Journal of Physics: Conference Series **2605** (2023) 012020 doi:10.1088/1742-6596/2605/1/012020

Diagnosis of the conservation status in archaeological objects from Museo de la Patagonia by using imaging complementary techniques

J M Schweickardt[1, 2,*], R Bradbury [3], M Bianchi Villelli [2,4], N Kardjilov[3], F Cantargi[1] and N Vega [5]

[1]Comisión Nacional de Energía Atómica, Laboratorio Argentino de Haces de Neutrones, Centro Atómico Bariloche, Av Bustillo km 9500, Bariloche, Argentina
[2] Consejo Nacional de Investigaciones Científicas y Técnicas-CONICET, Argentina
[3] Helmholtz Zentrum Berlín, Berlín, Deutschland
[4]Instituto de Investigaciones en Diversidad Cultural y Procesos de Cambio/Universidad de Rio Negro -IDyPCA/UNRN-
[5]Comisión Nacional de Energía Atómica, Laboratorio Argentino de Haces de Neutrones, Centro Atómico Constituyentes, Av General Paz 1499, San Martín, Argentina

* josefinaschweickardt@cnea.gob.ar

Abstract. We present the application of imaging complementary techniques to the interdisciplinary study of a selection of archaeological metal objects belonging to funerary assets from Patagonean Indigenous. This selection belongs to the archaeological collection "Andres Giai" which is under the care of the Museum of Patagonia, Bariloche, Argentina. It was regrettably left with no contextual data and most of the objects were kept in uncontrolled storage conditions over many years. Its general conservation status motivated the design and implementation of an interdisciplinary methodology to address a Conservation Plan considering the application of analytical techniques for materials in its approach. This work intends to achieve the first stage on this Plan, which consists in a suitable diagnosis of the conservation-status to specific and representative pieces of the Andrés Giai metal collection. We highlight the Diagnosis stage as the most important to determine accurate treatments for each object during any conservation plan. The diagnosis was carried out by implementing neutron and X-Ray tomography at the Helmholtz Zenturm Berlin, Germany. The results obtained allowed us to: study the distribution of corrosion products and other degradation products such as crusts; verify the presence of a metal core under these product, study the homogeneity of the thicknesses, and show characteristics of the internal surfaces. This information is vital for the proposal of tailored conservation treatments that allow guaranteeing sustainable interventions.

1. Introduction

The “Andrés Giai” collection is under the care of the Museum of Patagonia, Bariloche, Argentina (Nahuel Huapi National Park -National Parks Administration). This institution is currently the main repository of archaeological collections in the area of Patagonia and an interdisciplinary node where different institutions and organizations of the National Science and Technological System converge in research, as well as a point of tourist attraction of importance for the region. The Museum was created in 1940 with the purpose of organizing and preserving the cultural heritage of the past and history of the Patagonian Region. Nowadays, it hosts a variety of ethnographic, historical, and natural collections, as well as a great diversity of archaeological objects from various field-trips from the beginnings of the twentieth century.

This collection is named after the explorer who extracted several indigenous funerary assets from different sites around north center of Neuquén, Argentina, in 1943 (Figure 1). Regrettably it was extracted and compiled in absence of methodological strategies and scientific standards. In addition, since its arrival at the museum, due to discrepancies with the explorer and the institution, the collection was entered and registered in the absence of any field or excavation records, leaving behind poor documentation and the absence of excavation methodologies [1]. The collection consists on various body ornaments made on copper-based, silver-based, and iron-based alloys, such as earrings, earrings with glass beads, rings, headband with glass beads, animal tendon and thimbles; fragments of pectoral ornaments made of copper cylinders with animal tendon threads inside. Some of these objects, or pieces into the objects are made of European manufacture, such as jingle bells, thimbles and glass beads used on the mentioned headband.

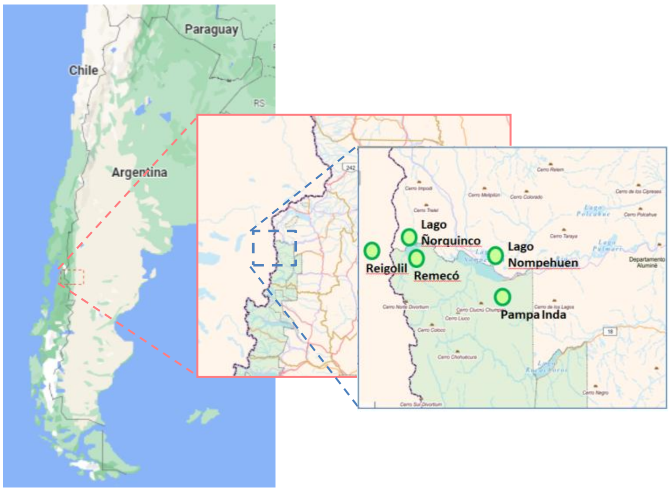

Figure 1. Exploration region, Argentina and Chile.

Considering typological and general characteristics of the collection, and the presence of European elements in the contexts, we can estimate for these objects a late temporality that goes from the beginning of the contact with the European, beginning of the 16th century onwards, until the 19th century, from that the so-called "Mapuche Silverware" was established [2]. The chronological estimate contemplates an approximate time range of 300 years, within which various socio-cultural processes are presented, with pre- and post- European contact influences [2-5]. These various socio-cultural processes are evidenced by the technological manifestations and their changes -raw material, manufacturing processes and typologies-. In addition, since the collection comes from various sites and burial places, we do not rule out they may correspond to diverse socio-cultural contexts and time frames, so it would not be appropriate to define a priori any contextual temporal homogeneity. This variety and combination of elements in the collection become very relevant to study the interethnic relations and exchanges of this period.

Considering the conservation status of the collection, as a result of a general survey, the need to address the conservation conditions of the collection was detected. In general, the objects present various corrosion products and crusts, as well as evidence of missing parts and cracks that denote a high degree of structural fragility.

Unfortunately, the lack of information surrounding the collection affects any conservation approach, since the characteristics of the objects, as well as their type of raw material; their specific interactions between more than one material in an object, their manufacturing processes; their specific context of burial; and documentation about past interventions, are essential information to address sustainable conservation treatments [6].

Therefore, both, the absence of contextual information and the conservation conditions surrounding the collection motivated the development of an Interdisciplinary Conservation Plan to address the study of this collection. In its design, the importance of diagnosis is highlighted, within which the interdisciplinary articulation of the study of objects is proposed, through the development of specific methodological instances, considering the implementation of analytical techniques as well as the needs from the archaeological field.

In order to investigate the degradations conditions and perform morphological studies for these goods we applied neutron and X-ray tomography techniques to a selection of representative locally and European manufactured metal objects. These are: a) a European manufactured copper-based jingle bell; b) a European manufactured copper-based thimble, which is part of a locally manufactured headband made up with animal tendon thread, European glass beads and European copper-based thimbles; c) a locally manufactured iron-based earring with ring shape and two blue glass beads; d) a locally manufactured copper-based cylinder/tube with animal tendon thread inside (Figure 2). A deterioration study was carried out first on this selection, in order to point specific degradation problems and its distribution, to guide the imaging interpretation (Figure 3).

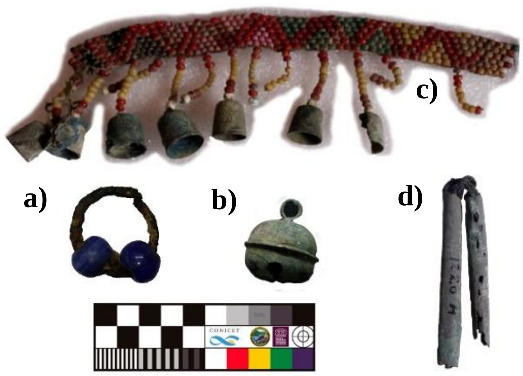

Figure 2. Selection. a) earring with glass beads; b) jingle bell c) thimble; d) tube with animal tendon thread inside.

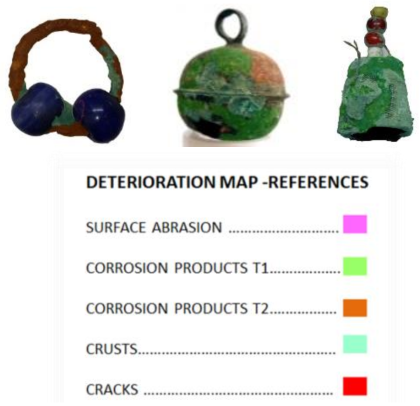

Figure 3. Deterioration type and distribution map.

2. Tomography Methods

Neutron tomography measurements were conducted using the Cold Neutron Tomography and Radiography (CONRAD, V7) instrument [7], in the BER II facility at the Helmholtz Zentrum Berlin (HZB). The instrument is capable of both radiography and tomography using cold neutrons. Here, only tomography measurements were performed, using white beam neutrons with wavelengths between 2Å and 6Å, and with maximum intensity at around 2.5Å. The sample position was located 5m from a 3cm pinhole for an L/D = 167. The sample itself was placed upon a 360° rotation stage (Huber Goniometer 408) and secured by a combination of vertical aluminium rods and foil. The rotation stage was mounted on a translation stage (Huber Linear Stage 5101.20) to permit flat field measurements to be performed with the sample translated out of the beam. The projections were recorded with an ASI 178mmc CMOS camera in combination with a 100µm thick 6LiF/ZnS scintillator. The attached camera lens had a focal length of 20mm, which yielded a field of view of 100mm x 65mm and a pixel size of 33µm. The sample was rotated through 272° while 2628 projections were taken, with an exposure time of 5 seconds. A series of flat field measurements were performed before the tomography measurements while dark field measurements were recorded with the beam off upon the conclusion of the tomography measurements.

The µCT system used at the HZB consists of a micro-focus 150 kV Hamamatsu X-ray source with a tungsten target and a flat panel detector C7942 (120x120 mm^2, 2240x2368 $pixel^2$, pixel size 50 µm). A 100 kV filament voltage and a current of 100 µA were used in this scan with an exposure time of 2.2 seconds. Image noise was reduced by using a 5-fold integration. The source-detector distance was 320 mm while the source-object distance was 100 mm in order to get the optimal magnification providing a spatial resolution of 16 µm. The sample was rotated inside the X-ray cabinet on a 360° rotation stage (Huber Goniometer 408). The internal structure of the sample was subsequently reconstructed from the 2D angular projections. For this measurement, 2165 projections were acquired over a 360° sample rotation.

A commercial software program, Octopus (V8.6), was used to implement the back-projection algorithm with convolution and correction for cone and parallel beam, depending on whether it is x-ray or neutron, respectively.

3. Results and discussion

The selected samples were investigated by dual mode tomography measurements using X-rays and neutrons. The tomography method allows for volumetric reconstruction of the 3D matrix of the attenuation coefficients, where the two kinds of radiation show their complementarity. The X-rays provide strong contrast for heavier elements like metals and metallic alloys and the neutrons show their sensitivity to hydrogenous compounds, e.g. metal corrosion and light elements like boron and lithium. In the present experiments the obtained 3D-sample volumes from the X-ray and from the neutron tomographies were aligned and registered using the software tool SPAM [9]. In this way a direct comparison of the attenuation coefficients for each point of the sample was possible, which helps for better separation between different material compositions like metal which is still in-takt and corrosion products on the surface. For advanced segmentation a bivariate histogram was calculated for each sample using the registered volumes. By selecting proper areas from the histograms, a proper separation between the metal matrix and the corrosion products was possible. The volumes of the selected parts of the sample were quantified and some important dimensions were determined.

3.1. *Earring.* The images of the tomographic reconstructions are shown in Figure 4. The 3-D visualization (a) shows the complementary contrast provided by the X-rays and neutrons. The complementarity is evident in the 2-D cross sections (b) where the X-ray image presents the high absorbing metal part and the corresponding neutron image shows in addition the high absorbing corrosion products due to their hydrogen content. The high-resolution X-ray tomography slice depicts a crack in the metal ring (yellow arrows) which is partially filled by corrosion products considering the results from the neutron investigation. The bivariate histogram of the two volumes (c) shows the areas of attenuation coefficients for the metallic material (red) and the corrosion products (blue) which were identified in the sample. Quantification of the sub-volumes and thickness variations of the metallic ring and the corrosion layer are presented as well.

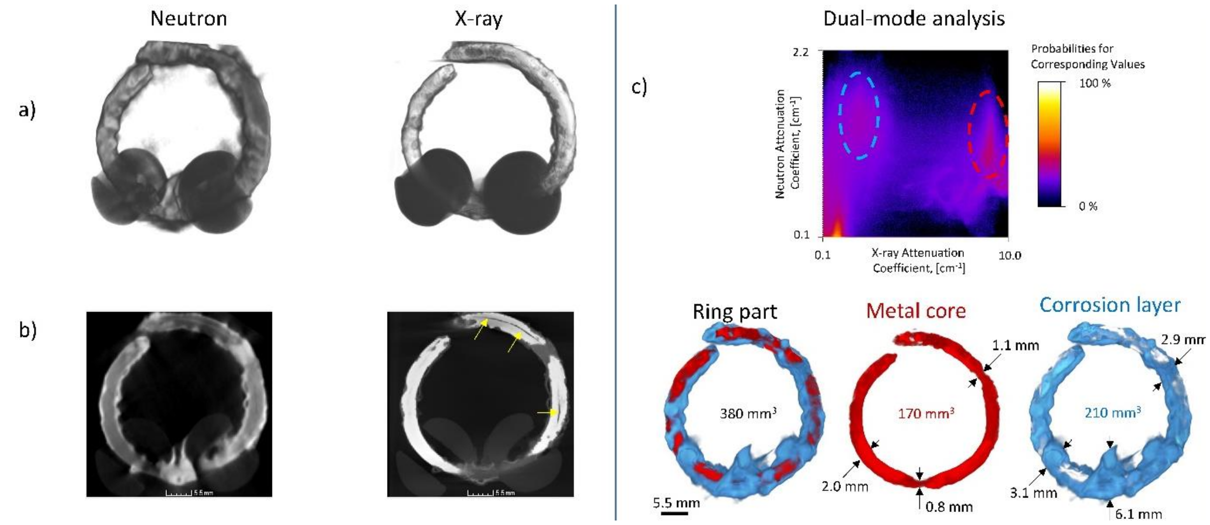

Figure 4. Tomography investigation of Earring. a) 3-D visualization of the sample; b) Tomographic slices through the middle of the sample; c) Bivariate histogram. Quantification of the sub-volumes and thickness variations of the metallic ring and the corrosion layer.

3.2. *Jingle bell.* The same analysis was performed for the Jingle bell sample, Figure 5. The 2-D slices (b) show the thin walls (~0.8 mm) of the sample, which are well preserved without large areas of corrosion. The complementary contrast between X-rays and neutrons helps to identify the tongue on the bottom as a metal part with a size of approximately 10 mm with a corrosion layer thickness of about 1-2 mm, which are well seen in the neutron image. The metal parts have close attenuation coefficients for X-rays and neutrons. The bivariate histogram was used for segmentation of the metallic matrix and the corrosion products on the sample surface and on the tongue.

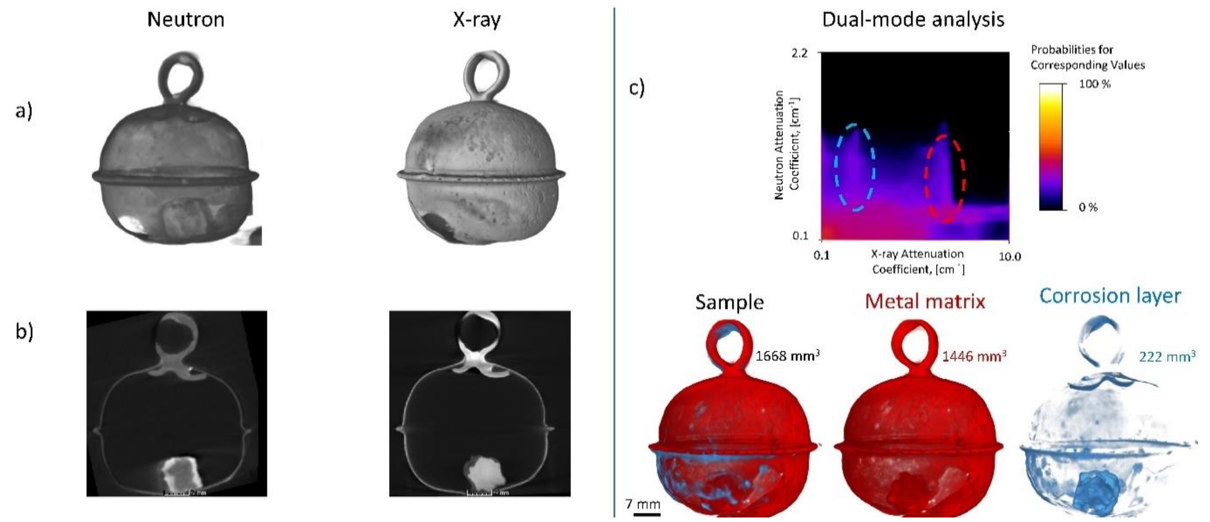

Figure 5. Tomography investigation of Jingle bell. a) 3-D visualization of the sample; b) Tomographic slices through the middle of the sample; c) Bivariate histogram helps for a quantification of the sub-volumes of the metal material and of the corrosion layer.

3.3. Thimble. The tomography investigation of the Thimble sample is shown in Figure 6. Tomographic slices (b), shows a metallic structure with a thickness of ~2.3 mm with a corrosion layer from outside of 0.8-1.0 mm. The tongue has low attenuation coefficients for X-rays and neutrons, which in combination with the missing corrosion layer tends to the conclusion that it is a glass bead. The volumes of the metallic matrix and of the corrosion layer were calculated using the bivariate histogram as shown in the previous sample analysis.

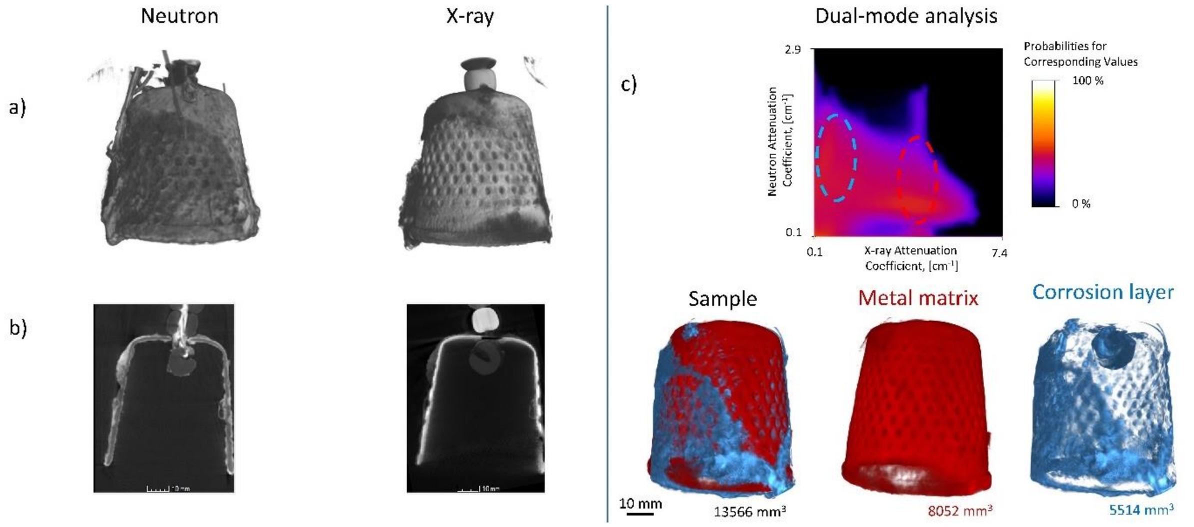

Figure 6. Tomography investigation of Thimble. a) 3-D visualization of the sample. b) Tomographic slices through the middle of the sample. c) Bivariate histogram helps for a quantification of the sub-volumes of the metal material and of the corrosion layer.

4. Conclusions

Imaging techniques provided relevant information to the study of these selection, guaranteeing a non-destructive approach. The advantages of the complementary analysis are highlighted in the study of neutrons and X-ray aligned slices, which provided exclusive information for distinguishing between materials, and metals and their corrosion products even inside the bulk. It also allowed us to verify the presence of a metal core under these products, study the homogeneity of the thicknesses of the material, and show characteristics of the internal surfaces of the same.

Verifying the presence of a metallic core is essential to discuss possible cleaning treatments for the corrosion layers. In addition, knowing the type of materials interacting in the same objects is essential to propose present and future interactions that may produce other degradation processes. Other studies of these data, such as the analysis of morphological traces in the inner and outer surfaces, could complement studies of manufacturing processes, especially for those objects manufactured locally. The information obtained in this analysis has been of great contribution to the construction of an accurate conservation status diagnosis, showing the capabilities and potential of these complementary techniques in this field.

Acknowledgments

The authors would like to acknowledge IAEA for supporting the visit to Berlin, where measurements were performed at the HZB. We would also like to thank to the imaging group at HZB for the pleasant working environment and team spirit, and to Boyana Kozhuharova, who did the registration of the volumes. Thank should also be given to the argentine organizations that allowed the transfer of archaeological goods such as the National Parks Administration, National Park Nahuel Huapi, Museum of Patagonia, and the National Register for Archaeological Sites, Collections, and Objects.

References

[1] Bianchi Billelli M, Piantoni G and Schweickardt J M 2022 *Runa* **44** accepted

[2] Campbell R 2004 *PhD Thesis* Pontificia Universidad Católica de Chile, Santiago de Chile

[3] Campbell R and Quiróz D 2015 *Quat. Int.* **356** 39

[4] Campbell R Carrión H Figueroa V Peñaloza Á Plaza M T and Stern C 2018 *Chungara Rev. Antrop. Chil.* **50** 217

[5] Núñez Regueiro P and Guerra M F 2015 *Chungara Rev. Antrop. Chil.* **48** 33

[6] Guerrero Baca L F 2009 *Conservación de Bienes Culturales: Acciones y Reflexiones* (Ciudad de México: Instituto Nacional de Antropología de México)

[7] Helmholtz-Zentrum Berlin für Materialien und Energie 2016 *JLSRF* **2** A98

[8] Kardjilov N, Hilger A, Manke I Woracek R and Banhart J 2016 *J. Appl. Cryst.* **49** 195

[9] Stamati O, Andó E *et al* 2020 *J.Open Source Softw.* **5** 2286