

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

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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 “Andrés Gai” which is under de guard 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 Gai 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 Zentrum 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 Gai collection is under the guard 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 researches, 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.

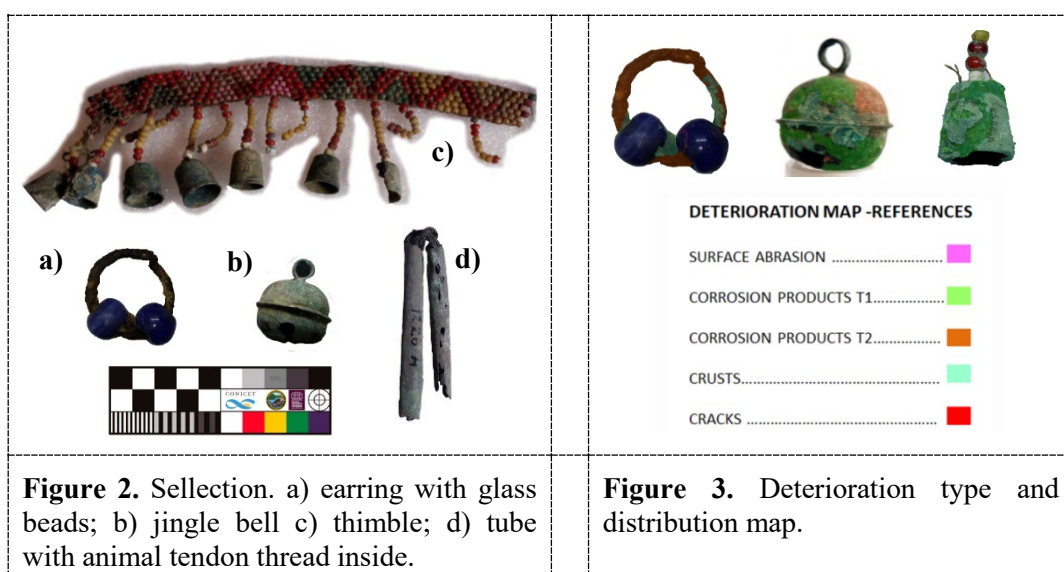
Considering typological and general characteristics of the collection, and the presence of European elements in the contexts, we can estimate for these objects a late temporality that goes from the beginning of the contact with the European, beginning of the 16th century onwards, until the 19th century, from that the so-called "Mapuche Silverware" was established [2]. However, this 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 local 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. Some of these were inappropriately intervened in the past for having implemented surface cleaning with abrasive products, leaving a heterogeneous distribution of unidentified degradation products on their surfaces.

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 archeology field.

In order to carried on the degradations conditions and morphological studies for this goods we applied neutron and X-ray tomography techniques to a selection of representative locally and European manufactured metal objects. These are: a) European manufactured copper-based jingle bell; b) European manufactured copper-based thimble, which is part of a local manufactured headband made up with animal tendon thread, European glass beads and European copper-based thimbles; c) local manufactured iron-based earring with ring shape and two blue glass beads; d) local 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).



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 100 μ m 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 33 μ m. 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 μ CT 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 mm², 2240x2368 pixel², pixel size 50 μ m). A 100 kV filament voltage and a current of 100 μ A 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 μ m. The sample was rotated inside the X-ray cabinet on a 360° rotation stage (Huber Goniometer 408). A commercial software program, Octopus (V8.6), was used to implement the back-projection algorithm with convolution and correction for cone beam. 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.

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 bithium. 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 SPAM¹. 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.

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 arrow) which is partially filled by corrosion products considering the results from the neutron investigation. A position of fully corroded metal ring section of ~ 20 mm³ on top right was determined (red ring). This area was identified for further analysis and possible conservation treatment. The histograms of the two volumes (c) show the peaks of attenuation coefficient for the main materials identified in the sample. These are metal (blue), corrosion (green) and glass beads (orange).

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-

¹ <https://ttk.gricad-pages.univ-grenoble-alpes.fr/spam/intro.html>

rays and neutrons. The histograms of the two volumes (c), show the peaks of attenuation coefficient for metal body (blue), metal ring holder on the top (light blue), corrosion (green) and tongue (orange) are marked in the presented histograms.

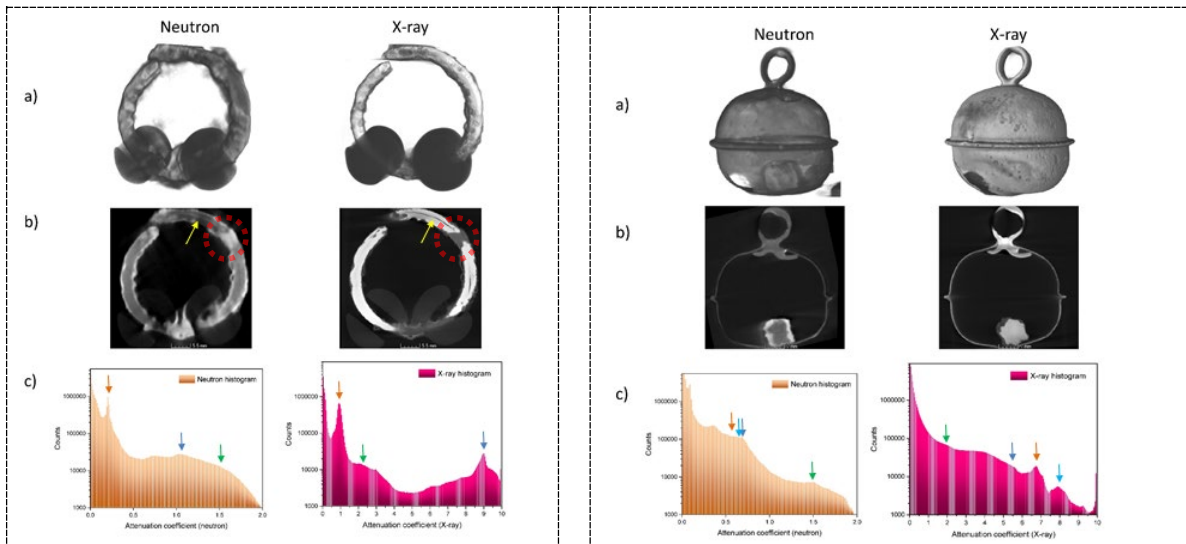


Figure 4. Tomography investigation of Earring.

Figure 5. Tomography investigation of Jingle bell.

a) 3-D visualization of the sample; b) Tomographic slices through the middle of the sample; c) Histograms. Attenuation coefficients marked in.

4.3. Thimble

The tomography investigation of the Thimble sample 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 histograms (c) show the attenuation coefficient for identified metal body (blue), corrosion (green) and tongue (orange).

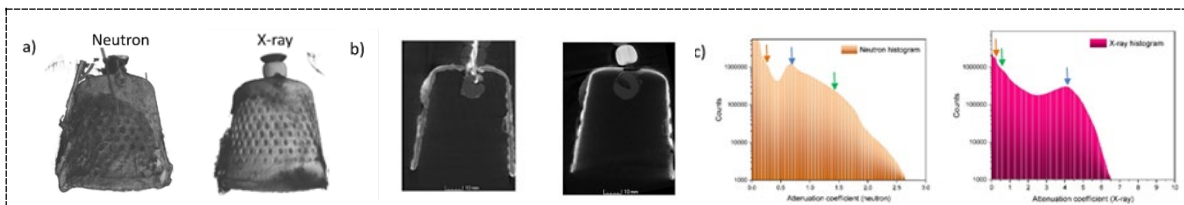


Figure 7. Tomography investigation of Thimble. a) 3-D visualization of the sample. b) Tomographic slices through the middle of the sample. c) Histograms. Attenuation coefficients marked in.

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.

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