


# Sambaquis from the coast of Guarapari, Espírito Santo - Brazil: chemistry, physics and malacofauna


*Rafael Said Bhering Cardoso*<sup>1</sup> 

*André Luiz Lopes de Faria*<sup>2</sup> 

*Pablo de Azevedo Rocha*<sup>3</sup> 

*Rafael Cardoso Teixeira*<sup>4</sup> 

*Liovano Marciano da Costa*<sup>5</sup> 

*Angelo Adriano Faria de Assis*<sup>6</sup> 

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## Abstract

Sambaquis are archaeological sites present mainly in coast and close to the fluvio-lake systems. They are found in most of the Brazilian coast. Sampling and analysis of soils and malacofauna species provide important information about human occupation in a given place. This research aimed to verify, through the analysis of chemical elements present in soils, the occurrence of human occupation in three sambaquis located in the Guarapari, Espírito Santo State, Brazil. Three profiles were delimited, one for each sambaqui, called Una I, Una II and Concha D'Ostra. The soil samples were dried, grinded, sieved, and then sent to the laboratory analysis. Significant amounts of chemical elements such as phosphorus, potassium, sodium, calcium, magnesium, manganese, zinc, copper and also organic matter were found. It was also verified significant change in the pH levels, cation exchange capacity, sum of bases and base saturation. The remains of malacofauna species used as food source by the sambaquieiros as well as the soil chemical analysis allow to conclude that there was human occupation in the three sambaquis. The high levels of phosphorus and potassium found in the Concha D'Ostra sambaqui as well as its scale suggest that there was human occupation there for a longer period of time than in the Una I and Una II sambaquis.

<sup>1</sup> Universidade Federal de Viçosa. [rafasaid@gmail.com](mailto:rafasaid@gmail.com)

<sup>2</sup> Universidade Federal de Viçosa. [andre@ufv.br](mailto:andre@ufv.br)

<sup>3</sup> Universidade Federal do Espírito Santo. [pab\\_zulu@yahoo.com.br](mailto:pab_zulu@yahoo.com.br)

<sup>4</sup> Universidade Federal de Viçosa. [teixeirarcgeo@gmail.com](mailto:teixeirarcgeo@gmail.com)

<sup>5</sup> Universidade Federal de Viçosa. [liovandomc@yahoo.com.br](mailto:liovandomc@yahoo.com.br)

<sup>6</sup> Universidade Federal de Viçosa. [angeloassis@ufv.br](mailto:angeloassis@ufv.br)

## INTRODUCTION

In Brazil, sambaquis have been researched since 1871, when Karl Rath began researching these shell mounds (FUNARI, 1994). Until the middle of the twentieth century, there were three approaches regarding the artificiality of sambaquis formation. The first defended that sambaquis were formed by the action of nature itself. Another defended that there was human intent in sambaquis' construction. Finally, the third approach was a combination of the other two (MENDONÇA DE SOUZA, 1991). Today, it is widely accepted the human intent in the formation of sambaquis.

In the Brazilian territory, the sambaqueiros lived about 7,000 to 2,500 years ago. During the formation of sambaquis, the place was inhabited for periods longer than a thousand years (GASPAR, 2000). In Brazil, sambaquis are found from Rio Grande do Sul to the coast of Pará. They are associated with environments with an abundance of food on the coast or in interior fluvial-lake systems. They were also found in the Lower Amazon region (CORRÊA, 2007).

The most ancient Brazilian sambaquis were formed in the Holocene. These areas were vulnerable against sea level fluctuations that have occurred since the Pleistocene (ERLANDSON, 2013). These fluctuations impacted the way of life of prehistoric humans, demanding them to adapt, always looking for new places to settle their people.

The study of the chemical constitution of the sambaquis shows relevant information about them. It allows us to correlate certain chemical elements in the soil and human occupation (CUSTER et al., 1986). The soils formed in the sambaquis usually have high levels of a diversity of chemical elements, mainly Calcium (Ca), due to the strong presence of remains of shells and ceramics; phosphorus (P), an element present in bones, and also in human tissues, among other structures of animal origin; and in smaller quantities, Magnesium (Mg), Copper (Cu), Zinc (Zn) and Manganese (Mn) (CORRÊA, 2007).

The soil sample collection from the sambaquis clarifies some aspects of their culture. Bertrand and Bertrand (2007) confirm the importance of field research with collection and analysis of soil samples for a deeper study about prehistoric humans.

Villagran (2010) mentions the archaeological record as an essential source of information about the environment and human actions in a location. The author defines this record as what has been deposited by human of the past, even contributing to the formation of anthropogenic or archaeoanthrosol soils, such is the case of sambaquis.

The Brazilian tropical climate contributes for its dynamic landscape, distinguishing its weather, geomorphological, and pedogenic processes. This climate does not contribute to the preservation of archaeological sites such as sambaquis, preserving only a few fragments of ancient cultures (CORRÊA, 2007).

Sambaquis have been largely explored, mainly for lime extraction obtained from shell accumulation, which makes them difficult to study. Throughout the country, lime resulting from this exploration was used in a multitude of ways: as materials for civil construction; for fertilization; paving of roads; and in some regions even becoming pet food (MENDONÇA DE SOUZA, 1991).

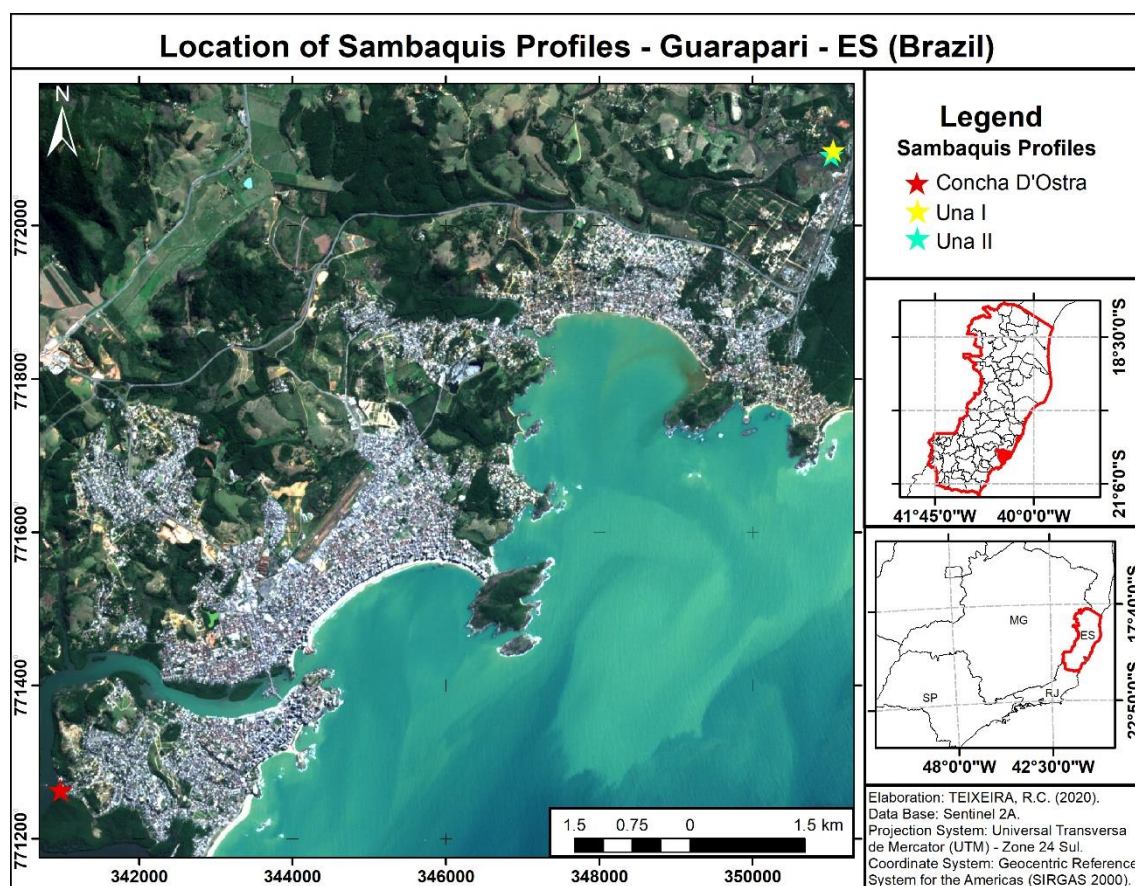
This research aims to evaluate whether samples collected, of malacological fauna and soils, in three sambaquis in the city of Guarapari, Espírito Santo, corroborate the past human occupation in these places.

## MATERIAL AND METHODS

### *Characterization of the study area*

The city of Guarapari is located in the southern portion of the Espírito Santo State (Figure 01), with an estimated population of 123.166 inhabitants and an area of 591,815 km<sup>2</sup> (IBGE, 2018), and a demographic density of 177,1 inhabitants/km<sup>2</sup>.

**Figure 01.** Location of the sambaquis (archaeo-antrossol) studied in the city of Guarapari - ES, Brazil.



Source: IBGE, 2018. Org.: Authors, 2020.

The Espírito Santo coast is defined by stretches of sedimentary deposition (MARTIN *et al.*, 1996), classified into three geomorphological units: the Precambrian Crystalline Basis, the Barreiras Group's Paleogen-Neogenous Formation Trays and the Quaternary Coastal Plain. Guarapari is in the area that includes the coastal zone located in the corridor between the Espírito Santo bay and the Itapemirim River mouth. This region features outcrop zones of Precambrian crystalline rocks that have direct contact with quaternary deposits. There are also deposits of the Barreiras Formation.

Guarapari soils originate from crystalline rocks, with a predominance of granite and gneiss, sedimentary rocks that belong to the Barreiras Formation and sediments from the Quaternary period, these having fluviomarine origin. Weathering is very strong on the large massifs and hills of the region, resulting in an intense process of pedogenesis. Most soils have a clayey texture derived from crystalline rocks. The predominant soil type in that area is the Red Yellow Latosol, with a clay texture, occurring in all the regional landscape (DER, 2010), besides Gleisols, Quartzarenic Neossols,

Yellow Latosols, Spodosols and Organossols (ROCHA, 2016).

Guarapari is located under the influence of the high pressure center of the South Atlantic, with average rainfall between 1300mm to 1400mm per year, whose rains predominate in the summer months. Average atmospheric temperatures range from 21°C to 29°C (ALBINO *et al.*, 2004).

### *Gathering and soil sample analysis*

The sampling of the sambaquis considered the recommendations of Santos *et al.* (2015) for soils, performing the same routine for the three sambaquis. They were called Una I and Una II, located on the banks of the Una River; and Concha D'Ostra, located in the Concha D'Ostra Sustainable Development Reservation (Figure 01). The area was cleaned for each profile, then they were opened and a morphological description was used to recognize their horizons. To distinguish the horizons in each profile, we used the Brazilian Soil Classification System (EMBRAPA, 2006).

For Sambaqui Una I, a profile was opened

(Figure 02) with a depth of 70cm and five horizons were characterized: 0-15cm: superficial organic matter, with abundant presence of shells, some roots, leaves, with a paleoanthropic horizon (concheiro); 15-25cm: predominantly sandy horizon; 25-40cm: change from sandy

horizon to clayey horizon; 40-55cm: presence of reddish material, indicating the presence of hematite due to the burning of the peat that exhumed the site; 55cm+: very dark horizon, presence of organic matter.

**Figure 02.** Sambaqui Una I Profile



Source: Authors' Collection, 2014.

For the Sambaqui Una II, a profile was opened (Figure 03) with over 70cm of depth and five horizons: 0-15cm: horizon with very hardened, preserved shell; 15-40cm: fragmented

shell in an advanced stage of decomposition; 40-55cm: transition from fragmented shell to ash; 55-70cm: very reddish material; 70cm+: very reddish material

**Figure 03.** Sambaqui Una II Profile



Source: Authors' Collection, 2014.

For the Concha D'Ostra sambaqui (Figure 04) the profile was defined according to the following data: 0-15cm: horizon A; 15-25cm: horizon A2; 25-60cm: A3 paleoanthropic horizon; 60-135cm: horizon A4; 135-180cm: horizon A5; 37-180cm+: horizon C. Up to horizon A2, it was detected tree roots and shrubs. Shells

are seen in all horizons, but more intensely in the A5 horizon. Almost the entire profile was defined as "horizon A", which indicates human influence over it. This specific Sambaqui is influenced by tide, as it is located in a marine channel directly connected to the Guarapari bay.

**Figure 04.** Concha D'Ostra Sambaqui profile

Source: Authors' Collection, 2014.

The collected samples from each Sambaqui were dried, grinded and sieved with a 2mm mesh to separate the air-dried fine earth (TFSA). The TFSA samples were sent to the Laboratório de Geoquímica do Departamento de Solos da Universidade Federal de Viçosa, where chemical analyzes were carried out according to EMBRAPA (2011).

The chemical analyzes were for: determination of the hydrogen potential (pH) through of a combined electrode immersed in soil: liquid suspension (1:2,5); Cation Exchange Capacity potential ( $T = K + Ca + Mg + [H + Al]$ ) and effective ( $t = K + Ca + Mg + Al$ ); Sum of Bases ( $SB = K + Ca + Mg + [Na]$ ); Base Saturation Percentage ( $V [\%] = [SB \times 100] / T$ ); Percentage of Aluminum Saturation ( $m [\%] = [100 \times Al^3] / t$ ); the Sodium Saturation Index ( $ISNa [\%] = 100 \times Na + / T$ );  $Al^3 +$ ;  $H + Al$ ; macronutrients (P, Ca, Mg and K) and micronutrients (Cu, Zn and Mn); and soil organic matter (OM).

## RESULTS AND DISCUSSION

### *Malacofauna found in the sambaquis of Guarapari*

The diet of the sambaquieiros that inhabited

Guarapari, considering the sambaquis found in this research and the samples of malacological fauna collected, evidences that they lived close to the sea, as they consumed fauna specimens from the marine environment. Discovering the diet type that prehistoric people consumed allows us to understand aspects of their cultural apparatus, their behavior pattern, their adaptation level to the environment, besides providing information about foods that can be included in current diets.

No evidence was found in the samples collected in relation to fish, animal, and vegetal consumption that were used to supplement the sambaqueira diet. The Chart 1 shows the species sampled in the three sambaquis studied. The described species were found in the three sambaquis.

By analyzing the chemical composition of samples from the *Anadara notabilis*, found in Galinhos, Rio Grande do Norte, Araújo (2010) found the mineral richness of the species, suggesting its consumption by humans. High concentrations of macronutrients were detected by the author, especially magnesium and phosphorus. Concerning micronutrients, iron had the highest concentration, with 586,7mg/kg and zinc with 12,31mg/kg. This species is found in Asia, Africa, Oceania and South America.

**Chart 1.** Species of marine malacofauna found in the sambaquis of Guarapari, Espírito Santo – Brazil.

Species	Class	Family	Currently found
<i>Anadara notabilis</i>	Bivalvia	Arcidade	Throughout The Brazilian coast
<i>Trachycardium muricatum</i>	Bivalvia	Cardiidae	Throughout The Brazilian coast
<i>Crassostrea rhizophorae</i>	Bivalvia	Ostreidae	Only in the Bahia coast
<i>Phacoides pectinatus</i>	Bivalvia	Lucinidae	Throughout The Brazilian coast
<i>Pugilina morio</i>	Bivalvia	Lucinidae	Throughout The Brazilian coast
<i>Bostrycapulus aculeatus</i>	Gastropoda	Calyptraeidae	Throughout The Brazilian coast
<i>Codaria orbiculata</i>	Bivalvia	Lucinidae	Throughout The Brazilian coast

Org.: Authors, 2015.

The *Trachycardium muricatum* specimens also had high concentrations of iron, in addition to chromium. Such mollusks are highly effective in preventing anemia due to the large iron concentrations found in them. The chemical composition of this species was analyzed by Portella (2005), who found 87% of water, 7% of protein, 1.05% of lipids, and 1.90% of ash. The author indicates that this species can be toxic to humans if ingested in large quantities.

Concerning the last four species of the malacological fauna displayed, no information or studies have been found that report their importance in food or other human activities.

### Chemical analysis of the soil samples

The results of the chemical analyzes present in the sambaquis soils are shown in tables 1, 2 and 3:

**Table 1.** Chemical analysis of the Una I sambaqui samples.

Profile	pH H <sub>2</sub> O	P	K	Na	Ca	Mg	Al	H+Al	SB
			mg dm <sup>-3</sup>			cmolc dm <sup>-3</sup>			
0-10 cm	7,52	9,00	39,00	170,40	8,14	0,87	0,00	0,20	9,85
10-40 cm	7,20	3,40	11,00	145,50	40,83	0,15	0,00	0,20	41,64
40-70 cm	5,50	3,90	22,00	53,50	19,76	0,25	0,00	6,10	20,30
Profile	t	T	V	m	ISNa	Cu	Zn	Mn	MO
	cmolc dm <sup>-3</sup>			%		mg dm <sup>-3</sup>			dag kg <sup>-1</sup>
0-10 cm	9,85	10,05	98,00	0,00	7,52	0,58	0,26	6,80	9,10
10-40 cm	41,64	41,84	99,50	0,00	1,52	0,57	0,00	6,00	5,34
40-70 cm	20,30	26,40	76,90	0,00	1,15	0,67	1,34	16,20	4,71

Org.: Authors, 2015.

**Table 2.** Chemical analysis of the Una II sambaqui samples.

Profile	pH H <sub>2</sub> O	P	K	Na	Ca	Mg	Al	H+Al	SB
			mg dm <sup>-3</sup>			cmolc dm <sup>-3</sup>			
0-15 cm	7,96	10,30	2,00	78,50	9,88	0,51	0,00	0,20	10,81
15-40 cm	7,05	3,00	11,00	45,30	9,37	0,79	0,00	3,20	10,39
40-55 cm	6,41	3,00	18,00	74,50	10,53	0,39	0,00	3,40	11,29
55-70 cm	4,21	2,70	42,00	40,20	1,86	0,26	1,66	5,60	2,40
70+ cm	4,64	15,00	20,00	34,20	0,70	0,14	0,29	4,30	1,04
Profile	t	T	V	m	ISNa	Cu	Zn	Mn	MO
	Cmolc dm <sup>-3</sup>			%		mg dm <sup>-3</sup>			dag kg <sup>-1</sup>
0-15 cm	10,81	11,01	98,2	0,00	3,10	0,55	0,29	2,90	5,44
15-40 cm	10,39	13,59	76,50	0,00	1,45	0,80	1,36	7,50	6,72
40-55 cm	11,29	14,69	76,90	0,00	2,20	0,57	1,64	6,90	6,72
55-70 cm	4,06	8,00	30,00	40,90	2,18	1,39	1,57	0,80	0,38
70+ cm	1,33	5,34	19,50	21,80	2,78	1,01	0,69	0,40	0,77

Org.: Authors, 2015.

**Table 3.** Chemical analysis results of the Concha D'Ostra sambaqui samples.

<i>Profile</i>	<b>pH</b> H <sub>2</sub> O	<b>P</b>	<b>K</b> mg dm <sup>-3</sup>	<b>Na</b>	<b>Ca</b>	<b>Mg</b> cmolc dm <sup>-3</sup>	<b>Al</b>	<b>H+Al</b>	<b>SB</b>
<i>0-15 cm</i>	7,93	83,60	56,00	147,00	8,73	0,93	0,00	0,50	10,44
<i>15-25 cm</i>	7,81	10,20	13,00	24,10	2,97	0,43	0,00	0,30	3,54
<i>25-60 cm</i>	7,67	221,00	10,00	31,20	7,91	0,32	0,00	0,50	8,39
<i>60-135 cm</i>	7,83	1.132,80	11,00	331,90	11,86	0,84	0,00	0,20	14,17
<i>135-180 cm</i>	8,30	609,70	1.513,00	3.925,00	1,66	5,15	0,00	0,00	27,76
<i>180+ cm</i>	8,37	88,50	1.362,00	3.573,10	1,26	4,44	0,00	0,00	24,00
<i>Perfil</i>	<b>t</b> cmolc dm <sup>-3</sup>	<b>T</b>	<b>V</b>	<b>m</b> %	<b>ISNa</b>	<b>Cu</b>	<b>Zn</b> mg dm <sup>-3</sup>	<b>Mn</b>	<b>MO</b> dag kg <sup>-1</sup>
<i>0-15 cm</i>	10,44	10,94	95,40	0,00	5,84	0,46	1,20	5,60	5,12
<i>15-25 cm</i>	3,54	3,84	92,20	0,00	2,73	0,39	0,41	1,70	1,02
<i>25-60 cm</i>	8,39	8,89	94,40	0,00	1,53	0,43	1,28	13,60	3,52
<i>60-135 cm</i>	14,17	14,37	98,60	0,00	10,04	0,48	0,14	1,80	6,72
<i>135-180 cm</i>	27,76	27,76	100,00	0,00	61,49	0,62	2,59	2,20	0,77
<i>180+ cm</i>	24,73	24,73	100,00	0,00	62,82	0,99	0,97	3,20	0,30

Org.: authors, 2015.

According to Corrêa (2007), sambaquis may have characteristics derived from anthropic actions measurable in laboratory, including P, Ca, Mg and OM, besides Mn, Zn and Cu. Thus, the archaeo-anthrosols chemical analyzes of seek to investigate the chemical constituent values for each profile according to the variations in the horizons.

P is an element indicating human occupation and a key element in the archaeo-anthrosol identification, also used as a marker of past occupations (KÄMPF; KERN, 2005). P is related to the time of pedogenesis (CORRÊA, 2007), and a longer period indicates greater release of P for the assorted soil complex from deposited anthropic materials.

A research carried out by Rocha (2012) investigated five sandbank environments in Paulo César Vinha State Park. In one of the environments, with an open clusia vegetation, were found P levels ranging from 0,10 to 1,00mg dm<sup>-3</sup>. In Una I and Una II sambaquis the contents ranged from 3,40 to 9,00mg dm<sup>-3</sup> and 2,70 to 15,00mg dm<sup>-3</sup>, respectively. Although there is no marked anomaly in the P levels, the levels found when they were analyzed in relation to the soils of that region may indicate that there was a more intense human occupation in the sambaquis, when compared to the environment analyzed by the author. P is present in animal and vegetable tissues, besides being present in the deposited bones in the sambaquis (WOODS, 2003).

The Concha D'Ostra sambaqui has an anomaly in due to the P levels. It has been found the highest P content among the three studied sambaquis and the highest variability of values between the horizons of the profile. The values

range from 10,20 to 1,132.80 mg dm<sup>-3</sup> (average of 367,63 mg dm<sup>-3</sup>), indicating that the sambaqueira occupation in Concha D'Ostra was likely carried out by a greater number of people over a longer period when compared to the two other sambaquis.

The high levels of P found in horizons without the presence of shells and bones suggest the diagnostic importance of P to identify the horizons or anthropic profiles, because P is a "geochemical marker" (KÄMPF; KERN, 2005) rather mobile on the profile (CORRÊA, 2007). Moreover, the similar levels of P found for the sambaquis Una I and Una II, as they show that they may have been occupied at the same time by the same group, as the sambaquis were generally built in groups and not isolated in any given location (RICKEN et al., 2013).

Teixeira et al. (2012) emphasize that the P variability in the different horizons may come from distinct anthropic activity during the sambaquis formation. Therefore, the higher P concentration in some horizons may indicate greater waste disposal in a period in relation to the horizons with lower P concentrations. The 60-135cm horizon of the Concha D'Ostra profile is the one that has the largest contribution of residues of biogenic apatite (bones), possibly coming from a longer time and occupation intensity and reject deposition, during the formation of this horizon.

Ca also comes from bone tissue, shellfish, fish bones and discarded shells. The latter are probably the primary source of Ca in the sambaquis. The accumulation of shells are sources of Ca in the form of Calcium Carbonate, a form that provides and keeps the alkalinity of

the horizons that have these types of rejects (CORRÊA, 2007).

The Ca levels found by Rocha (2012) in the clusia vegetation environment varied between 0,00 a 0,27cmolc dm<sup>-3</sup>, while the contents in the sambaquis Una I and Una II varied between 8,14 to 40,83cmolc dm<sup>-3</sup> and 0,70 to 10,53cmolc dm<sup>-3</sup>, respectively. These values can be interpreted due to the large amount of shell and bone remains in these sambaquis. High levels of Ca, such as those found for these sambaquis, help to preserve elements of the sambaquieira lytic industry due to consequent more alkaline pH.

The levels of Ca in the Concha D'Ostra ranging from 1.26 to 11.86cmolc dm<sup>-3</sup>, together with the size of this sambaqui, are indications that there can be found lithic material from the sambaquieira industry.

Another complementary chemical feature in sambaquis are the high values of MO found, which influences many chemical properties analyzed. Part of the organic materials are naturally more recalcitrant, being able to stay for long periods in the soil (CORRÊA, 2007). Having the capacity to retain cations, because of their high value of cation exchange capacity (CTC), stimulating the maintenance the high values of macro and micronutrients, and also the sum of bases (SB), base saturation (V%), T and t.

According to Luchese *et al.* (2002), MO influences the increase in CTC. This is because humus retains cations, reducing the loss from leaching, which can be made available in the form of nutrients after mineralization, mainly P, K, Ca and Mg (CHIODINI *et al.*, 2013) and Zn, Cu and Mn. MO also influences pH control because of its buffering effect (LUCHESE *et al.*, 2002). Among the nutrients, Teixeira *et al.* (2012) highlight that high levels of Ca influence the stabilization of MO. This was the nutrient found in a larger quantity in the three sambaquis, mainly influenced by the remains of shells and bones.

According to Silva and Mendonça (2007) the addition of MO leads to an increase in pH when the soils are acidic, with decreasing H<sup>+</sup> activity. Therefore, the old soils, formed and leached before the action of anthropic activities, were acidic, which is observed in the horizons that generally less influence from anthropic activity and also from the MO amount for the sambaquis Una I and Una II.

As for Mg, its main sources are vegetable ashes as the first source, dried vegetables and animal tissues as secondary sources when they occur in substantial additions (CORRÊA, 2007),

besides the primary biogenic apatite, shellfish shells and hedgehog spikes. By observing the Mg values for the three sambaquis analyzed, we realized that they display values close to those found by Corrêa (2007) and Teixeira *et al.* (2012).

Nevertheless, Corrêa (2007) investigates a profile whose average is 5,47cmolc dm<sup>-3</sup>, that is, a higher value than the others analyzed by him and also those analyzed in this work. The averages for the sambaqui Una I and Una II were 0,42 e 0,41cmolc dm<sup>-3</sup>, respectively. The Concha D'Ostra sambaqui had an average of 2,01cmolc dm<sup>-3</sup>. It is important to mention the two deeper horizons, which presented values of 5,15 e 4,44cmolc dm<sup>-3</sup>, respectively, suggesting a greater supply of Mg source materials at the time of formation / deposition of rejects that originated the two highlighted horizons.

Contrasted to Rocha's data (2012), the Mg levels for the sambaquis Una I and Una II were higher than those analyzed by the author in the restinga soils close to these two sambaquis. Despite finding lower values compared to Concha D'Ostra, the Mg values for Una I and Una II, which have the lowest found vales, are still likely to indicate that the Mg values for the profiles occurred because of anthropic action.

Regarding the values of Cu, Zn and Mn, these are anthropic action indicators on soils and they are associated with organic colloids, present in anthropic horizons (WOODS, 2003). According to Woods (2003), Cu and Zn are good indicators of prehistoric human activities for a long period on soils. Corrêa (2007) points out that the dynamics of these two elements occurs differently in the soil. Where Cu has more motion than Zn, its presence extends beyond anthropogenic horizons. On the other hand, Zn, having less motion, has values more confined to anthropic horizons.

This greater Cu mobility indicates that its permanence in the soil does not last long (Corrêa, 2007). Therefore, the three profiles the Cu values tend to be higher in the deeper horizons, even in non-human horizons. According to Woods (2003), in a 2,000 years time, most of the Cu is leached; hence, it appears in a smaller amount compared to Zn and Mn. This is also the pattern observed in the chemical analyzes of the sambaquis, where the amount of Zn and Mn is generally greater compared to Cu. The sources of Cu and Zn for anthropic soils are plant and animal tissues (BOWEN, 1966). It is likely that the more intense the occupation, the higher the values of these elements.

Therefore, because of the lower mobility of Zn and Mn compared to Cu, these two



micronutrients reveal a greater association with prehistoric anthropic interventions (KERN; KÄMPF, 1989). The only exception among the analyzed sambaquis is Una I, because it has a higher Cu average than Zn. The averages for the horizons of the three sambaquis are shown in Table 4.

**Table 4.** Cu, Zn, and Mn average concentration for each sambaqui.

<i>Profile</i>	<i>Cu</i>	<i>Zn</i>	<i>Mn</i>
	mg dm <sup>-3</sup>		
<i>Una I</i>	0,60	0,53	9,66
<i>Una II</i>	0,86	1,11	3,70
<i>Concha D'Ostra</i>	0,56	1,08	4,68

Org.: Authors, 2015.

The pH in all sambaquis has an alkaline profile (pH > 7,1) in horizons from anthropic activity, while in the deeper, more weathered and natural horizons, formed before the anthropic occupation, it possesses acid pH. According to Gernet (2013), the alkaline pH is mainly related to the weathering of calcium carbonates, abundant in shell skeletons. In this case, horizons naturally formed (deeper), without shells, in the profiles Una I and Una II have acidic pH values. With a value of 5,50 on the 40-70cm horizon of Una I and a value of 4,21 and 4,64 for the horizons 55-70cm and 70+cm of Una II, respectively.

Rocha (2012) found pH levels varying between 4.15 and 5.19 in restinga soils. In Una I sambaqui the levels varied between 4.38 and 7.04, with the highest content presented in the superficial horizon, which is expected due to past human occupation. From the depth of 40 cm in the sampled profile, the pH levels are close to those found by the author, which indicates the depth of the sambaqui profile, resulting from the beginning and end of the occupation of the site. In the Una II sambaqui the pH levels ranged from 4.21 to 7.96, also showing pH values close to those found by Rocha (2012) from the depth of 55 cm.

The pH values in the Concha D'Ostra sambaqui ranged from 7,67 to 8,37, always keeping themselves basic, suggesting that there was occupation of this site for a long period of time, greater than the occupation of the sambaquis Una I and Una II and illustrating that probably the entire profile sampled is the result of a past human occupation.

Still related the pH, the presence of Al<sup>3+</sup> is observed only where the pH is less than 5,5, because above this pH value, Al<sup>3+</sup> precipitates in the form of Al oxide. Therefore, Al is found only

in the natural horizons which have a pH below this value, being detected Al<sup>3+</sup> in the sambaqui Una II, in the adjacent horizons the anthropic layers 55-70cm and 70+cm.

According to Corrêa *et al.* (2011), sambaquis generally demonstrate a high soil fertility index, data demonstrated in its chemical analyzes. The Concha D'Ostra sambaqui showed fertility rates higher than the sambaquis Una I and Una II.

The sodium (Na) levels displayed contribute to high SB levels. This happens because most of the sediments existing in sambaquis belong to marine origin. The highest levels of Na in the Concha D'Ostra sambaqui can be explained because this sambaqui is found on the banks of Guarapari Bay, suffering direct influence from the tide.

The three sambaquis analyzed displayed high levels of Ca and Mg in the exchange complex, with Ca being more prominent than Mg in almost all horizons of the three profiles. There is an exception only in the Concha D'Ostra profile, in the 135-180cm and 180+cm horizons, possessing more Mg than Ca in the exchange complex. Corrêa (2007) also found a predominance of Ca in sambaquis, in this case, in all horizons that he analyzed.

As for the V (%) index, indicating whether the soil is eutrophic (V ≥ 50%) or dystrophic (V < 50%), all anthropic layers were defined as being eutrophic. While the natural horizons presented themselves as being dystrophic, with emphasis on the horizons 55-70cm and 70+cm of the sambaqui Una II, with 30,00% and 19,50%, respectively.

## CONCLUSION

The analyzes provided important information to understand the Una I, Una II and Concha D'Ostra archaeological sites. The anthropic action provided an increase in V%, and the horizons of sambaquis are characterized as eutrophic or "eutrophized" by anthropic action.

The high levels of phosphorus and potassium detected by the samples collected in the profile of the sambaqui Concha D'Ostra suggest that there may be remains of fish and animals, and possibly human burials. Adding up to this conclusion is the fact that the diet based on malacofauna alone was not enough for the nutrition of the sambaqueiro communities.

The dimension of this sambaqui and the fact that it was occupied for a longer period when compared to the sambaquis Una I and Una II, together with the chemical elements

aforementioned, allow us to infer these indications.

Chemical analyzes of soil samples and the remains of the malacofauna, mostly from the marine environment, suggest that the sambaquis were formed by past human occupations.

Taking into consideration that they were formed by human occupation, it is important to protect these archaeological sites so that the memory of these people can also be preserved. New research may bring further information about the sambaqueiro people who occupied the city of Guarapari.

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