad sense, the constitutive geological material of Vitoria Island is essentially continental. During the Quaternary, part of the relief was drowned by sea oscillations, removing the eroded material deposited at the foot of the massif. Compared to the current, the higher sea levels during the Holocene formed the estuarine system around the island, with extensive mangrove deposits but limited by the steep relief. The low input of river sediment and the very geomorphological setting that provides low hydrodynamics around the Vitoria Island did not favor the formation of coastal plains in the region. The few emerged sand deposits were confined to small sections between the relief and almost exclusively on the northern part of the island - where the Camburi plain developed (Machado, 2014).

2.2. Delimitation of technogenic deposits

To achieve the goals, the procedures were divided into three steps. The first step consisted of acquiring bibliographic references and documents on the subject, such as technical papers and reports, and free information plans as shown in Table 1, with all the mapping and processing of vector and matrix data conducted in the GIS ArcGIS 10.4.

The second step consisted of developing a project and adding the Information Plans covering the study site and neighboring areas, adjusted when necessary, in the UTM projection system, datum SIRGAS-2000 Zone 24 South. All mappings followed the cartographic standardization proposed by Menezes and Fernandes (2013) and Lo and Yeung (2008).

The technogenic deposits were delimited by the refining of the landfill polygons from 2012, by the Municipal Strategic Management