2013 International Nuclear Atlantic Conference - INAC 2013
Recife, PE, Brazil, November 24-29, 2013
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
ISBN: **978-85-99141-05-2**

CHARACTERIZATION OF CERAMIC ARCHAEOLOGICAL BY HIGH RESOLUTION X RAY MICROTOMOGRAPHY

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ABSTRACT

Characterization of ceramic fragments is a very important area of research in art and archeometry area because it enables a greater understanding of how ancient civilizations behave and what were their traditions and customs. Petrography and chemical analyses are commonly used, but these techniques are destructive, which is not interesting for this type of sample. Through the exchange of multidisciplinary scientific knowledge and new partnerships, high resolution X-ray microtomography has been introduced in archaeological area as a great possibility of 3D inspection in a non-destructive way. The goal of this work is to investigate the internal microstructures of four samples of archeological ceramic, from the Archaeological Site of Macacu – RJ. The X-ray microtomography were performed in a high resolution setup, and can be used to infer the nature of organic temper even with all plant remains completely burnt out during the firing process and also to ensure the homogeneity of samples envisaged for geochemical analyses, especially with respect to the distribution of chemically diverse fabric compounds. In this way this study intends to contribute to our understanding of the archaeological and historical formations of this region.

1. INTRODUCTION

Pottery-making can be considered as a complex activity combining technical and social constraints. The study of archaeological ceramic materials has many insights into behavior and environment of the people involved into both production and use of pottery. To facilitate subsequent interpretations, e.g., concerning organizational aspects of pottery production such as craft specialization, or implications of provenance studies for regional trade and interaction, a thorough reconstruction of the production technology as well as scientific investigation of the desired use of the ceramic products (e.g., storage vs. cooking pots) is essential. In this respect, geochemical, petrographic and spectroscopic techniques have proven to contribute substantially to our understanding of the technological aspects such as raw materials, manufacturing techniques and vessel function. That investigation is most often accompanied by a destructive preparation of the samples [1].

High resolution 3D computed microtomography (microCT) is a powerful technique used to visualize and characterize the internal structure of objects. It is a non-destructive method that produces images of the internal structure of an object which does not need to be previously modified [2]. The X-ray microtomography technique employs X-rays to inspect the three dimensional distribution of matter inside the object of investigation. The term “micro” indicates that the resolution achieved is in the µm-range. The method is based on the detection and subsequent localization of the degree of attenuation of the incident X-rays in the sample. The attenuation of X-rays by matter depends on both the chemical elements it consists of as well as their density [1].

The great advantage of microtomography is that quantitative information such as volume, size, shape, distribution and connectivity of the pores can be obtained through the entire 3D volume of the samples, from micro-scale to nano-scale [3,4]. In this way this study intends to contribute to our understanding of the archaeological and historical formations of this region.

2. MATERIALS AND METHODS

Four samples of ceramics from the Macacú Archeological Site, located in Itaboraí, Rio de Janeiro, were analyzed in this study. This is one of the most important archaeological sites in Brazil. This is an area that contained important information about the African occupation in Reconcavo Guanabara Bay [5]. The samples were identified as sample M412690, M413599, M410051 and M410030 (Fig. 1).

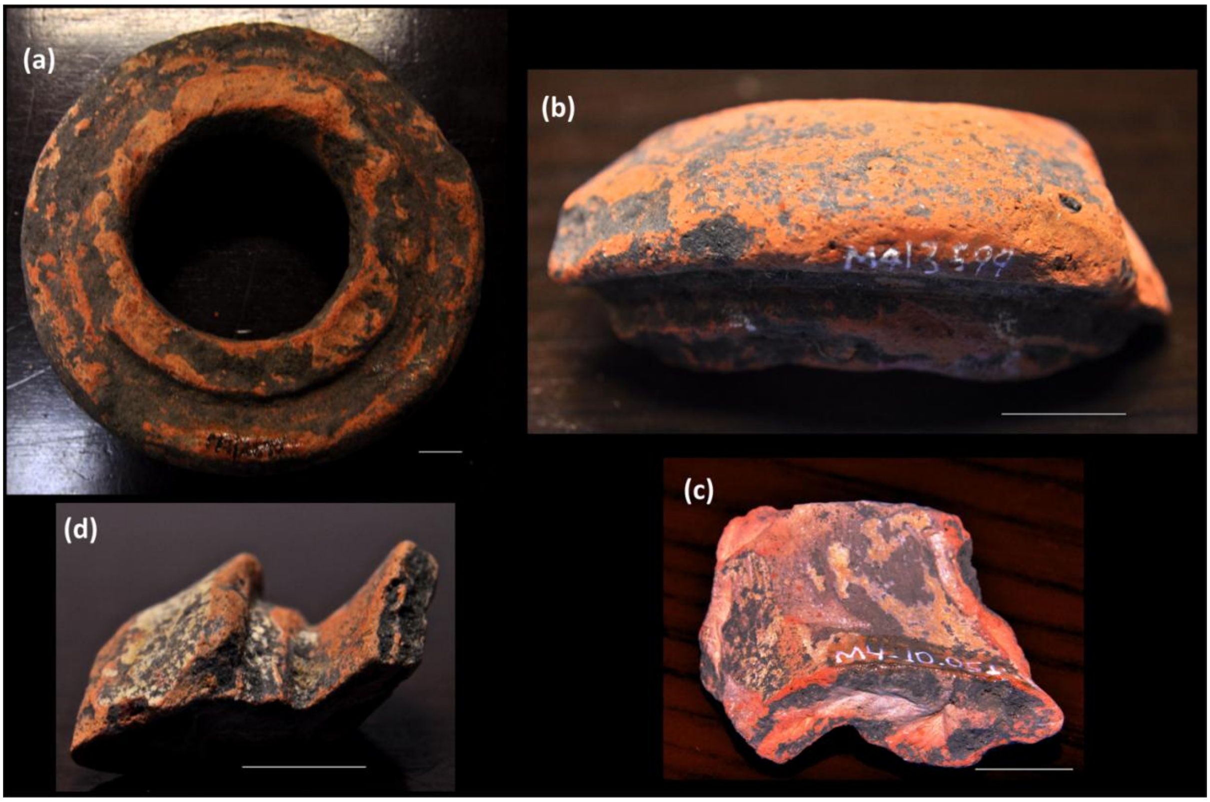

Figure 1: Samples photography, (a) sample M412690, (b) sample M413599, (c) sample M410051 and (d) sample M410030 The scale bar corresponds to one centimeter.

MicroCTs were obtained in a high energy microtomography system (Skyscan/Bruker, model 1173). The system was calibrated to operate at high voltage of 100 kV and a current of 80 μA. In order to reduce the contribution of low energy photons, which cause beam hardening effect, one aluminum filter (1.0 mm thickness) was used. The samples 1, 2, 3 and 4 were scanned with pixel size of 70, 55, 41 and 41 μm, respectively.

In the system one uses a flat panel detector with three matrix options: 2240x2240, 1120x1120 and 560x560 pixels. In the present study, the acquisitions were performed with the pixel matrix 1120x1120. Scanning was made with a 360º rotated sample along the axis z, at each step of 0.50º. It is important to emphasize that other image acquisition parameters can be adjusted, such as the number of frames per projection, exposure time and corrections of sample involuntary movements. In this paper, parameters have the values of 5 frames/projection, exposure time of 250 ms and random movement equal to 10. The random movement is a vertically movement, which randomly varies the position of the sample, in units of pixels, to reduce the intensity of ring artifacts arising due to difference efficiency or defect of photoelements in the detector.

After the acquisition process, images were rebuilt using Nrecon® SkyScan - version 1.6.4.1 [6] and InstaRecon - version 1.3.5.0 [7] the algorithm of which is based on the works of Feldkamp [8]. From the reconstructed slices it is possible to visualize the 3D models of each sample using the CTVox software [9] and the transaxial, coronal and sagittal sections using the DataViewer software [10].

3. RESULTS

Unlike sample 1, samples 2, 3 and 4 are not whole pieces, but they are only fragments of archeological ceramics and they have a denser material on their surfaces. Sample 1 does not have an outer layer of dense material. The results of samples M412690, M413599, M410051 and M410030 are shown in figures 2, 3, 4 and 5 respectively. Through the reconstructed images of the transaxial, coronal and sagittal oriented sections (Fig. 2c, 3c, 4c and 5c) is possible to analyze the porosity of the samples . In the 3D model of sample 2 it is possible to notice the presence of a superficial layer of a denser material (green) than the ceramic matrix (yellow) with an approximate thickness of 0.5 mm (Fig. 3c). It is also possible to identify in the 3D model of sample 3 the presence of a superficial layer (green) with thickness between 0.5 and 1.0 mm, suggesting the use of a kind of paint in the surface of those ceramic pieces. As in sample 2 and 3, sample 4 also suggests the use of paint on the ceramic surface, as shown in the 3D model in Green color (Fig. 5c). This layer has thickness between 0.5 and 1.0 mm.

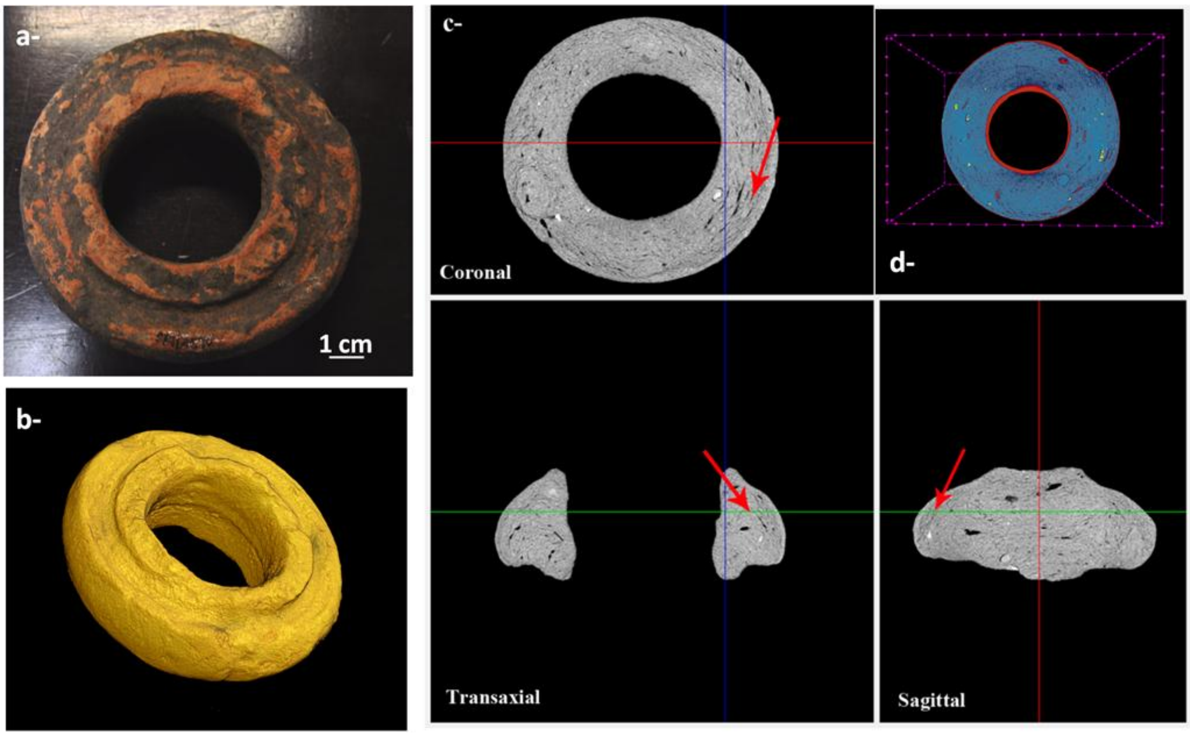

Figure 2: (a) Photograph, (b,d) 3D models and (c) Reconstructed images of transaxial, coronal and sagittal oriented sections of the sample M412690.

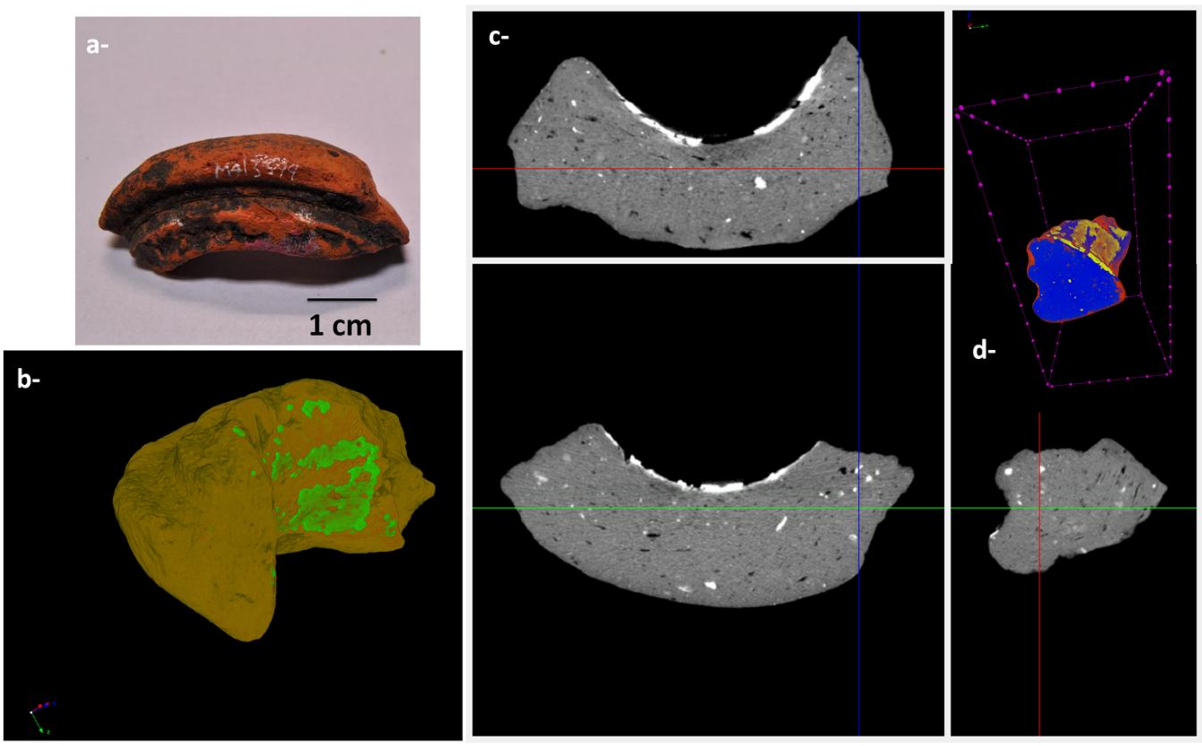

Figure 3: (a) Photograph, (b,d) 3D models and (c) Reconstructed images of transaxial, coronal and sagittal oriented sections of the sample M413599.

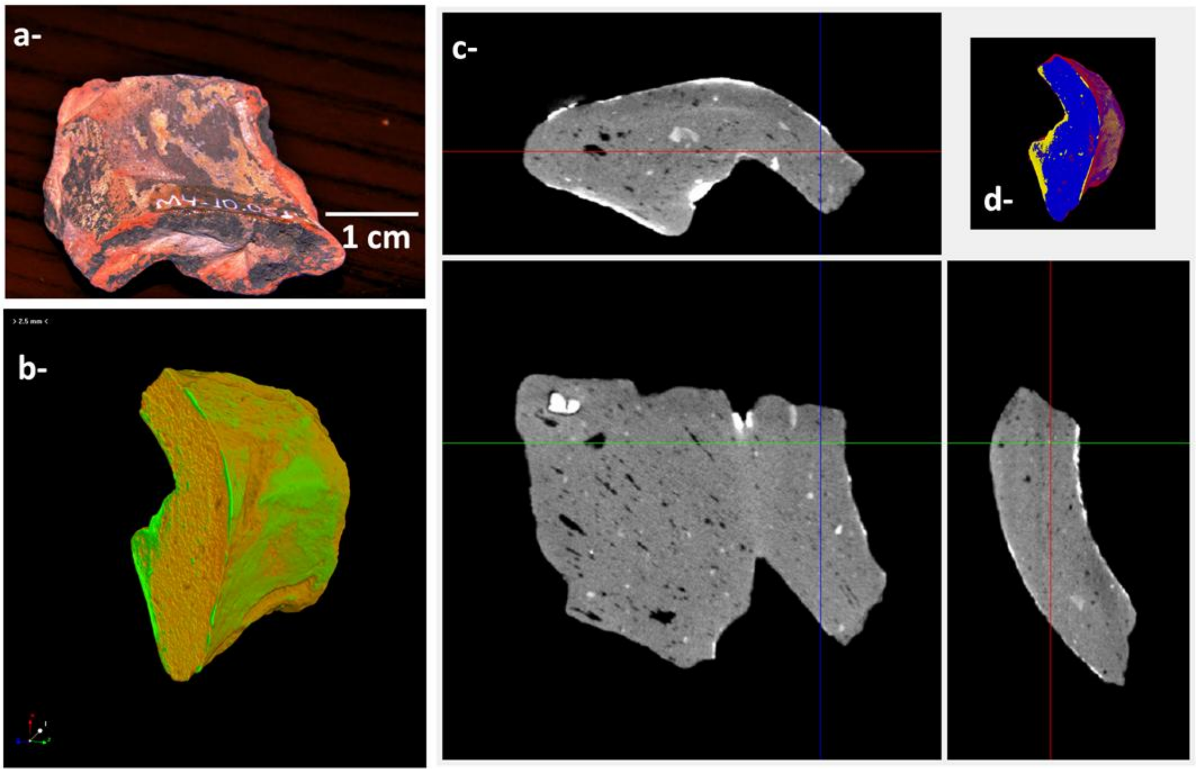

Figure 4: (a) Photograph, (b,d) 3D models and (c) Reconstructed images of transaxial, coronal and sagittal oriented sections of the sample M410051.

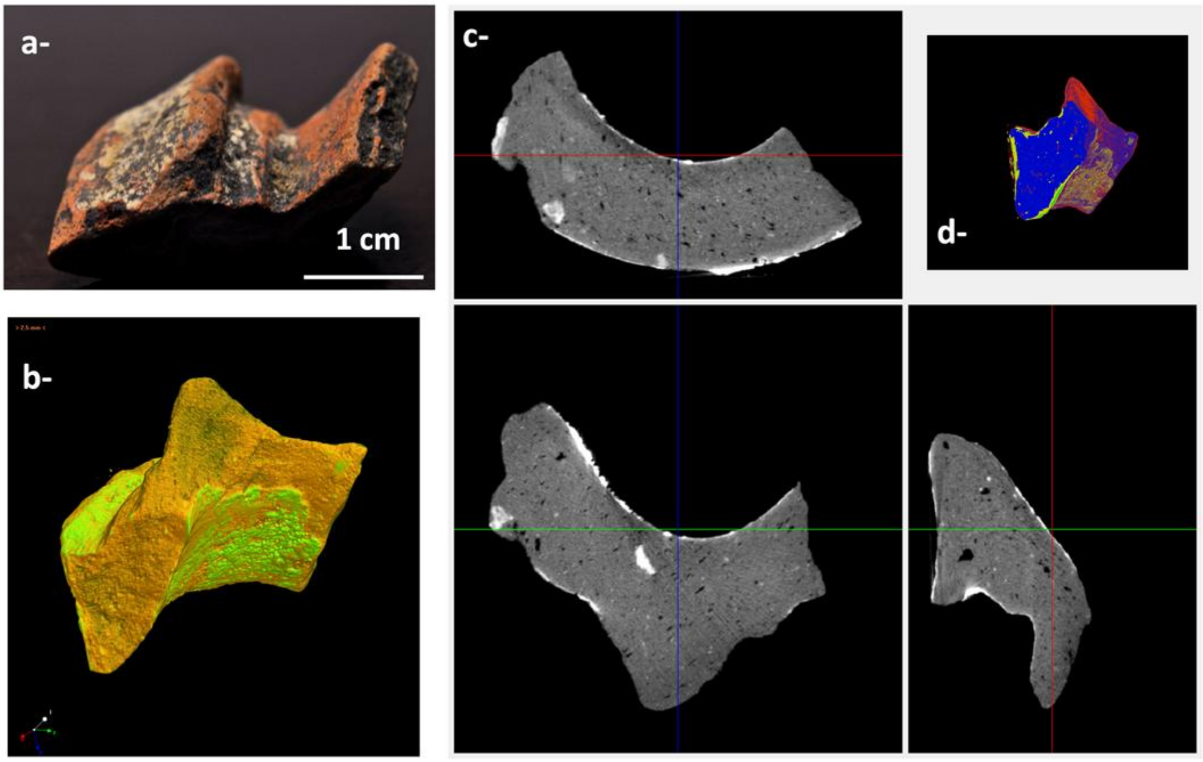

Figure 5: (a) Photograph, (b,d) 3D models and (c) Reconstructed images of transaxial, coronal and sagittal oriented sections of the M410030.

The microtomographic images allow assessing the manufacturing techniques of these archeological ceramic pieces, following the direction of the pores, because pore orientation is strongly influenced by the formation technique used by the potter.

There are two rolling techniques U and N, and they differ by pore orientation. Technique U can be recognized by the typical U-shaped porous structure, oriented from the surface of one wall to the other, while samples formed with the N technique show distinct diagonal orientation of the pores, pointing to the walls [1].

In this manner, according to [1], the images of the pieces studied in this paper suggest that they were manufactured with the technique N. Arrows have been made in the Fig. 2, showing the orientation of the porosity, and from this it was possible to identify the technique.

4. CONCLUSIONS

High resolution x-ray microtomography proved to be a valuable tool for archeological ceramic characterization, because it was possible to observe the different mineralogical compositions, as well as the identification of fractures and porosities. It is important to know that by using this technique it is also possible to identify the form mode of the archaeological cooling of the ceramics.

ACKNOWLEDGMENTS

The authors would like to thanks the financial supports by CNPQ, FAPERJ, CAPES and PETROBRAS.

REFERENCES

1. W. -A. Kahl and B. Ramminger, "Non-destructive fabric analysis of prehistoric pottery using high-resolution X-ray microtomography: a pilot study on the late Mesolithic to Neolithic site Hamburg-Boberg", *Journal of Archaeological Science*, **Vol 39**, pp. 2206-2219 (2012).
2. K. Remeysen and R. Swennen, "Application of Microfocus computed tomography in carbonate reservoir characterization: Possibilities and limitations", *Marine and Petroleum Geology*, **Vol 25**, pp. 486-499, (2008).
3. M.F.S.Oliveira, I.Lima, L.Borghi, R.T.Lopes, "X-ray microtomography application in pore space reservoir rock", *Applied Radiation and Isotopes*, **Vol 70**, pp.1376-1378, (2012).
4. A. C. Machado, I. Lima, R. T. Lopes, "Effect of 3d computed microtomography resolution on reservoir rocks", *Radiation Physics and Chemistry*, doi: 10.1016/j.radphyschem.2012.12.029 (2013).
5. M. D. Gaspar, "Os próximos passos... aperfeiçoar a prospecção arqueológica e abrir a caixa do passado", *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas*, **Vol 6**, pp. 41-55 (2011).
6. NRecon, SkyScan/Bruker micro-CT, Kartuizerweg 3B 2550 Kontich, Belgium (2011).
7. InstaRecon,®, CBR Premium 12-8K™, InstaRecon, Champaign, IL, USA (2011).

8. L. A. Feldkamp, L. C. Davis, J. W. Kress, “Practical cone beam algorithm”, *“J Opt Soc Am A”*, **Vol 1**, pp. 612-619 (1984).
9. CTVox, Skyscan/Bruker micro-CT, Kartuizerweg 3B 2550 Kontich, Belgium (2012).
10. Data Viewer, Skyscan/Bruker micro-CT, Kartuizerweg 3B 2550 Kontich, Belgium (2012).