



Bognanni, F., Capparelli, M.I., and Pérez, M. (2012) 'A geoarchaeological study about the use of space in *Isla Martín García* (Buenos Aires, Argentina)'.
Rosetta **11**: 1-28.

http://www.rosetta.bham.ac.uk/Issue_11/Bognanni_Capparelli_and_Perez.pdf

**A geoarchaeological study about the use of space in *Isla Martín García*
(Buenos Aires, Argentina)**

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Abstract

Martín García is an island in the delta of the province of Buenos Aires, Argentina, located on the mouth of the Uruguay River.

Geomorphological and archaeological information was used as a basis for the analysis. The geomorphologic study arises from the comparison of aerial photographs and satellite images that allow us to understand the variations of the three current sandy areas and the North coast over time. It was observed that due to the advancing sediment of the island, it is likely that the three sandy areas are remnants of a large one. This area has been a place of human settlement (Guaraní groups) for at least 500 years ago.¹ This paper aims to develop an integrated vision on how Guaranian groups used physical space in this area.

For the archaeological analysis, comparative work was carried out on ceramics excavated from the three sites. The ceramics were analyzed both

¹ Cigliano 1968.

macro and microscopically, and are of the same type in the different excavated sandy areas.

Key words: Martín García Island, Archaeology, Geomorphology

Introduction

Martín García is an island situated on the delta of the province of Buenos Aires, in the South of the mouth of Uruguay River. It is in the area of Upper Río de la Plata and near the southern border of the lower delta of the Paraná and Uruguay rivers (Figure 1). It is 3.5 km from the Uruguayan coast and 46 km in a straight line from the city of Buenos Aires. It has a surface area of 168 hectares and a maximum height of elevation above sea level of 28 m.

The geological origin of Isla Martín García corresponds to Río de la Plata Craton, part of Brasilia Massif, which is over 1.8 million years old and is characterized as the 'Igneous-metamorphic Complex of *Isla Martín García*'.² The remnants of the complex form low mountain ranges in the south of Brazil, and in some areas in Uruguay and the province of Buenos Aires. This origin is different to the rest of the islands in the delta, which were formed by sedimentary accumulation from the Paraná and Uruguay rivers.

In Figure 1 can be seen a series of dunes on the Martín García island, probably formed by rivers. These have been modified through time, mainly by anthropic action and wind. At present, three clearly distinguishable sandy areas or dunes can be observed.³

Archaeological studies in the region can be traced back to the beginning of nineteenth century, and soon after the first excavation was made by Felix

² Dalla Salda 1981.

³ Ravizza 1984.

Outes.⁴ According to archeological evidence, the inhabitants of the island were Guarani communities.⁵ They settled in areas near watercourses,⁶ and their settlements were placed in high hillocks close to rivers, hidden in vegetation. These groups from the High Paraná, mainly canoeists, expanded into the Uruguay River until they reached Río de la Plata. It is likely that the migrations and dispersals were made through wetlands, particularly through the rivers mentioned previously. Their subsistence was based on hunting, fishing and gathering, complemented by the growing of pumpkin and corn.⁷

The arrival of the Guarani Indians to the Northeast of Argentina occurred in several phases from the tenth century.⁸ These movements were altered by the Europeans' arrival in 1516. The settlements in the island coincide with this last stage of migration, confirmed by radiocarbon dating of the charcoal remains of an aboriginal fireplace from one of the sites in El Arbolito de Molina⁹ whose result yields an age of 405 +/- 35 years ¹⁴C BP (GrN 5146), which corresponds to AD 1510-1580. According to the historical evidence, the Isla Martín García is considered the entry point of the first Europeans in Argentinean territory when Juan Díaz de Solís landed on the island.¹⁰ This milestone marks the division between prehistory and history in Río de la Plata.

⁴ Outes 1917.

⁵ Consult: Outes 1917; Maldonado Bruzzone 1931; Serrano 1933; Vignati 1936; Cigliano 1968; Caggiano 1984; Bogan 2005; Capparelli 2005, 2007, 2009.

⁶ Lafón 1971; Caggiano 1984; Noelli 2004.

⁷ Caggiano 1984.

⁸ Brochado 1973; Loponte and Acosta 2008.

⁹ Cigliano 1968.

¹⁰ Medina 1897; Gandia 1937.

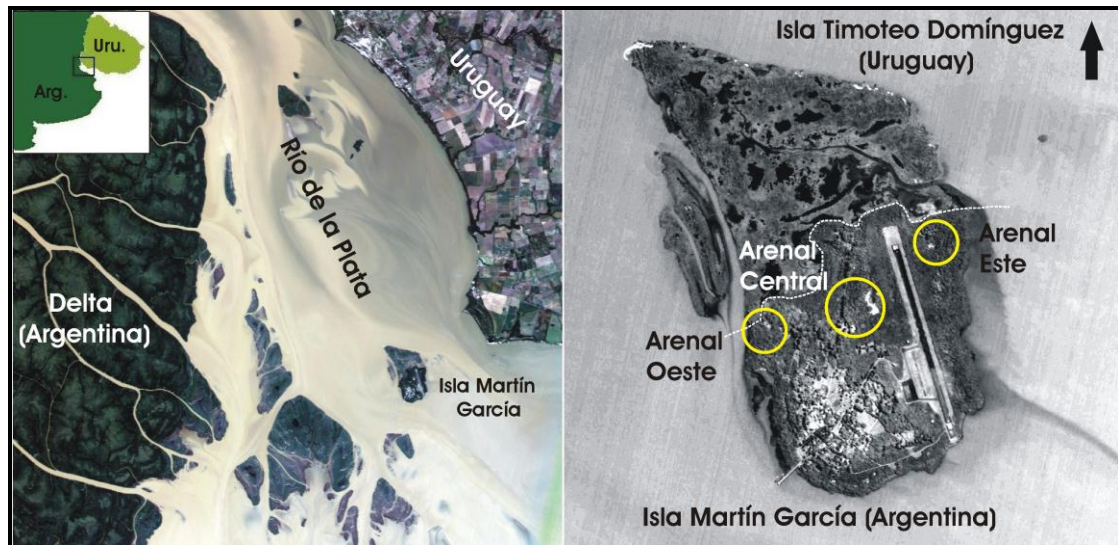


Figure 1. Left: General map with the position of Isla Martín García. Right: Isla Martín García. Notice the union with Timoteo Domínguez islet (the dotted line marks the boundary of both islands).

The fundamental characteristics of prehistoric Guarani groups are the presence of polychrome pottery (red and/or black on white slip and/or red) and corrugated pottery, secondary burial in urns, polished stone tools and the use of a rod of stone, bone or wood through the lower lip called tembetá.¹¹ This pottery became the 'guide fossil' of the entire culture.

Objectives

This investigation attempts to gather geomorphologic information about Isla Martín García through historical and comparative analysis of aerial photographs and modern satellite images, thus illustrating the variations in dunes and the coast through time.

It is necessary to take into account that in the current investigation the concept of site will be used merely in an operational manner since we are convinced of the existence of a continuity of use across the whole of the territory. That is why the notion of place as a standstill unit loses value in the

¹¹ Chmyz 1976.

face of population mobility and objectivation of the territory made by different societies in the past. Our objectives are to ensure that the three sites correspond to the same archaeological ethnic unity, without ruling out different times of occupation and even reoccupation. To confirm this we use ceramic material excavated from three sites because it is abundant evidence in the area. A comparison will be made between the ceramic material extracted from the Arenal Central site (Figure 2), the El Arbolito de Molina site and material extracted by Vignatti in 1935.

Ours results offer an integrative vision regarding the Guaraní groups' use of the physical space in a limited environment, such as an island; unlike the fragmentary view presented by earlier studies before our intervention. Analysis of the existing archaeological evidence integrated with geomorphological studies thus allows an understanding of how the Guarani use of these areas as settlements changed over time. To understand how space is used on the island it is necessary to first establish how the physical space was structured at the time that the Guarani groups were there; the use of space by the Guarani related to the mobility required to obtain resources. Our work is based on the archaeological data from sites linked to the sandy area because there is no archaeological evidence from the rest of the island. In this study we exclude issues related to the symbolic use of space by Guarani groups because it is not included among our objectives. But we recognize that is a potential aspect of analysis in land use by humans.



Figure 2. Arenal Central Site, Isla Martín García.

Hypothesis

The archeological studies carried out on the island to date offer a fragmentary interpretation of the use of space by settlements. These previous studies were based on excavations of single sandy areas in isolation, thus showing the space in a fragmented way, rather than a wider comparative study of the region as a whole.

From an integral conception of the use of space, and taking into account the contributions of different disciplines such as Archaeology, Geology and the analysis of satellite images and aerial photographs, we can propose that the three existing sandy areas are relicts of a sandy front deposited by a single geomorphologic process; and, thus, that the different archeological sites excavated at the three sandy areas constitute a single space of human occupation.

Materials and method

The use of maps and satellite images, of various dates, informs the hypothesis on which we base our work, and would support future investigations related to the use of space by the island's past inhabitants.

By using technological tools like Geographic Information Systems (GIS) and advanced software for processing satellite images and aerial photographs, it is possible to interpret the past without a need of an expensive and time consuming archeological excavation.¹² In the current investigation, remote sensing is considered to be the application of any method using electromagnetic energy that enables the retrieval of information with archeological relevance.

In order to understand the modification of the coastline, as well as the transformations of the sandy grounds, 1950 and 1969-70 aerial photographs were taken into account, in addition to images from the Chinese-Brazilian satellite CBERS 2B¹³ obtained by sensor HRC on February 4th, 2008 in orbit 163 C and point 138 4. This is a panchromatic satellite image in high resolution (2.7 m) that reveals details on the surface of the island. A CBERS 2 satellite image was also used. The multi-spectral sensor CCD, which has a space resolution of 20 m and was obtained on February 26th, 2004, made this image. Aerial photographs were converted to the projection of the satellite image (UTM 21S projection system and datum SAD 69) in order to overlap the three images. The software used for overlapping and creating the Terrain Digital Model (MDT) is ArcView 3.2.¹⁴

It is also necessary to take into account that even though new technologies contribute to research, they must be complemented by archaeological data, which enables the hypothesis to be more fully tested. For this reason, a comparison of pottery has also been made. Ceramics were analyzed both

¹² Bognanni 2008.

¹³ See www.inpe.br

¹⁴ See www.esri.com

macroscopically (Arenal Central site, Vignati site and El Arbolito de Molina) and microscopically (Arenal Central site and El Arbolito de Molina). Arenal Central site and El Arbolito de Molina are the two sandy areas excavated.

The archaeological material analyzed for the El Arbolito de Molina site is kept in two boxes in the deposit of *Museo de Ciencias Naturales de La Plata*.¹⁵ It was extracted from the northern area of the landing strip,¹⁶ which corresponds to the eastern sandy area of the island, near the aircraft runway.¹⁷ The author does not give an exact location. In the same deposit, there are two boxes with archeological material labeled as Luis Tosti with two dates in 1935. It can be inferred that the material is the one published by Vignati in 1936. The provenience is unknown but the label refers to a sand dune area. However it is unclear to which of the three areas it belongs.

Macroscopic techno-morphological analysis was applied to a total of 1802 fragments from the Cigliano and Vignati excavations and to pottery found in the Arenal Central site, which constitutes almost 70% of the total of the collection.

The comparisons were made based on technical and decorative aspects of the pottery and use regional archaeological terminology.¹⁸ Some modifications have been made:

Pottery with smooth decoration: presents a homogeneous finished surface with absence of other details such as cuts, lines, furrows or impressions.

Painted pottery: presents a finished surface with at least one of its external or internal sides painted. This category can be divided into monochromatic or

¹⁵ Natural Science Museum of La Plata (Buenos Aires).

¹⁶ Cigliano 1968.

¹⁷ Cigliano 1968.

¹⁸ Brochado 1973; Caggiano 1977.

poly-chromatic groups according to the quantity of pigments used in decoration.

Corrugated pottery: presents a textured surface, with overlapped imbricated patterns, similar to fish scales, as a result of finger pressure and the dragging of the paste.

Unguiculate pottery: presents a finished surface made by hand but without dragging of the paste. The fingernail of the potter can be seen on the surface.

In this investigation, petrography is very important since it allows a qualitative and quantitative analysis of different inclusions and pores, allowing us to learn about certain characteristics of pastes such as composition, structure, colour and texture. Furthermore, this geological technique is a valuable archaeological tool for the technological study of pottery. That is why we can consider the pottery as a metamorphosed sedimentary rock due to the composition and texture resemblances that this type of rocks presents.¹⁹

The microscopic analysis of four individual cuts in the pottery were examined (two from Arenal Central site and two from El arbolito de Molina) by INGEIS (*Instituto de Geocronología y Geología Isotópica*)²⁰ using a *Zeiss Axioplan 2 Hal 100* petrographic microscope, with a natural increase of 10x and other optical aggregates. Photographs were taken with a *Sony* digital camera using a zoom of 1.5x.

Results

Diachronic analysis of coasts and sandy areas

¹⁹ Curl 1987.

²⁰ Institute of Geocronology and Isotopic Geology.

Isla Martín García has unique characteristics among the set of islands that constitute Río de la Plata Delta because the combination of a crystalline base and sedimentary material, carried here by the Uruguay and Paraná rivers. The other islands of the area are entirely sedimentary.

Figure 3 shows how the coastline has been modified through the last 60 years, mainly on the northern shore. Due to the high rate of sedimentation in the north shore of Paraná River, there is a process of accretion that has resulted in the union of the island with a set of large islets that belong to the territory of República Oriental del Uruguay. This is why it is presently known as Complejo Martín García-Timoteo Domínguez²¹ and is the only frontier between Argentina and Uruguay that can be crossed on foot. Furthermore, the satellite image shows sand dune formation on Timoteo Domínguez islet's north shore. This is the result of the same acrecional action that affected Isla Martín García. This coincidence regarding the position of sand dunes (on the north coast) on both islands is not accidental since it was part of the same sedimentary process.

At present, Isla Martín García has a great quantity of vegetation that makes viewing the sandy areas difficult; in addition to this, urbanisation is also affecting the deposits. An example of this is the landing strip that crosses that the entire island almost longitudinally. A great difference regarding the limits of the shore can be seen if the aerial photograph from 1950 and the most recent ones are compared (1969-70 and satellite image 2008). The discrepancy is caused by a project to extend the landing strip by building a jetty to enlarge it towards the Uruguayan island of Timoteo Domínguez, which was later canceled.²² The withdrawal of the project was possibly due to the signing of '*Tratado del Río de la Plata y su Frente Marino*', completed on November 19th, 1973 between Argentina and Uruguay; in this treaty the dispute over Río

²¹ Dalla Salda 1981.

²² Alfonsín 2002

de la Plata came to an end and the jurisdictions of both islands were delimited.



Figure 3. Comparison of the boundaries of Isla Martín García. The base image is from satellite CBERS HRC from 2008.

Figure 4 shows a Digital Terrain Model (DTM) formed from a Triangulated Irregular Network (TIN), which is a vector model representing the terrain elevation from discrete vector objects such as contour lines.²³ In this case, given the relatively low-lying terrain as well as the small area of the island, all

²³ Conolly and Lake 2009.

of the contour lines at an equidistance of 1 m interval were successfully digitalized. However, it is necessary to take into account that:

TIN's principal disadvantage is that the surface of elevation withholds a triangular impression, which gives an unrealistic sensation to the model surface, although not necessarily inaccurate.²⁴

We understand that the island's crystalline base was the anchor for sediments from the Paraná and/or Uruguay rivers (see Discussion section) and this base, though coastal in the beginning, was retained thanks to the north coast's vegetation (composed mainly of floodplain shrubland and reed beds). Because these sediments were on the north of the island (an area of lower elevation -see Figure 4-) they were protected from aeolian erosion by the dominant winds of the region: *Sudestada* and *Pampero*. The *Sudestada* winds blow from the southeast with north-western direction and cause great flooding since they prevent the normal drainage of tributary rivers in Río de la Plata. On the other hand, the *Pampero* winds are cold winds that blow from the south or southwest towards the north or northeast.

Therefore, over time and by steady deposition of new sediments, the north coast formed by sediments from the Uruguay or Paraná rivers turned into the three sandy areas. At the same time, this transformation caused by the modification of the coast meant that the sandy areas were confined to the interior of the island.

²⁴ Conolly and Lake 2009:154.

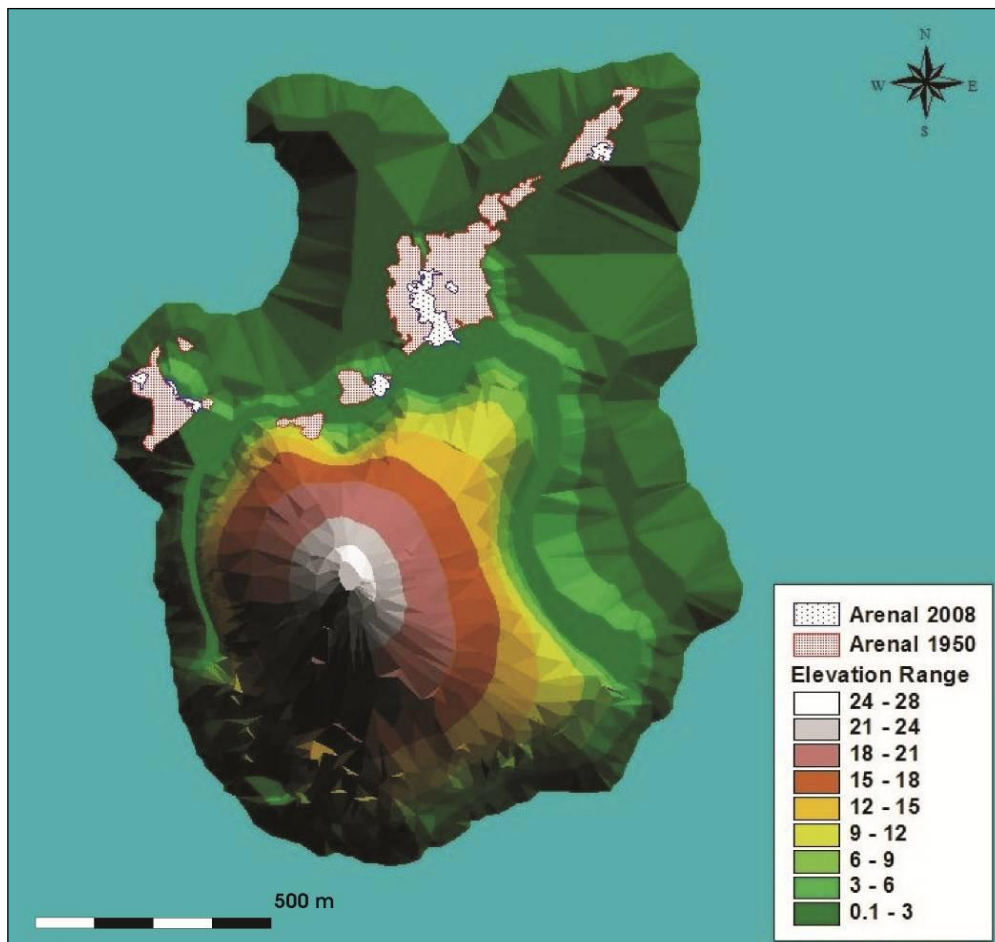


Figure 4. Digital Terrain Model of Isla Martín García. Note the decrease in size of sandy areas.

Also in the Figure 4, a reduction of sandy areas can be observed; by 2008 it was 15% the size it had been in 1950. The study of old aerial photographs shows how sandy areas have been modified through time. It is necessary to take into account that archaeological material can only be found in sandy areas, as they were the places where humans settled. In the rest of the island no archaeological material has been found, even though prospected several times.

The sandy area called Puerto Viejo, which corresponds to the area studied by Outes in 1917, is no longer visible. This area was intensely used because it was close to the ancient port. Near this port, the first village called 'Barrio

Chino²⁵ was built at the beginning of the nineteenth century, becoming a center of commerce.²⁶ During this time the sand was extracted from this area and sent to Buenos Aires to be used in industrial processes due to the small size of its grains. This event could have significantly altered the natural limits of the sandy area providing one probable cause for the disappearance of the dune areas.

The eastern sandy area is located in a restricted area; access is denied to the public in order to preserve the development of natural flora and fauna. It is located on the east of the island and is parallel to the landing strip. These sand dunes are younger and are almost entirely covered up by vegetation. A superficial survey and exploration has been made and indigenous materials have been found, which are similar to the materials collected in Arenal Central site. El Arbolito de Molina was located in this sandy area.²⁷

From 2003, there have been a number of excavations in the sandy area located in the center of the island at a place called Arenal Central, producing new results regarding Guarani communities in the area.²⁸

This site is located in 34° 10' 50.2" south latitude and 58° 15' 01.7" west longitudes, west of the landing strip. At present this is the largest sandy area. On its borders, towards the east, there are temporary lagoons that are located in depressions and a larger body of water is located in the north with a high grade of eutrophication. It is possible that these bodies of water were used in the subsistence strategy employed by the Guarani tribes. These temporary bodies of water may correspond to a lake identified as Laguna de las Garzas in the map of the island made in June 1887 by the Director of National Lazarettos, the engineer Miguel Decker. This lagoon, dry at present, was used

²⁵ Chinatown.

²⁶ Llambi 1972.

²⁷ Cigliano 1968.

²⁸ Bogan 2005; Capparelli 2005, 2007; Capparelli and Vázquez 2009.

until the mid-twentieth century by the inhabitants of the island 'as a place with crystalline waters where the sailors practiced rowing'.²⁹

The three sandy areas are in three sectors of the island and are the result of the same geomorphologic process since they have similar microscopic and macroscopic evidence. According to geological studies:

The three sandy areas correspond to geological units D, represented by sandy superficial accumulations. The one belonging to the bigger surface is in the center of the island. They are constituted by uncemented sands, chestnut-brown-colored, with a predominance of medium sands and coarse sands composed mainly of quartz. The individuals of minor fractions are colorless and the bigger ones are covered by a chestnut-colored patina, possibly because of iron oxide. Fossils were not found. A parallel stratification was observed, which has been determined by changes in the grain size and color and partially cross-stratification was also found. Its character, morphology and absence of fossils and lithology are similar to deposits in Uruguay River.³⁰

Geomorphological changes of the dunes sector led to a change in the current landscape, and therefore in the archaeological visibility.

Comparative analysis of pottery

The pottery found in the Arenal Central, El arbolito de Molina and Vignati sites constitutes the comparative base for descriptive techno-morphologic macroscopic aspects. On the other hand, microscopic analysis will apply only to materials from Arenal Central and El Arbolito de Molina.

²⁹ Girau 1988:53.

³⁰ Ravizza 1984:129.

Table 1 shows the quantities and types of pottery recovered from one hundred years of archeological excavations on the island. As can be observed, the categories previously described (pottery with smooth decoration, painted pottery, corrugated pottery and unguiculate pottery) are represented in every pottery set. The types of pottery found are the same at the three sites, but the totals between El arbolito de Molina and Vignati site, on the one hand, and Arenal Central on the other hand, differ considerably. Arenal Central has been the only site systematically excavated by the same work group through several archaeological expeditions.

Painted monochrome pottery is mostly red in its interior, although there are some pieces of smooth pottery painted red on both sides. Polychromatic paint can be seen in different combinations: black over red, red over white, black over white and black over cream. Figure 5 shows the four characteristic kinds of Guaraní pottery of the *Isla Martín García*.

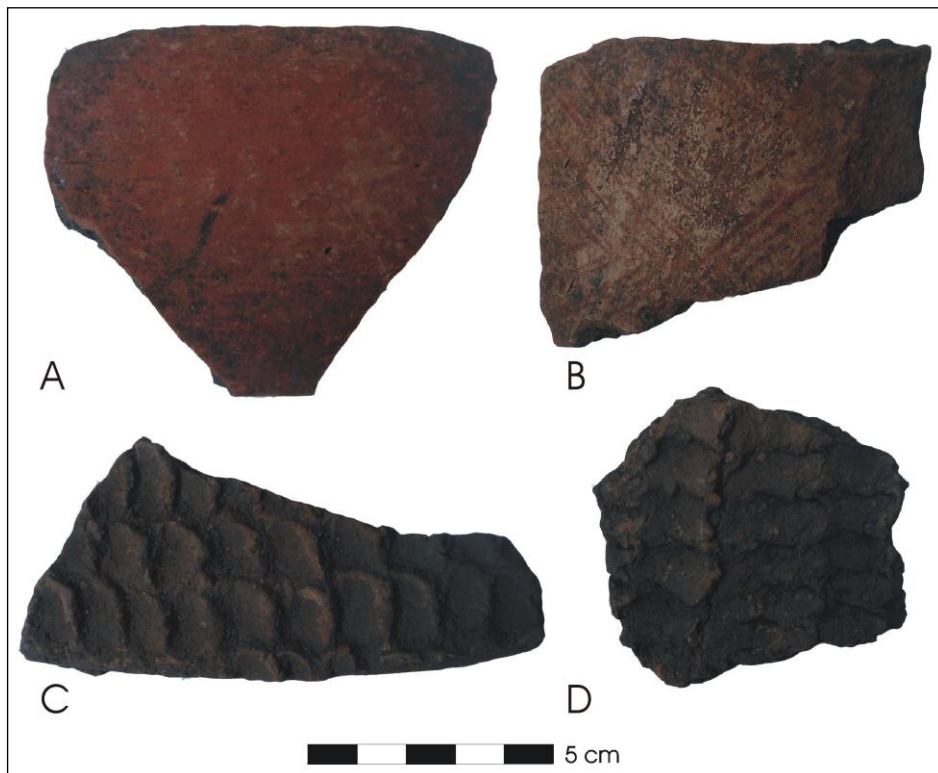


Figure 5. A: Painted monochrome pottery. B: Painted polychrome pottery. C: corrugated pottery. D: unguiculate pottery.

Regarding the firing of the pottery, the remains show the use of kilns with an incomplete oxidizing atmosphere, leaving the firing core darker. The external aspects of many of the sherds shows dark stains made by this type of firing, which have been seen in the entire set of materials.

Regarding retrieved forms, we consider rims as diagnostic in the absence of complete pieces. Using the technique described by Rice,³¹ the diameter of every piece has been calculated and straight rims, everted rims or rims with opened and closed shapes, have been observed. In every ceramic set there are pots with remains of grease in the internal walls, produced by the burning of some kind of vegetable or animal food. These analyses are currently in study.

Another characteristic that can be observed in every examined set is a technique that consists of rolled clay modeling. The smoothing marks and unions among rolls that remain are proof of the technique.³² The technique consists of the ceramic paste until the desired shape is achieved. This method has been repeatedly cited for the Guaraní's pottery.³³ Several fragments of rolls have been found as proof of this technique.³⁴

For the analysis of clay, several samples were excavated from the lagoon near Arenal Central site. The clay has a very plastic consistency and experimental works of firing at open cast kilns have been made. In this experiment we attempt to recreate the original conditions of ceramic production: sources of supply of raw material, similar characteristics of the clay and cooking under similar conditions.³⁵ These experimental pieces have the same colors, textures and types of firing as archaeological pottery. Some

³¹ Rice 1987.

³² Rye 1981.

³³ Outes 1917, 1918; Noelli 2004; Oliveira 2008; Ribeiro 2008; Pérez *et al.* 2009.

³⁴ Capparelli y Vázquez 2009.

³⁵ Pérez *et al.* 2009.

samples of the soil and sediments from some areas have been taken to be examined under comparative studies with the site's materials.

The results obtained and the presence of pieces of pottery with similar decorative characteristics, and techniques of manufacture enable corroboration of our hypothesis.

	Monochrome Painted Pottery	Smooth Pottery	Polychrome Painted Pottery	Corrugated pottery	Ungulate Pottery	Total
Arbolito						
de	15	193	5	109	10	332
Molina	(4.5%)	(58%)	(1.5%)	(33%)	(3%)	
Vignati	10	102	4	110	8	234
site	(4%)	(44%)	(2%)	(47%)	(3%)	
Arenal	192	507	16	279	242	1236
Central	(15.5%)	(41%)	(1%)	(22.5%)	(20%)	

Table 1. Comparison of amounts and percentages of the ceramic material excavated from three sites

Microscopic ceramic analysis shows that the color of the paste corresponds to the conditions of the firing of the vessels and also to the clay's chemical properties. The four samples show relatively dark pastes, ranging from dark brown to black (see Figure 6a). Anisotropy is frequent, which is defined as an interference of colors typical of pottery that has not reached high temperatures in the process of firing (see Figure 6b). The anisotropy revealed in most of the cuts is also supported macroscopically.³⁶ Indeed, we observed that the firing of ceramics is primarily oxidative and incomplete, resulting in well oxidized sides and black or very dark cores. This is a characteristic technical attribute of the Guarani groups.³⁷

³⁶ Pérez *et al.* 2009.

³⁷ Outes 1918; Noelli 2004.

Even though clay crystals cannot be distinguished, in some cases a singular texture generated by filosilicate banding can be found. This is known in metamorphic rocks as lepidoblastic texture. This has its origin in the realignment of the crystalline structure of clayey minerals, produced fundamentally by the kneading of the pieces (see Figure 6c).

Petrography makes it possible to explore some post-deposit processes that deal with the alteration, recrystallization and growth of minerals caused by the burial of pottery. In one of the cuts that belongs to Arenal Central site, devitrification was registered, a process through which glass changes from its amorphous state and begins a crystalline phase. The combination of this process with the fluidity of the matrix for a longer period of time enhances this tendency. When glass crystallizes, it can do it into different minerals such as opal or its by-product: chalcedony. In spite of the fact that devitrification has not been seen in the rest of the samples of Isla Martín García, it is a very common process in archaeological pottery. Therefore, the size of the sample needs to be enlarged in future studies.

The examined pastes show a low or light fluidity (see Figure 6d). In the cases where it could be determined, the uniform orientation of the elements occurs only in certain areas of thin cuts, especially in the areas that are in contact with inclusions and/or cavities. These cavities, which all the ceramic pastes have, present geometry, sizes and dispositions that are related to the intensity of the kneading, the modeling technique of the pieces, the composition of the paste, the loss of water during the drying process and the contraction of components. The four observed pieces show an elevated porosity.

Regarding the inclusions, the samples from the El Arbolito de Molina and the Arenal Central sites indicate a similar composition. Among the minerals, there is a presence of quartz, feldspars (included plagioclase) and opaque minerals; especially iron oxides (hematite and magnetite) (see Figure 6e).

There are also animal remains, called bioclasts, to consider. Among the excavated elements, foraminifers, seashells and echinoderms are frequent and can be easily identified due to their carbonate composition. Diatoms are microorganisms abundant in many types of silt. Right after their deposition, bioclasts are generally replaced by silica.

Anti-plastic material is also incorporated (see Figure 6f). The percentage of this element in the total composition of analyzed pastes is over 15%. It is likely that its use is related to a limitation in other types of organic and/or mineral inclusions. Moreover, pot ground is found in a great quantity of most of the Guaraní's pottery, in sets spanning several eras of this great distribution of this tradition, from the Brazilian Amazon to the Paraná Delta and the estuary of Río de la Plata.³⁸ The pot ground was used as temper.

Inclusions of lithic fragments are particularly abundant in sets of Guaraní pottery, although these samples have not seen lithic inclusions in a microscopic level. However, in the macroscopic analyses many lithic fragments are observed.

³⁸ Consult: Pérez *et al.* 2009; Pérez 2009

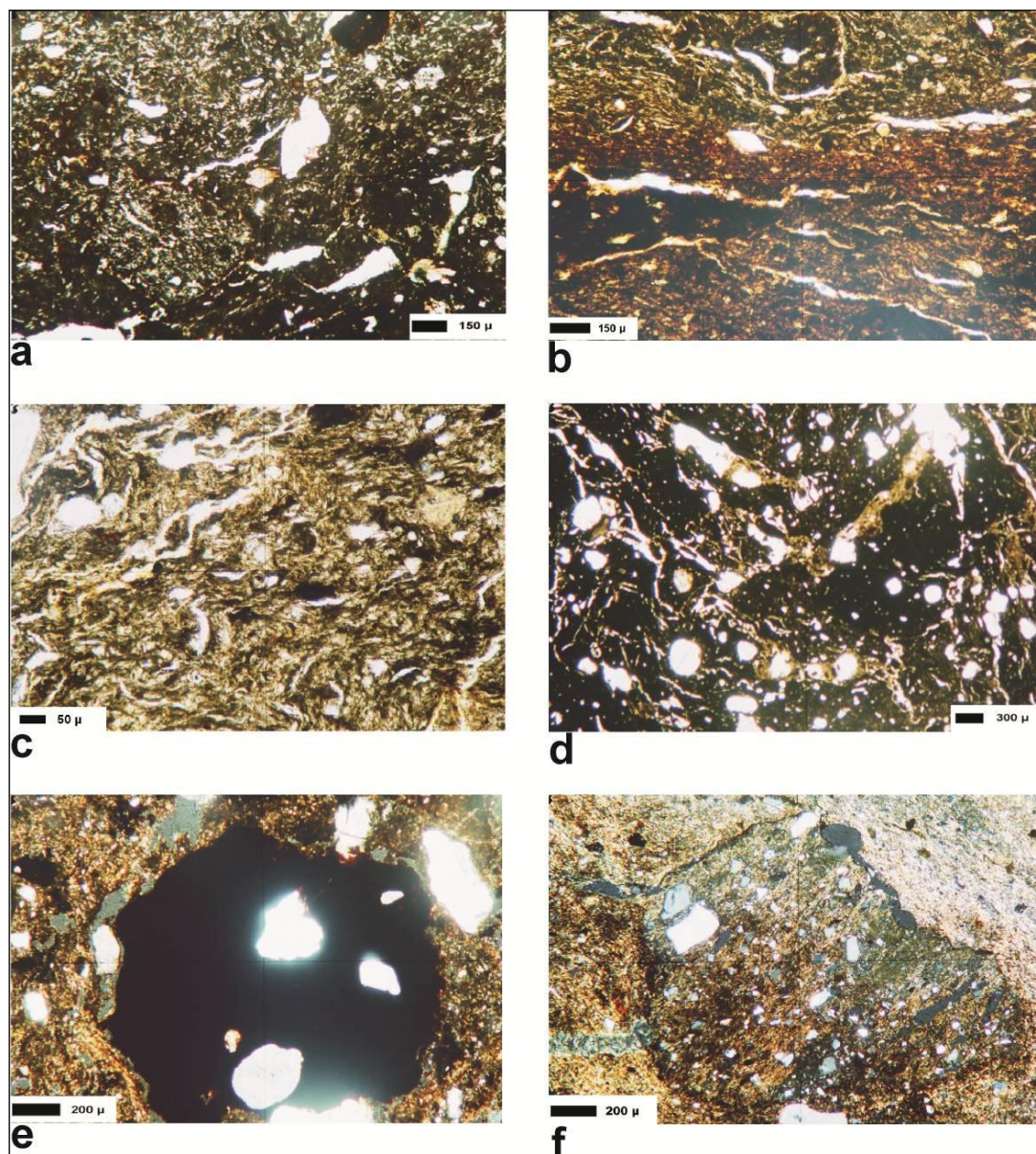


Figure 6: a: Dark paste from a cut from El Arbolito. b: Different colors in ceramic paste from Arenal Central site. c: lepidoblastic texture in a cut from El Arbolito, where the organizing components are recognized, including the cracks d: Scarce fluidity in a sample from El Arbolito. See the different orientations of inclusions and pore. e: Opaque mineral with quartz granules in its interior. The reddish border suggests that it is hematite. f: Pot ground in a paste from Arenal Central site. Angular outlines, contrasting composition and different constituent members in the matrix that holds them.

Discussion

Archeological studies in Isla Martín García throughout the twentieth century did not consider the use of space in an integrated manner, but considered each place as a circumscribed occupation site, without taking into account the information obtained in other areas of the island. Recent studies of groups Guarani in Brazil consider the sites hold an occupation area of about 200m².³⁹ The distance between the sites analyzed is around 500m; it might be possible that each site was a part of an archaeological macro-unit used in different time periods, but separated by short time.

If the sedimentary process of the island is taken into account, it is likely that the three sandy areas are relicts of a bigger sandy area that was located on the north coast and was the place of Guarani settlement groups which were moving south using canoes mainly on the margins of the Uruguay River, as well as other rivers in the region. The use of coasts by Guarani groups in the continental area is documented⁴⁰ and as it is before the arrival of these people at Isla Martín García, one of the most southern, thus being reached later. Multiple analyses of archeological records and the geomorphology of the island enable an understanding of the landscape not only as a consequence of historic processes but also as a complex integration of environmental and human activity; these modifications are conditioned by the social, political and economic characteristics of the groups that accomplish them.⁴¹ Here is where the method acquires its main importance: the use of Geographic Information Systems, microscopic and macroscopic analysis of pottery allows theoretic deductions to be generated from empiric elements.

The integration of segments of this information with the spatial characteristics of Geographic Information Systems (GIS) enables the presentation of certain results:

³⁹ Prous 2011.

⁴⁰ Among others: Lafón 1971; Caggiano 1984.

⁴¹ Álvarez González 1993.

The connection of space remote sensing with a GIS is, to our judgment, the more logical conclusion of the use of this technique. It offers enormous possibilities to make environmental studies, evaluation of resources, analysis of impacts, models of location, etc. With the support of these informatics technology systems, the scholar of the natural (or social) environment may worry more about the analysis than obtaining the information.⁴²

The combination of these technologies enables us to get an overview of a series of elements and processes that affect and/or affected the geomorphology of the island.

The possibility that the three sandy areas that exist nowadays in *Isla Martín García* were deposited by the same geomorphologic process is highly plausible, since the sedimentary characteristics, as has been discussed previously, are similar. However, the discussion about the origin of these sediments continues: were they transported by the Uruguay River or the Paraná River? Some authors like Ravizza (1984) and Groebber (1961) base the intervention of the Uruguay River on the sand's detritus and make an account of the process:

Subfluvial delta is situated in front of the mouth of the effluents of the Paraná River. There, it deposits the dragged material because of the cessation of its effluents, restrained by almost stagnant waters from the Río de la Plata. A subfluvial delta is formed, whose outlines are determined by the current of the Uruguay River in the Northeast and by the one belonging to the Luján River in the South. The Uruguay River and its detritus collaborate with the edification of subfluvial delta. This can be inferred from minerals of crystalline base from Brasilia found among sands, absents in Paraná's silt.⁴³

⁴² Chuvieco 1990:413.

⁴³ Groebber 1961:34-35.

However, other authors believe that Paraná River has a part in the phenomenon under consideration and estimate that:

The Uruguay River joins Paraná in the delta area but has no influence in the evolution of the delta (...) the area of sedimentation of the Uruguay ends at Gualeguaychú's area, in the North of the confluence (...) Uruguay River has its own delta, and its evolution reproduces, in a minor scale, the same events that the Paraná River went through. At present, the delta complex gets completely flooded during Paraná's big rises in the level of its waters, which occur once every several years. The rise of the Uruguay and Gualeguaychú river level can produce partial floodings in the Oriental area. Sudestada Winds's effects can be important, raising the water level to 2.5 meters above ground in some areas. The inferior delta is affected by tides, which have a normal amplitude of one meter. In spite of the fact that some of these agents can produce spectacular floodings, the exclusive morphogenetic agent of delta area is the Paraná River itself.⁴⁴

Cavalloto and Violanti also consider that:

Sediments that reach the Río de la Plata come, almost entirely, from the Paraná River (mainly Paraná de las Palmas and Paraná Guazú), with an average of contribution of sediments of 79,800,000 tons a year. Of this total, some 10% are bottom sediments (sand and silt) and 90% is material carried in suspension (clays).⁴⁵

The rise of the delta not only causes modification of its shape, but it also affects the archeological visibility of the area, including Isla Martín García. This rise is a fact that favors the validation of our hypothesis of a single archeological site that at the present has been fragmented due to different natural and cultural reasons.

⁴⁴ Iriondo 1980:77.

⁴⁵ Cavalloto and Violanti (without date); [http:// www.atlasdebuenosaires.gov.ar](http://www.atlasdebuenosaires.gov.ar)

In addition, the analysis of the ceramic material of the three sandy areas, which is the most abundant archeological record in the island, shows a similarity among their features. In the Arenal Central site, faunal and floral remains were gathered, but they were not taken into consideration in this work because we do not have comparative material from the other excavations; this absence may be due to the expeditious character of previous interventions, as a consequence of anthropic modifications (construction of the landing strip, extraction of sands, etc.) or environmental influences on preservation. With regard to this matter, it is said about littoral zones that:

Stratigraphic dating possibilities are again excellent at such localities, although environmental aspects are more difficult to reconstruct. Organic materials, apart shell and bones, are more likely to be absent.⁴⁶

Conclusions

After examining images and maps from different time periods, we observe the presence of a vast front of uniform sand dunes that used to occupy the area along the north coast and that nowadays continues receiving sedimentary deposit. We checked that the areas of current sand dunes are relicts of this great area. In order to be able to identify the sites as contemporary, it was important to complete a comparative analysis of ceramic materials that support our investigation. This way we observed than examined pottery, macro and microscopically analyzed, is the same in the three sandy areas.

In spite of the lack of archaeological evidence from the rest of the island, it is very probable that the Guarani groups used the entire island for different activities; however their settlement was limited to the dunes zone.

⁴⁶ Butzer 1972:237.

In less than 60 years, the north coast and sandy areas have suffered a great alteration. The coast suffered the accretional dashing of the Uruguay and/or Paraná rivers, uniting *Isla Martín García* to the Timoteo Domínguez islet and forming an archipelago that practically doubled its surface area.⁴⁷

In addition, we consider that one of main causes of the modification of the sandy areas was, without a doubt, human action. This was due to the extraction of sand during urban growth, mainly observed at the construction of the landing strip.

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⁴⁷ Codignotto 1996

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