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Isotopic evidences regarding migration at the archeological site of Praia da Tapera: New data to an old matter

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ABSTRACT

The present study aims to elucidate, using $\delta^{13}C$, $\delta^{15}N$ and $^{87}Sr/^{86}Sr$ analysis of tooth enamel and dentin, some aspects of the geographic origin and the dietary habits of 42 individuals associated with a ceramic group buried in the coastal shallow site of Praia da Tapera, located on the island of Santa Catarina, Southern Brazil. The ceramic shreds found on this site would be associated with groups that inhabited the Southern Brazilian Plateau, and the presence of this evidence at Praia da Tapera and some other coastal sites raises important questions, not yet resolved, about the origin and the way of life of these pre-Columbian coastal groups that emerged in the region around 1500 years BP.

The isotopic results suggest that none of the analyzed individuals would have come from the Plateau region. They probably were born and raised on the coast, including the site area. The wider $^{87}Sr/^{86}Sr$ variation found in the women may be signifying a patrilocal post-marital residential system to this group. The isotopic results also suggest that marine resources such as fish were the main food source. Despite the terrestrial fauna not being an important part of the protein diet, the boars analyzed from the site presented strontium values incompatible with the local geology, suggesting that these animals were hunted on the continent. This first isotopic study on a shallow coastal site with ceramic reinforces the idea of complexity regarding migration and trade networks between groups that inhabited the coast and the Plateau of Serra Geral around a thousand years before the arrival of Europeans in the region.

1. Introduction

The occupation of the coast of Santa Catarina state, located in southern Brazil, happened about 6000 years B.P. The first inhabitants were fisher–gatherer groups that built shell mounds that could reach more than 30 m in height and some hundreds of meters in length, known in Brazil as Sambaquis (Prous, 1991, DeBlasis et al., 1998). The Sambaqui builders, however, were not alone on the coast; there were other hunter–fisher–gatherer groups in the area since at least the fourth millennium before the Christian era, as indicated by radiocarbon dating of the deepest levels of the site of Pantano do Sul (Rohr, 1977, Schmitz and Bittencourt, 1996). These groups occupied sites known as "shallow sites", which are primarily characterized by thin archeological packages, a much less significant number of shells compared to the Sambaqui sites and a predominance of fish among the faunal remains, although a high diversity and quantity of terrestrial fauna is also found.

Radiocarbon dates available for the coastal sites indicate that around the first millennium of the Christian era the Sambaqui system was already in decline (Gaspar, 1996, Lima, 1999/2000). Simultaneously to the end of this system, the coastal occupation is marked by the appearance of shallow sites with ceramics. This ceramic type, associated with the Itararé ceramic tradition, was originally related to ceramic groups from the Plateau of Serra Geral in Santa Catarina, which is located about 100 km away from the coast.

The ceramics found on the coast associated with groups that inhabited the plateau is a topic of great relevance for understanding the occupation process in this area, which includes issues such as migration and intergroup contacts. These topics are widely discussed in different perspectives and methodology by Brazilian archeologists (e.g. Beck,

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1972, Chmyz, 1976, Rohr, 1977, Neves, 1988, Bryan, 1993, Lessa, 2005, Okumura, 2007, Wesolowski, 2007, Hubbe et al., 2009, Bastos et al., 2011).

The main discussions are about the possibility that horticultural ceramic-producing groups from the plateau occupied these shallows sites. Therefore, the present study aims to contribute to the understanding of the geographic origin and diet of the occupants of these ceramist sites by doing the first isotopic study on shallow sites with ceramic, more precisely tooth enamel strontium isotopes analysis ($^{87}Sr/^{86}Sr$) and carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotope analysis of the collagen contained in the dentin of individuals buried at the Praia da Tapera site, a shallow ceramist site located on the central coast of the state of Santa Catarina. From these results, we expect to identify whether the analyzed individuals were born on the coast or have migrated from the Southern Brazilian plateau.

Isotopic analyses have been used for decades in archeology as important tools to identify residential mobility and reconstruct diets in different past groups, with strontium isotopes being commonly used to identify immigrants in archeological populations (Price et al., 2002, Bentley, 2006), while carbon and nitrogen stable isotopes can distinguish, among other aspects, diets based on marine or terrestrial food (Ambrose, 1993).

1.1. Santa Catarina Island and Praia da Tapera Site

Praia da Tapera is located on the island of Santa Catarina, southern Brazil, which is characterized by Neoproterozoic (1 Ga to 530 Ma) crystalline basement rocks and by Quaternary coastal plains deposits (Caruso and Awdziej, 1993) (Fig. 1). In contrast, the Santa Catarina Plateau is formed by Cretaceous basalts that form plateau areas as high as 1800 m above sea level (Perrotta et al., 2004). These two areas are separated by the Serra Geral and Serra do Mar. mountains ranges, which are important physiographic features in that portion of South America.

The site is located on the South Bay of the Santa Catarina Island, about 20 km from the city of Florianopolis, the capital city of the state of Santa Catarina. It is situated in a plain area, next to the ocean and a creek. Around the area there is also a big mangrove which extends for more than 4 km, a wide area of shallow lands and the Atlantic forest on the higher grounds (Rohr, 1966, Silva et al., 1990).

The site was excavated between the years of 1962 and 1966. It was excavated to a total area of 2000 m^2 and in it were found scattered shells, charcoal, numerous lithics, bone artifacts, food debris, 172 human burials and 4631 ceramic shreds (Rohr, 1966). Fig. 2 shows the Beach of Tapera and the site excavation during the decade of 1960s.

According to Silva et al. (1990), there were a total of three occupation periods in the site of Praia da Tapera. The first two occupations are associated with the Itarat´e ceramic tradition, presenting radiocarbon dates of 1140 $\pm$ 180 B.P. and 1030 $\pm$ 180 B.P. The first occupation lasted around 100 years and was formed by a small group of individuals that buried their dead under their dwellings. The second occupation was composed by a larger number of individuals that remained longer in the area and buried their dead in delineated areas next to their houses. The last occupation occurred much later (550 $\pm$ 70 B.P.) and was associated with another group, the Tupiguarani. This last occupation is restricted to the farthest portion of the site from the beach, on the periphery of the village of the former occupations. All the human burials were concentrated in a 608 m^2 area and are believed to be associated with the Itararé occupations.

All lithic, bone tools and food debris found in the archeological site point to a fishing, hunting and gathering economy. The terrestrial and

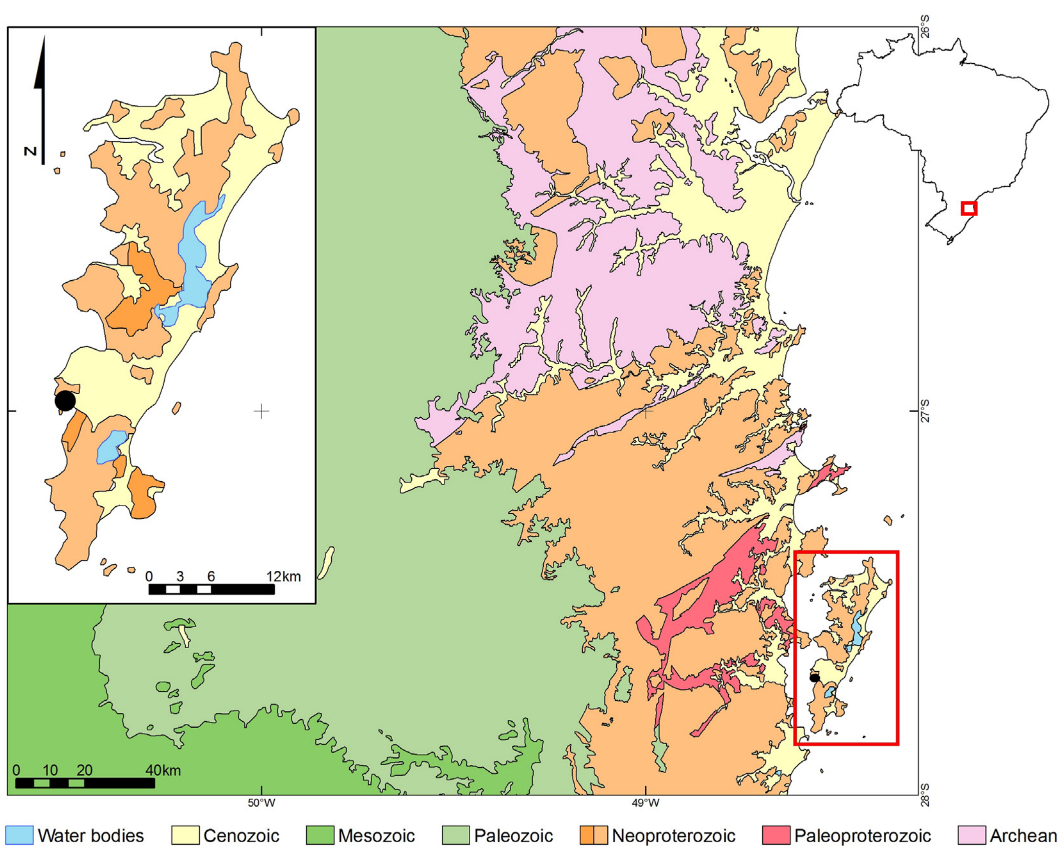

Fig. 1. Geological map of part of the coast and interior of Santa Catarina. The island of Santa Catarina is magnified and the site Praia da Tapera location is identified with a black circle. The outline of Brazil is in the upper right corner.

Fig. 2. Top picture shows the beach of Tapera, where the Praia da Tapera site is located. The bottom picture shows the excavation of a burial (Collection Museu do Homem do Sambaqui/Colégio Catarinense).

marine fauna are well represented on the site. Besides the many species of mollusks and fish (Teleosts and Chondrichthyes), bones of terrestrial and marine mammals such as the tapir, whales, ocelot, howler monkey, capybara, wild cat, jaguar, paca, sea lion and boar have been identified (Silva et al., 1990).

1.2. Strontium isotopes ($^{87}Sr/^{86}Sr$)

The geographic origin determination of human remains by strontium isotopes is based on the ratio between the isotopes ^{87}Sr e ^{86}Sr of this element, which varies according to the type and age of the rocks that compose the surface of a given region. While ^{87}Sr is formed by the radioactive decay of the ^{87}Rb isotope, ^{86}Sr doesn't change over time. Thereby, old rocks rich in rubidium which had more time for radioactive decay of the ^{87}Rb present high ^{87}Sr/^{86}Sr ratios. Meanwhile, younger rocks have less time for ^{87}Rb undergoing decay and hence have lower ^{87}Sr/^{86}Sr ratios (Faure, 1986).

The strontium isotope ratio doesn't change during the soil formation process or during the food chain (Sillen and Kavanagh, 1982). Thus, the strontium isotopic composition observed in plants and in the fauna is related to the sources found in the environment that are rich in strontium such as soil, water and atmosphere (Miller et al., 1993; Bentley, 2006).

Strontium tends to replace calcium in biologic processes such as in the hydroxyapatite crystals of bones and teeth. Teeth don't suffer remodeling throughout life and, because of that, the strontium present in the tooth of an individual is related to the food and water ingested during the tooth formation, which occurs in the early years of that individual's life, varying according to the analyzed tooth (Ericson, 1985; Hillson, 1996). Thereby, analyzing an individual's tooth provides the ^{87}Sr/^{86}Sr signature of the region that he or she inhabited during childhood, and so it is possible to distinguish, in an archeological site, those individuals that are local from those who are immigrants (Schweissing and Grupe, 2003, Price et al., 2002). Usually strontium analyses are performed on tooth enamel since this tooth part is more resistant to post-depositional contamination than the dentin and bones (Hillson, 1996; Montgomery et al., 1999).

1.3. Stable carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes

The reconstruction of the diet from isotopes assumes that the isotopic composition of carbon and nitrogen in the body is directly related to food intake (Ambrose, 1993). Carbon stable isotopes have been used to distinguish plants that present the C3 photosynthetic pathway (e.g. wheat, rice, manioc and yams) from plants that presents the C4 pathway (maize, millet and sorghum). While C3 plants shows quite negative δ^{13}C values, between −34‰ and −23‰, C4 plants values are from −17‰ to −9‰. These different δ^{13}C values found in plants are passed on to their consumers and, by analyzing the δ^{13}C present in the consumers' tissues, it is possible to determine whether they had a diet based on C3 or C4 plants, or a mixture of both (Smith and Epstein, 1971, Schoeninger and DeNiro, 1984, Ambrose, 1993).

Stable carbon analysis can also discriminate terrestrial and marine diets. This distinction is possible due to the 7‰ difference between the δ^{13}C found in the atmospheric CO_2 and the bicarbonate dissolved in sea water. Therefore, the marine biota presents δ^{13}C values less negative than terrestrial C3 plants. Carbon isotope analysis alone cannot distinguish, however, a marine diet from a C4 terrestrial diet, since there is an overlap in the carbon isotopic values of these two food sources (Schoeninger and DeNiro, 1984, Schwarcz, 1991).

Nitrogen stable isotopes can be used to evaluate the diet's trophic level of a given individual, distinguishing if the eating habits were based on plants or meat. The nitrogen present in the atmospheric air has a δ^{15}N equal to 0‰, and enriches between 3‰ to 4‰ during each level of the trophic chain (Schroeninger et al., 1983). Thus, plants present δ^{15}N lower than herbivores, which have inferior values compared to carnivores. In marine environments, the δ^{15}N can reach higher values when compared to terrestrial environments because there are a greater number of trophic levels in the ocean and a difference around 4‰ between the terrestrial and marine autotrophic organisms (Ambrose, 1993, Yoder, 2010). In general, humans who have a diet based on land resources, such as plants, present nitrogen isotopes values around 10‰, while individuals who consume a large amount of marine resources may have values above 20‰ (Schoeninger and DeNiro, 1984).

The carbon and nitrogen contained in the collagen of bones and teeth are related to the protein diet of the analyzed specimen. Bones remodel during life, providing isotopic information only about the last years of an individual's life. Teeth, on the other hand, keep the δ^{13}C and δ^{15}N values of foods consumed during the period that they were formed (Ambrose, 1993), which starts during pregnancy and finishes at early adulthood, varying according to each tooth (Hillson, 1996).

2. Material and methods

The skeletal remains analyzed in this study are composed of 42 adult individuals (42.8% of all adults) excavated from the archeological site of Praia da Tapera during the 1960s. The skeletal remains are located at the

Museu do Homem do Sambaqui in the city of Florianópolis, Santa Catarina state. We estimated the sex of all individuals using the Buikstra and Ubelaker (1994) protocol for pelvic and cranial markers. For the isotopic analysis we selected a pre-molar tooth of each individual, i.e. a permanent tooth that has the enamel formed from around two years old until seven years old, and the dental root formed between six and eleven years of the individual's life (Smith, 1991, Hillson, 1996, Scheid, 2007). Some adult individuals could not be included because they presented high stages of dental wear (a common pattern for these populations) and didn't have enough enamel for strontium analysis. Since this is a destructive analysis, we did not include teeth that presented any pathology, dental calculus, specific dental wear or any other feature that could be important for further bioarcheological studies.

In addition to the human pre-molars, we analyzed terrestrial fauna from the Tapera site, which includes teeth from an oncilla (*Leopardus tigrinus*), an ocelot (*Leopardus pardalis*), a paca (*Cuniculus paca*), an agouti (*Dasyprocta aguti*), a capybara (*Hydrochoerus hydrochaeris*) and a mandible fragment and teeth from three boars (*Tayassu tajacu*). A shell from the bivalve *Anomalocardia brasiliana* was also analyzed.

All human and faunal remains selected in this study were mechanically and chemically cleaned in order to remove post-depositional contaminants that could change the biogenic isotopic values (Wright and Schwarcz, 1998). In order to remove post-depositional contaminants all samples were brushed and scraped with a toothbrush and a scalpel, followed by an ultra-sonic bath for 20 min in deionized water.

The $^{87}Sr/^{86}Sr$ analysis was performed on enamel, which is the most resistant fraction of the teeth in terms of diagenetic contaminations (Hillson, 1996, Sharp et al., 2000). From each tooth we removed around 10 mg of enamel with a dental drill. The enamel powder was placed in a Teflon beaker and soaked in acetic acid 0.5 M for 1 h in order to remove possible carbonate contaminants, and then rinsed in deionized water. After dissolving the powder by adding nitric acid (14 N) for 1 h, the solution went through a chromatographic separation with a resin SR-B50-A (Eichron) in a 2.9 N solution of nitric acid. The strontium isotope ratios were determined using a Neptune MC-ICP-MS™ spectrometer (Thermo Scientific) of the Geochronology Laboratory of the Universidade de Brasília. The accuracy and reproducibility of the analytical protocol was verified by a standard solution of 100 ppm Sr reference material NIST SRM 987.

For $\delta^{13}C$ and $\delta^{15}N$ analyses we collected between 200 and 300 mg of dentin from each tooth. The samples were soaked in NaOH 0.1 M for 24 h for humic acid neutralization. After being rinsed in deionized water the samples were soaked in HCl 0.25 M for 72 h for demineralization. After another NaOH step, the lipid residues were removed with a 2:1:0.8 chloroform, methanol and water solution. The collagen pseudomorphs were then rinsed and dried overnight. The samples were

Table 1
Isotopic results of the individuals analyzed from Praia da Tapera.

Lab ID	Sex	Tooth	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ collagen	$\delta^{15}N$ collagen	C:N ratio	% of collagen
T2	Female	Pm1	$0.71035 \pm 1 \times 10^{-5}$	−11.2	18.5	3.2	12.3
T4	Female	Pm2	$0.70980 \pm 1 \times 10^{-5}$	−11.9	20.1	3.2	9.5
T11	Male	Pm2	$0.71113 \pm 2 \times 10^{-5}$	−11.6	17.5	3.3	11.6
T12	Male	Pm2	$0.71111 \pm 1 \times 10^{-5}$	−10.8	16.7	3.4	7.5
T14	Female	Pm1	$0.71074 \pm 1 \times 10^{-5}$	−11.5	18.0	3.3	9.8
T16	Female	Pm1	$0.71054 \pm 8 \times 10^{-6}$	−10.7	16.9	3.2	12.4
T18	Female	Pm1	$0.70994 \pm 1 \times 10^{-5}$	−10.9	19.1	3.2	7.4
T19	Male	Pm2	$0.71084 \pm 2 \times 10^{-5}$	−10.9	17.3	3.2	10.9
T20	Female	Pm2	$0.71125 \pm 1 \times 10^{-5}$	−12.3	17.4	3.2	10.9
T23	Female	Pm1	$0.71090 \pm 8 \times 10^{-6}$	−11.2	16.3	3.2	9.4
T28	Male	Pm2	$0.71139 \pm 1 \times 10^{-5}$	−11.1	16.9	3.2	9.3
T31	Female	Pm1	$0.71068 \pm 2 \times 10^{-5}$	−10.4	17.0	3.2	14.9
T32	Female	Pm1	$0.71016 \pm 1 \times 10^{-5}$	−12.4	19.2	3.2	7.9
T34	Male	Pm1	$0.71062 \pm 1 \times 10^{-5}$	−9.9	16.6	3.2	12.2
T35	Male	Pm1	$0.71139 \pm 1 \times 10^{-5}$	−10.5	16.4	3.3	8.4
T39	Female	Pm1	$0.71198 \pm 1 \times 10^{-5}$	−12.3	16.6	3.3	12.7
T41	Female	Pm2	$0.70992 \pm 1 \times 10^{-5}$	−12.4	19.0	3.3	8.6
T42	Male	Pm1	$0.71147 \pm 1 \times 10^{-5}$	−10.7	17.0	3.3	14.0
T56A	Male	Pm2	$0.71119 \pm 1 \times 10^{-5}$	−11.0	17.5	3.1	14.2
T63	Male	Pm1	$0.71150 \pm 3 \times 10^{-5}$	−11.5	17.1	3.2	12.7
T66	Female	Pm1	$0.71061 \pm 6 \times 10^{-6}$	−9.6	16.8	3.1	12.4
T72	Female	Pm1	$0.71101 \pm 1 \times 10^{-5}$	−10.7	16.7	3.2	13.7
T73	Female	Pm2	$0.71074 \pm 1 \times 10^{-5}$	−11.0	17.8	3.1	14.3
T97	Male	Pm1	$0.71084 \pm 1 \times 10^{-5}$	−11.2	16.9	3.2	13.4
T98	Female	Pm1	$0.71052 \pm 1 \times 10^{-5}$	−10.5	16.7	3.1	14.3
T100	Female	Pm2	$0.71189 \pm 1 \times 10^{-5}$	−10.8	16.4	3.1	10.7
T107	Female	Pm1	$0.71031 \pm 1 \times 10^{-5}$	−11.1	17.0	3.1	13.5
T115	Female	Pm2	$0.71033 \pm 1 \times 10^{-5}$	−11.9	19.8	3.1	8.8
T117	Female	Pm1	$0.71143 \pm 8 \times 10^{-6}$	−11.3	17.3	3.1	11.0
T119	Male	Pm1	$0.71103 \pm 1 \times 10^{-5}$	−10.8	17.0	3.2	7.9
T122	Female	Pm2	$0.71149 \pm 1 \times 10^{-5}$	−11.5	16.4	3.1	11.8
T125	Male	Pm1	$0.71060 \pm 2 \times 10^{-5}$	−11.1	17.7	3.2	13.2
T131	Female	Pm2	$0.71113 \pm 1 \times 10^{-5}$	−11.0	17.5	3.2	10.5
T146	Female	Pm2	$0.71099 \pm 1 \times 10^{-5}$	−10.7	18.2	3.2	12.4
T150	Female	Pm1	$0.71221 \pm 1 \times 10^{-5}$	−11.1	17.2	3.1	12.9
T152	Female	Pm2	$0.71060 \pm 1 \times 10^{-5}$	−12.2	18.5	3.2	10.7
T156	Male	Pm1	$0.71150 \pm 2 \times 10^{-5}$	−12.1	17.0	3.4	5.6
T158	Male	Pm1	$0.71098 \pm 1 \times 10^{-5}$	−10.2	17.9	3.3	10.4
T159	Male	Pm1	$0.71054 \pm 8 \times 10^{-6}$	−10.3	18.8	3.3	11.8
T166	Male	Pm2	$0.71087 \pm 1 \times 10^{-5}$	−10.8	20.7	3.3	10.2
T167	Male	Pm1	$0.71024 \pm 1 \times 10^{-5}$	−10.3	20.8	3.4	12.9
T169	Female	Pm2	$0.71026 \pm 8 \times 10^{-6}$	−10.8	20.8	3.3	11.7

Pm — premolar.
L P — lower premolar; U P — upper premolar.

Table 2
Faunal isotopic results from the site of Praia da Tapera.

Id	Species	$^{87}Sr/^{86}Sr$	$\delta^{13}C$ collagen	$\delta^{15}N$ collagen	C:N ratio	% of collagen
Capybara	*Hydrochoerus hydrochaeris*	$0.71319 \pm 6 \times 10^{-6}$				
Oncilla	*Leopardus tigrinus*	$0.70988 \pm 1 \times 10^{-5}$	−9.4	15.5	3.4	12.5
Ocelot	*Leopardus pardalis*	$0.71182 \pm 1 \times 10^{-5}$				
Boar 1	*Tayassu tajacu*	$0.71786 \pm 1 \times 10^{-5}$				
Boar 2	*Tayassu tajacu*	$0.72173 \pm 8 \times 10^{-6}$	−22.4	6.6	3.3	6.8
Boar 3	*Tayassu tajacu*	$0.72490 \pm 1 \times 10^{-5}$	−21.9	6.2	3.4	5.6
Paca	*Cuniculus paca*	$0.71234 \pm 7 \times 10^{-6}$	−21.8	5.4	3.3	6.5
Agouti	*Dasyprocta aguti*	$0.71271 \pm 5 \times 10^{-6}$				
Anomalocardia	*Anomalocardia brasiliana*	$0.70921 \pm 4 \times 10^{-6}$				

analyzed on a MAT Delta Plus™ mass spectrometer (Thermo Finnigan) connected to a CHN analyzer at the University of South Florida. Carbon and nitrogen percentages and the C:N ratio were obtained from each sample in order to monitor the collagen preservation degree (Tuross, 2002). The glutamic acid standards NIST 8573 and NIST 8574 were employed in the assays, and isotope abundances were expressed relative to PDB or atmospheric air (AIR). The collagen $\delta^{13}C$ and $\delta^{15}N$ standard deviation is ± 0.2.

Published $\delta^{13}C$ and $\delta^{15}N$ of archeological and recent fauna from the southern coast of Brazil (De Masi, 2001; Colonese et al., 2014) were also compared to the results obtained from Tapera.

3. Results

All analytical data for the human remains are shown in Table 1, whereas those for the fauna are shown in Table 2. The percentage of collagen in all samples ranged between 7.5% and 15.0%, while their C/N ratio ranges between 3.1 and 3.4. Since the C/N ratio of the samples fall within the expected range for preserved samples (DeNiro, 1985), we assume here that the dentin collagen of the individuals present a good preservation level.

The $^{87}Sr/^{86}Sr$ values of the individuals varied from 0.70980 to 0.71221, with an average value of 0.71088 ± 0.00055. Using a 2σ above and below the human mean to define a local range, according to Price et al. (2002), only the individual T150 would be considered as a non-local, presenting strontium results slightly above the 2σ limit. The terrestrial fauna presented values between 0.70988 and 0.72490. Considering only the capybara, the ocelot, the oncilla, the agouti and the paca, the results become much narrower (0.70988 to 0.71319) but still encompass the values found for the humans. The main sources of strontium to the local biota would be Neoproterozoic granitic rocks (see Fig. 1), recent ocean deposits and the seawater, which has today an $^{87}Sr/^{86}Sr$ ratio of 0.70918 (Faure, 1986, Wright, 2005). The analyzed bivalve shell (*Anomalocardia brasiliana*) from Tapera presented a similar value to that found in the seawater (0.70921).

The three boars that were analyzed presented values from 0.71786 to 0.72490, which are much higher than the values found for the human individuals and for the other terrestrial fauna. Fig. 3 shows the individuals and the fauna strontium results from Tapera site.

By comparing the $^{87}Sr/^{86}Sr$ values between the sexes (Fig. 4), it is observed that the variation in men (0.71024 to 0.71150) is narrower than in women (0.70980 to 0.71221), corresponding to 52% of the variation found for the females. A test for variance presented a $p = 0.028$ indicating that at the 0.05 level, men and women variances are significantly different. While women samples T4, T18, T32 and T41 present strontium values below the values found for men, women samples T39, T100 and T150 have higher values.

The $\delta^{13}C$ of the individuals varied from −12.4‰ to −9.6‰, with an average of −11.1‰. The $\delta^{15}N$ values varied between 16.3‰ and 20.8‰, with an average of 17.7‰. The less negative collagen $\delta^{13}C$ values and the high $\delta^{15}N$ results suggest that the analyzed individuals had a diet rich in marine resources such as fish and sea mammals, while C3 and C4 plants and terrestrial fauna would not be very significant as a protein source. Fig. 5 shows the carbon and nitrogen isotope distribution of the individuals from Tapera with the faunal isotopic results from the southern coast of Brazil analyzed by De Masi (2001); Colonese et al. (2014) and the present study. Some individuals from Tapera have nitrogen results around 6‰ above the $\delta^{15}N$ upper limit of the marine fauna. Although we can't discard the possibility of inter-laboratories error (Pestle et al., 2014), two individuals from Jabuticabeira II, another coastal site of Santa Catarina State, present similar values (Colonese et al., 2014).

4. Discussion

The results presented in this study show that none of the 42 individuals analyzed from the site of Praia da Tapera would have come from the interior region, the plateau of Serra Geral. On the contrary, the isotopic evidence suggests that they inhabited coastal regions during their childhood. The human and fauna $^{87}Sr/^{86}Sr$ results, except for boars, are slightly more elevated than those found in the sea water (about 0.7092) and this difference in values probably occur due to the Neoproterozoic granitic rocks that outcrop on the Santa Catarina island as well as other regions from the southern Brazilian coast (see Fig. 1).

In case any analyzed individual had migrated from the plateau, it would be expected that this individual would have presented lower $^{87}Sr/^{86}Sr$ values then those expected to be found in the coastal region of Santa Catarina State. Differently from the coast, the plateau of Serra

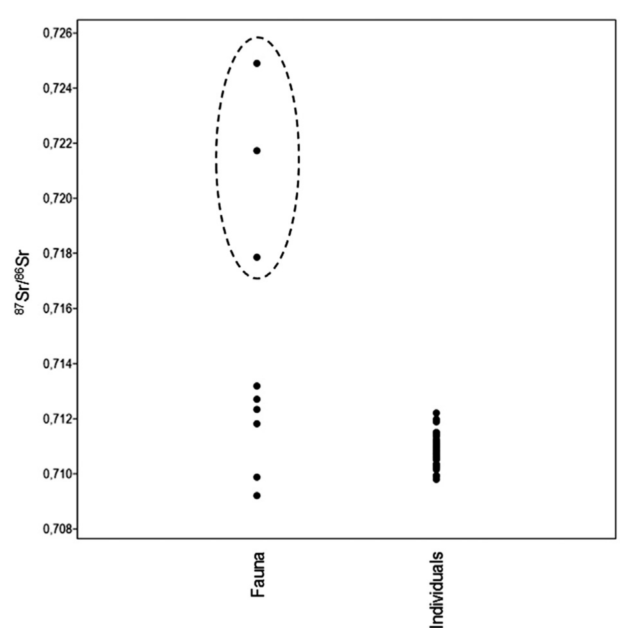

Fig. 3. $^{87}Sr/^{86}Sr$ distribution of the fauna (boars are inside the ellipse) and individuals from the site Praia da Tapera.

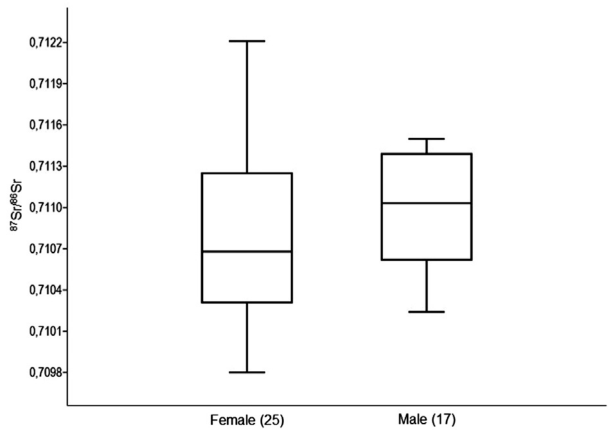

Fig. 4. Box-plot of $^{87}Sr/^{86}Sr$ values of males and females analyzed from the site of Praia da Tapera.

Geral is formed by juvenile volcanic rocks (from the Cretaceous), and presents the lowest strontium isotopes values found in the region, as low as 0.705 (Mantovani et al., 1985, Morbidelli et al., 1995).

Regarding diet, the $\delta^{13}C$ and $\delta^{15}N$ dentin collagen values strongly suggests that the individuals were consuming a high amount of marine resources, at least during the formation period of the pre-molar roots that were analyzed (between six and eleven years old) (Smith, 1991, Hillson, 1996). This result supports the inference that these individuals were born in the coastal region, since it is expected that individuals from the Plateau would not have marine food as their main protein source. Instead, they would have had access to a high amount of plants and terrestrial/freshwater animals, which usually presents lower $\delta^{15}N$ compared to those found in seafood.

De Masi (2001) analyzed carbon and nitrogen isotopes of eight individuals buried in sites located in the interior region of Santa Catarina, including sites from the Plateau of Serra Geral (see Fig. 5). The results were compatible with those expected for individuals that inhabited the interior, indicating a protein diet rich in terrestrial fauna and/or C3 and C4 plants like yams (*Discorea* sp.), Paraná pine nuts (*Araucaria angustifolia*), sweet potato (*Ipomoea batatas*) and maize (*Zea mays*), plants that were identified in dental calculus of pre-Columbian individuals from southern Brazil (Wesolowski et al., 2010).

Despite the isotopic evidence not identifying natives from the plateau buried in Tapera, the results do not discard the possibility that these individuals had migrated to the island of Santa Catarina and introduced the pottery-making technique in the region. The isotopic data, however, corroborate the paleogenetic results of Neves (1988) and Okumura (2007), which indicate that the Tapera group would be genetically similar to the pre-ceramist groups that occupied the coast of Santa Catarina, and not related to the interior groups of southern Brazil.

Among the possibilities to explain the Itararé ceramic at the site, it should be considered the hypothesis that other coastal groups had already incorporated the pottery making technique in a previous occupation period, or simultaneously to the first occupation of Tapera. The production technique would have been introduced during the occupation of Tapera, through the incorporation of some individuals from other coastal settlements, which had direct contact with individuals from the Plateau.

Regarding this scenario, it is possible that the pottery making technique arrived at Tapera by the incorporation of women from other parts of the coast, since the $^{87}Sr/^{86}Sr$ values found for the analyzed women have a larger range than those found for the men (see Fig. 4). Despite the absence of a strontium variation mapping of the region, it is possible to consider that small differences in the southern coast geology might provide strontium values slightly higher or lower than those found at Tapera. Based on this principle, there is a possibility that the women T4, T18, T32 and T41, that have $^{87}Sr/^{86}Sr$ values below those found for men, and the women T39, T100 and T150, with higher values, have come at least from other parts of the coast. The 2σ above and below the human mean to define a $^{87}Sr/^{86}Sr$ local range also reinforces that hypothesis, since only the woman T150 would be considered as non-local by this criteria.

This wider strontium isotope variation found in women from Tapera supports paleogenetic studies done in several skeletal series associated with ceramist groups from the southern coast of Brazil, which points to a greater heterogeneity between women when compared to men (Hubbe et al., 2009, Okumura, 2007). This same trend was observed by Lessa et al. (2011) after examining the strength index of long bone shafts from Tapera.

The heterogeneity of women could be related to a patrilocal post-marital residential system, in which there would have been an

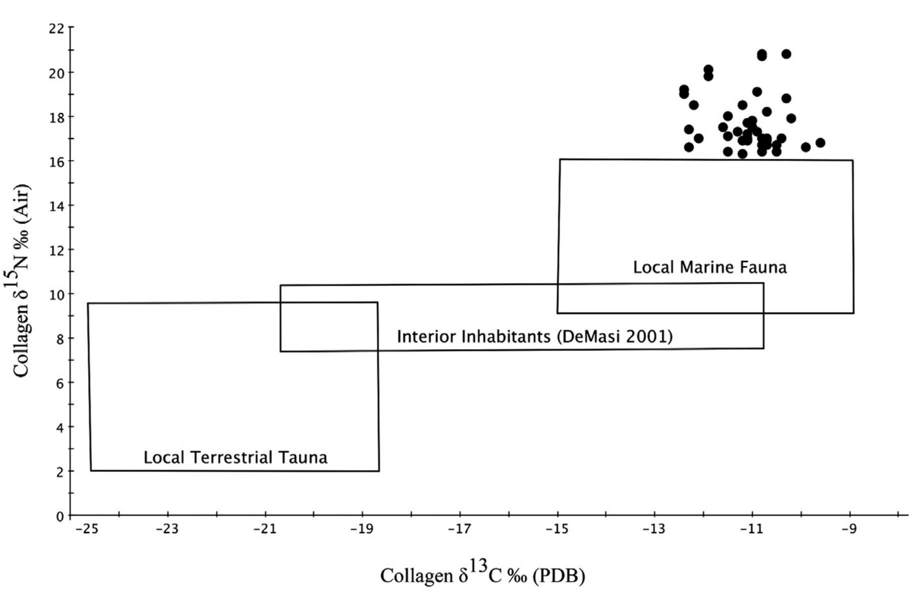

Fig. 5. $\delta^{13}C$ and $\delta^{15}N$ dentin collagen distribution of individual buried in the site of Praia da Tapera (black circles). Also shows the values of individuals from the interior region studied by De Masi (2001), and marine and terrestrial fauna (archeological and current samples) of southern Brazil (De Masi, 2001; Colonese et al., 2014).

extensive migration network of women among the coastal groups (Hubbe et al., 2009). Women could also have been incorporated into the group by kidnapping for marriage purposes and for the acquisition of a pottery making technique (Lessa, 2005).

Regarding the terrestrial fauna, the carbon and nitrogen isotopic data show that these animals were not an important protein source for the analyzed individuals from Tapera, although bone fragments of at least 34 boars among the fauna considered as food debris by Silva et al. (1990) were found. Herbivores like boar, paca, deer and tapir, all found during the site excavation, present low $\delta^{15}N$ values and, in case these animals were a significant part of the protein diet, the individuals would present $\delta^{15}N$ values tending to be lower than those found.

Maybe these animals were consumed on specific occasions, such as ritual feasts, or even for breaking the diet monotony focused on marine species. In any case, there is evidence that the boars were somehow important for the individuals from Tapera. The highest strontium isotopes values found for the three analyzed specimens suggest that these boars would not be native from the Santa Catarina island (see Fig. 3), but from a geologically older area, probably the region that presents Paleoproterozoic rocks located on the mainland, next to the island (Fig. 1). These animals may have been hunted by the Tapera inhabitants that have sailed from the island to the mainland, or they were traded with groups that inhabited the continent. The evidence that boars might have been from the mainland also provides important information regarding the mobility of these pre-Columbian groups for hunting and gathering practices.

5. Final remarks

Despite being a subject discussed for decades, there are still many unclear issues regarding the contact between the coastal and interior pre-Columbian groups that inhabited southern Brazil. The coastal origin for the individuals and an economy based on fishing marine resources, both evidenced by isotopic analysis, support the hypothesis that Praia da Tapera was not an occupation of groups from the interior, but an occupation of individuals from the coast that had ceramics originally made by groups from the plateau region. However, it is not discarded the possibility that some group members, especially women, are descendants of individuals that have migrated from the plateau to the coast.

Isotopic results of the individuals from Tapera site reinforce the southern Brazil occupation complexity, especially regarding the coastal groups' dynamics and their trade networks. Further archeometric studies with other sites from the same region may contribute to a better understanding of the mobility of these populations, as well as to clarify questions such as how the ceramics associated with groups from the Southern Brazil plateau arrived on the coast and its effects on the local way of life.

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