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Archaeometric Analysis of Potentially Damaging Material to the Collection of Museu de Ciências Naturais Carlos Ritter

Análise Arqueométrica de Material Potencialmente Danoso ao Acervo do Museu de Ciências Naturais Carlos Ritter

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ABSTRACT

Museological documentation is an indispensable activity in the daily operations of a museum. Its purpose is closely linked to the role of the institution as a "place of research." However, the conservation state of a collection is directly affected by the processes the museum undergoes, which is related to the concept of Preventive Conservation. Yet, these activities are not always properly documented. This study demonstrates the importance of documentation for the preservation of a museological collection based on a case at Museu de Ciências Naturais Carlos Ritter, Riogrande do Sul, Brazil. In this case, archaeometric analyses were necessary to characterize a material in contact with the taxidermized specimens of the collection. The application of this material has not been properly documented and could have posed risks to both the collection and the staff. Using EDXRF, XRD and FTIR, the material was characterized as a mixture of aluminum oxide and graphite, two solid substances that are non-reactive and non-toxic to humans. Nevertheless, the museum deemed the material a distraction for visitors and decided to remove the powder from the display cases.

keywords archaeometry, preventive conservation, museological documentation

RESUMO

A documentação museológica é uma atividade indispensável para o dia a dia de um museu, e sua finalidade está atrelada ao papel de "lugar de pesquisa" que essa instituição desempenha. Contudo, o estado de conservação de um acervo é impactado diretamente pelos processos pelos quais o museu passa, relacionados diretamente ao conceito de Conservação Preventiva; e nem sempre essas atividades são devidamente documentadas. Este trabalho demonstra a importância da documentação para a preservação de um acervo museológico com um caso do Museu de Ciências Naturais Carlos Ritter, Rio Grande do Sul, Brasil, em que análises arqueométricas foram necessárias para a caracterização de um material em contato com as peças taxidermizadas do seu acervo, cuja aplicação não foi devidamente documentada, e que poderia estar colocando em risco o acervo e os funcionários. Por meio de técnicas como EDXRF, DRX e FTIR, pôde-se caracterizar o material como uma mistura de óxido de alumínio e grafita, dois materiais sólidos que não são reativos e nem tóxicos para os seres humanos. Ainda assim, o museu entendeu que o material era um elemento de distração para os visitantes, e optou pela retirada do pó das vitrines expositivas.

palavras-chave arqueometria, conservação preventiva, documentação museológica

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Introduction

Currently, it is unthinkable for a museum institution not to have a catalog of its collection; however, this practice is not always carried out in a well-structured manner. As pointed out by Ceravolo and Tálamo (2000), the processes of museum documentation's consolidation have been marked by divergences of opinion regarding which information should be prioritized and what the main purpose of this activity should be. Since the 1980s, documentation has been linked to the function of "environments that foster research", one of the roles assigned to museums, and, accordingly, the information to be recorded is that which contributes to this purpose.

In this context, archaeometric analyses are gaining increasing relevance in the study of museum objects, employing analytical methods from the exact sciences with the purpose of expanding knowledge about the materials and techniques used in each artwork (Rizzutto, 2015). However, archaeometry is not limited to the objects themselves, but should consider their surroundings as an important object of study as well. It is within these surroundings that the efforts of preventive conservation of cultural heritage are concentrated.

Conceptually, preventive conservation is understood as all practices carried out around the object that directly impact the preservation of its condition (Bojanoski et al., 2017). The environment in which the object is situated is a determining factor for its conservation state, either slowing down or accelerating the degradation processes of its constituent materials. Therefore, understanding this surrounding, including all its microenvironments such as display cases, rooms, buildings, and broader regions, as defined in the field of preventive conservation, is crucial to assessing whether the collection is adequately protected and isolated from substances that may contribute to its deterioration. The present study presents a case in which archaeometric analyses supported decision-making related to the preventive conservation of the collection at the Museu de Ciências Naturais Carlos Ritter – MCNCR (Carlos Ritter Natural Science Museum), in Rio Grande do Sul, Brazil, due to the lack of comprehensive documentation regarding the processes to which the collection had been subjected.

Carlos Ritter was an important figure in the city of Pelotas, where the museum is located, as the owner of a brewery, at the end of the 19th century and at the beginning of the 20th century, which contributed significantly to the region's economy. He was also one of the founders of the Centro Agrícola-Industrial de Pelotas, in 1887 (Anjos, 2000). The MCNCR is named after Carlos Ritter due to his hobby related to the natural sciences: he collected insects and practiced taxidermy, the process of preserving animal skins, popularly known as "stuffing." Moreover, the museum's collection originated from the pieces crafted by Ritter himself, which were donated to the former Escola de Agronomia and later incorporated into the Universidade Federal de Pelotas (UFPel) in 1969. The museum houses a collection of taxidermy mount, insects, fossils, natural science textbooks, and other items.

Because it is a biological collection, the taxidermy mounts are classified as extremely sensitive, being directly affected by several factors such as high temperature and relative humidity, lighting, pollution, and insects that feed on organic matter (Nasrin & Abduraheem, 2021). The high sensitivity of the collection further underscores the importance of detailing the museum's activities that influence the preventive conservation of these objects. Additionally, the very process of taxidermy as it was originally practiced, which used arsenic soap, presents a particular concern in the preservation and handling of such collections (Omstein, 2010). Nowadays, however, due to the known toxicity of arsenic, it is no longer used.

Inside the museum's display cases, alongside the objects, small piles of a gray powdery material were observed, with no evident pattern of application, Figure 1. When asked about the nature of the substance and the reason for its use, the staff reported that they had no answers to these questions; they did not know what it was and had no documented records in the museum regarding the procedure behind its application.

Returning to the concept of preventive conservation, in which understanding the environment surrounding the object is crucial to its conservation state, the nature of this powdery material, which shares space with the collection, may contribute to the deterioration of the objects. In addition, if this substance possesses any level of toxicity, it could pose a risk to staff members and interns who come into contact with it while cleaning the collection.

Figure 1 - Photograph of an exhibition display case at MCNCR, showing the powdery material alongside the collection items.

The main objective of this study was to characterize this unknown powdery material, clarifying its chemical composition and seeking to understand the reason for its application in the display cases. Through this, the study aims to determine whether the collection and the staff are at risk due to direct contact with the material, and whether its presence is truly necessary for the preservation of the objects.

Materials and Methods

Samples of the powdery material were collected from the display cases for the analysis. It was not necessary to sample from multiple distinct locations, as it was assumed that the material spread throughout the display cases shared the same composition. Additionally, movement of the objects over the years has caused the powder to be displaced across the shelves, mixing its components.

An Energy-Dispersive X-ray Fluorescence Spectroscopy (EDXRF) analysis was performed using a Shimadzu EDX-720 instrument, under vacuum atmosphere, with a 10 mm collimator, Rh tube, and an acquisition time of 100 seconds. The instrument captures data from a 10 mm diameter circle of the sample, dispensing with the need to replicate the analysis.

X-ray Diffraction (XRD) was conducted using a Shimadzu XRD-6100 instrument, equipped with a copper cathode radiation source ($\lambda = 1.54184$ Å), with a scan range from $5.00°$ to $110°$ (2θ).

Additionally, a qualitative gravimetric analysis was carried out by submitting the material to an oven, at $600°$C for 6 hours. An enlarged image of the sample was obtained using a WITec Alpha300 Accessseries confocal microscope, equipped with a 50x objective (Zeiss LD Epiplan-Neofluar).

Both samples (pre-and post-calcination) were analyzed by Fourier Transform Infrared Spectroscopy (FTIR) with a Shimadzu IR Affinity-1 instrument, operating in the 4000–400 cm^{-1} range, with a resolution of 4 cm^{-1} and 100 scans.

Results and Discussion

Initially, the EDXRF technique was used to obtain a preliminary result regarding the chemical elements present in the sample. The list of detected elements is presented in Table 1, ordered by the percentage found.

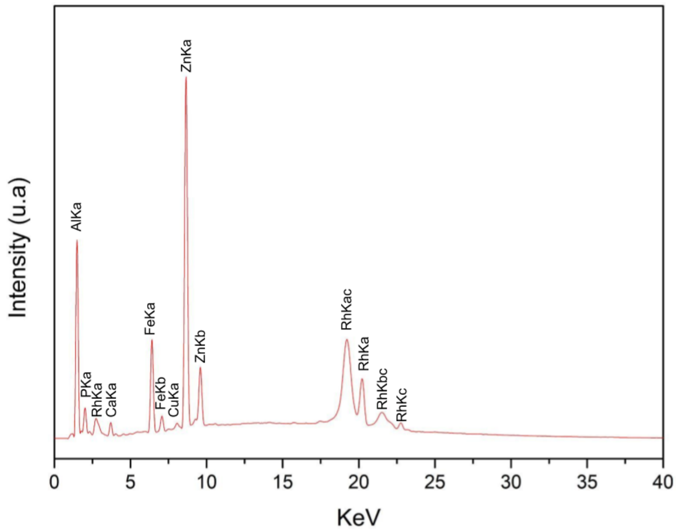
The percentage amount in the sample is relative due to the elements the technique is capable of identifying—that is, elements heavier than sodium ($Z = 11$). This technique does not allow the detection of light elements such as hydrogen, carbon, and oxygen; in other words, organic substances, if present (Linskens & Jackson, 1987). Figure 2 shows the obtained peaks corresponding to each identified chemical element.

Aluminum was identified as one of the main components of the sample, while the other elements are likely derived from secondary mineral phases of the used raw material. It is evident that the product's level of purity is not high, which is attributed to the nature of its application, as it does not require a meticulous purification process to eliminate other minerals. Additionally, since the material was exposed to the environment for an unspecified period, contamination may have occurred.

Table 1 - Chemical elements identified in the sample by EDXRF, along with their relative proportions.

Element	Percentage (%)	3-sigma (%)
Al	86.089	0.310
P	6.529	0.060
Zn	2.822	0.016
Si	1.412	0.081
Fe	1.403	0.015
Ca	1.301	0.018
S	0.290	0.016
Ag	0.057	0.005
Cu	0.050	0.005
Ga	0.047	0.004

Figure 2 - EDXRF spectrum obtained for the powder sample showing the elemental composition, with characteristic peaks corresponding to Al, P, Rh, Ca, Fe, Zn and Cu.



In order to assess whether the material contained any organic fraction, a gravimetric test was performed using 1 g of the sample, subjected to 600°C for a burning period of 6 hours. After this period, approximately two-thirds of the sample remained (66.48%). This indicates that one-third of the initial mass can be attributed mainly to moisture, organic matter, or the thermal decomposition of a low-stability mineral.

The presence of a carbon-bearing mineral in the sample was confirmed by XRD analysis, with the result shown in Figure 3. In addition to the presence of aluminum oxide (alumina), identified as the main component of the sample, a carbon fraction (graphite) was also detected. Peak indexing was carried out using ICSD cards No. 9770 (alumina) and No. 18838 (graphite), and the comparison between the experimental and reference values is presented in Table 2 (Didier et al., 2020; Finger & Hazen, 1978).

The diffractogram indicates the amorphous nature of the sample, and therefore other characteristic peaks of graphite were masked by this lack of definition. The mixture of distinct solid substances is also evidenced by an optical microscope image, in which darker and lighter grains can be identified, see Figure 4.

The safety data sheets for both substances were analyzed separately to assess the level of hazard these materials pose to the museum collection and staff. Regarding aluminum oxide, the substance is not considered hazardous, according to Directive 67/548/EEC. Due to its potential to cause irritation to the respiratory tract and skin, the use of gloves and masks is recommended when handling the product. In terms of reactivity, aluminum oxide is considered inert, with recommendations to avoid contact with strong acids and bases, and to store it in a cool environment due to its highly hygroscopic nature (Sigma-Aldrich, 2008).

Regarding graphite, the mineral is not classified as hazardous according to ABNT NBR 14725-2, and the same PPE recommendations apply. Graphite is chemically stable, requiring only the avoidance of contact with oxidizing agents, alkali metals, and their peroxides (Labsynth, 2022; Nacional de Grafite, 2012).

Figure 3 - Diffraction pattern obtained for the powdered sample. Indexing of the main peaks corresponding to alumina (blue) and graphite (red), numbered from 1 to 9.

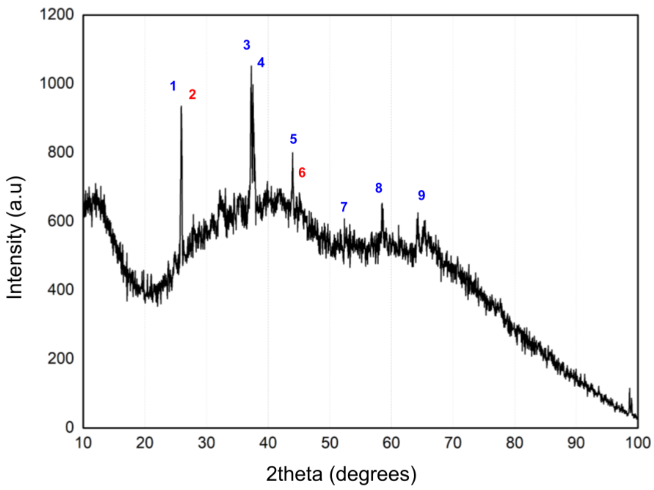
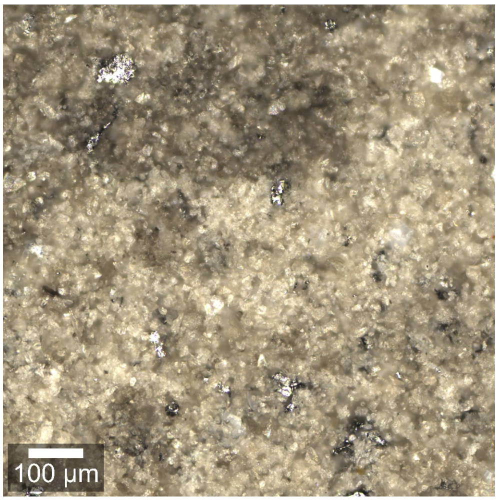


Table 2 - Indexing of graphite and alumina peaks, comparing experimental values with reference data.

Peak	Substance	$2\theta_{exp}$ (°)	$2\theta_{ref}$ (°)
1	Al_2O_3 (Alumina)	25.8	25.6
2	C (Graphite)	25.9	26.6
3	Al_2O_3 (Alumina)	35.2	37.2
4	Al_2O_3 (Alumina)	37.7	37.8
5	Al_2O_3 (Alumina)	43.9	43.4
6	C (Graphite)	43.9	44.6
7	Al_2O_3 (Alumina)	52.3	52.6
8	Al_2O_3 (Alumina)	58.4	57.5
9	Al_2O_3 (Alumina)	65.4	66.5

Figure 4 - Image of the sample obtained using an optical microscope.



There is a documented correlation between respiratory illnesses and the inhalation of aluminum oxide dust (Krewski et al., 2007) and graphite dust (Parmeggiani, 1950), but only under high and continuous exposure levels. The cited studies examine the cases of mine workers, which do not reflect the reality of the MCNCR. The powdered material is stored within the museum display cases, and these are only opened for mechanical cleaning of the collection. Therefore, staff are not frequently exposed to the dust, and when they are, gloves and masks are used to handle the objects inside the cases.

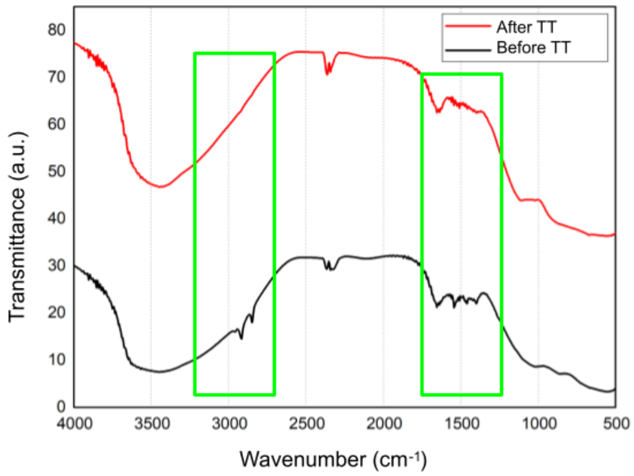
The presence of this powder does not pose any significant threat to the collection either, as both minerals are considered inert and no contact occurs with the reactive substances mentioned in the safety data sheets. Since there is no documentation regarding the application of this material, questions were raised about why the powder was placed inside the display cases.

As mentioned, aluminum oxide is hygroscopic and may have been used to absorb moisture inside the cases, considering that Pelotas is a city with high humidity (Colischonn & Ferreira, 2015). However, due to the method of application, this purpose was considered unlikely, though not entirely ruled out.

A large number of insects feed on keratin and can become agents of degradation for taxidermy specimens, leading to irreversible damage (Querner, 2015). One hypothesis is that this powder was applied to repel or eliminate such insects inside the display cases, preventing the taxidermy mounts from serving as a food source. Although aluminum-based pesticides do exist for controlling rodents, insects, and fungi, the commonly used compound is aluminum phosphide, not aluminum oxide (Hassan, 2020). Informally, aluminum oxide is sometimes sold as a rodenticide, but its effectiveness depends on ingestion, which does not seem to align with how the substance was applied in this context.

Another hypothesis considered is that the powder served as a solid carrier matrix for organic liquid insecticides, which are often formulated this way to prevent the rapid evaporation of active ingredients. Over time, the active compound would volatilize, leaving the solid matrix, which would be the only residue left. This hypothesis is supported by FTIR analysis, Figure 5, of the samples before and after thermal treatment. Upon heating the material, there is a disappearance of bands in the regions around 2850 to 2960 cm^{-1}, possibly indicating C–H, N–H, and O–H bonds; and in the range of 1400 to 1500 cm^{-1}, which may be associated with C–H bond vibrations; and between 1500 and 1600 cm^{-1}, associated with C=C bonds in aromatic compounds and N–H in amides. These findings suggest that organic substances were adsorbed onto the material and were eliminated during thermal treatment (Silverstein & Webster, 1996).

Figure 5 - Infrared transmission spectrum of the samples before (black) and after thermal treatment (red), highlighting the regions around 3000 and 1500 cm^{-1}.



It was not within the scope of this work to thoroughly identify the substances present in the sample, but rather to understand the reason for their application in the display cases. For that reason, based on the information obtained about the material, the current management of MCNCR concluded that, although its presence did not directly affect either the collection or the staff, it no longer served any practical purpose. Additionally, it had become a distracting element within the display cases, and so the decision was made to completely remove the material, leaving the exhibition space cleaner and allowing visitors to focus more on the displayed pieces.

Conclusions

The selected analyses were able to characterize the material primarily as a mixture of aluminum oxide and graphite, with smaller amounts of other minerals. To investigate the organic substances present in the sample in greater detail additional analytical techniques would be required. However, for the purposes of this study, the analyses conducted were sufficient to provide a report to the museum, which was interested in assessing the necessity of displaying this material alongside the collection.

This action directly impacted the museum visitor's experience, helping to direct their attention toward the exhibited pieces rather than to elements that might disrupt the immersive quality of the museological experience during their visit to the institution.

It is also concluded that there is a field of application for archaeometry beyond the analysis of cultural assets and works of art, particularly in the scope of Preventive Conservation of such objects. This approach provides relevant information about their preservation status and other external factors that may directly affect the safeguarding of cultural and artistic heritage.

Author contributions

L. de S. L. Pereira participated in: conceptualization, investigation, validation, data curation, methodology, writing – original draft. **L. G. Pereira** participated in: resources, supervision, writing – original draft. **B. da S. Noremberg** participated in: investigation, resources. **M. M. Ferrer** participated in: conceptualization, methodology, project management, resources, supervision, writing – revision and editing.

Conflicts of interest

No potential conflict of interest was reported by the authors.

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