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Fluorescent Surface Mapping of Mastodon Tusk

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Abstract

The subject of study is a *Mammut americanum* (American Mastodon) tusk. The tusk is currently damaged and in need of repair. To better understand the tusk and the preservation materials previously used, fluorescence spectrometry was used to make a surface map of the tusk. This data will be useful to the conservationists as they plan the care and restoration of the tusk.

Introduction

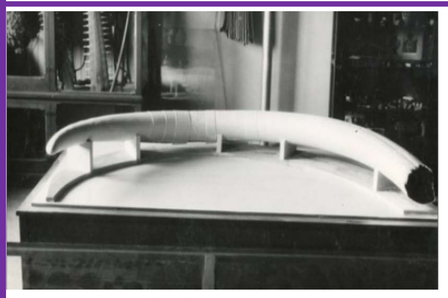


Figure 1: Tusk after restoration in 1960s

The UNI museum has a large collection of objects that are of anthropological interest, including the *Mammut americanum* (American Mastodon) tusk, as shown in Figure 1. Since its discovery in 1933, it has undergone a variety of preservation and restoration techniques, some of which were undocumented [1].

The tusk is covered in several layers of lacquer, the actual composition of which is unknown. Possible preservation materials depend on the period in which the techniques were performed [2]. The large window in which preservation was being performed means the lacquer could be composed of anything from natural materials, possibly including asbestos, to acrylic paints, possibly containing lead.

Figure 2: Current state of tusk (left) and detail (right)

The tusk itself is currently in disrepair and in desperate need of further preservation efforts, as shown in Figure 2. Funding for restoration and preservation has been provided through a grant from the Roy J. Carver Charitable Trust [1].

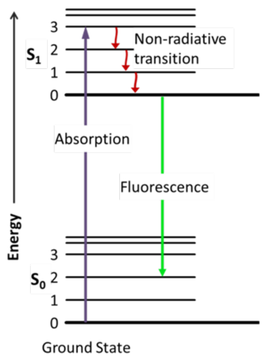
Before more steps can be taken toward ensure the tusk's safety, a thorough understanding of the lacquer is needed. This study proposed to make a topographical map of the tusk using fluorescence spectroscopy. This will allow us to understand the chemical content of the top layer of material, which will then help the conservator to decide on the best way to proceed with the care of the artifact.

Fluorophores

Fluorophores are molecules that are able to absorb light at one wavelength and emit it at another, less energetic wavelength. These molecules are often analyzed to determine chemical content of a given material.

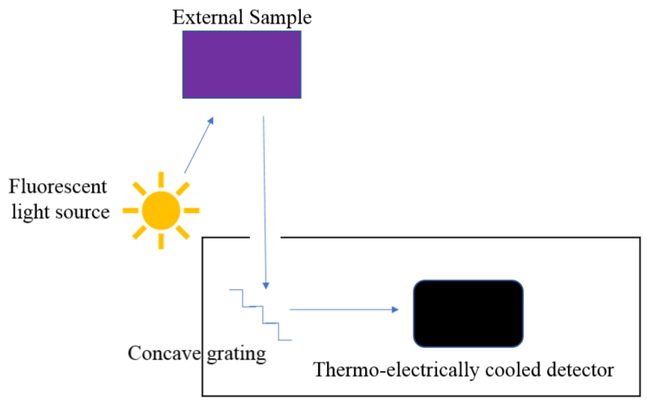
Fluorescence occurs in three steps:

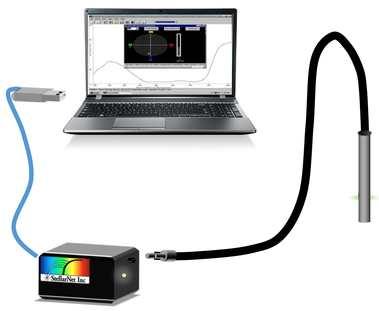
1. A photon from an external source excites, or is absorbed by, a fluorophore. This causes an excited electronic singlet state.
2. This excited state lasts for a brief time (usually 1-10 nanoseconds), during which the fluorophore interacts with its environment. This results in some of the initial energy being dissipated.
3. The fluorophore returns to its original state and emits a photon at a lower energy (longer wavelength). The difference in the excitation and emission wavelength is called the Stokes shift.



Jablonski diagram of absorption, decay, and fluorescence [4].

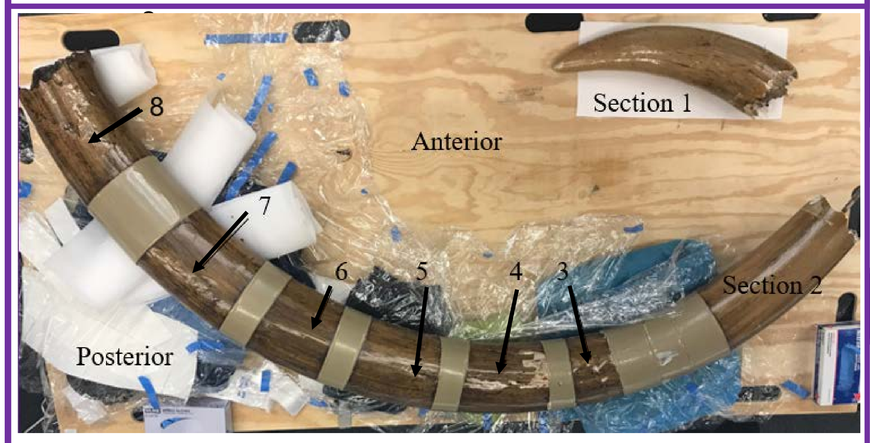
Instrumental Design



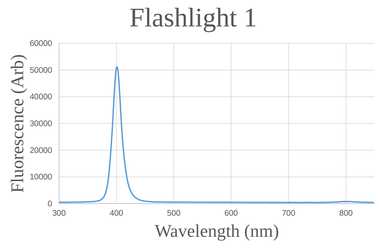


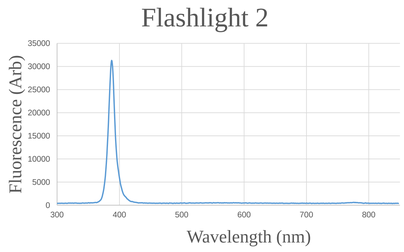
To take spectra of external samples a BLACK-Comet portable spectrometer and reflectance probe were used. This design includes concave grating and a cooling system for the detector, which reduces stray light to 0.02 % (at 435 nm). The signal to noise of this instrument is 1000:1 CCD with a dynamic range of 2000:1 with 6 decades, as well as a resolution of 0.25 nanometer.

Methods

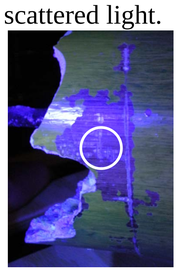


The tusk was assigned sections and orientation, in order to help with identification. It was cleaned with canned air to remove dust and debris.

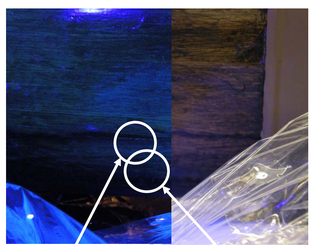




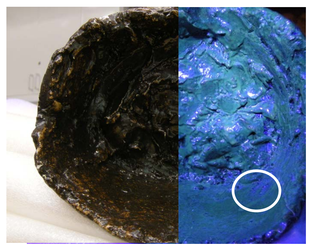
Initially, large fluorescence-inducing lights were used to determine at what wavelength the lacquer was fluorescing. After it was determined that the 388 and 400 nanometer lights exhibited the highest fluorescence quantum yield, regions of interest were identified on the tusk. The fluorescence spectra were cut off at 450 and 800 nanometers to reduce noise from scattered light.



1_C



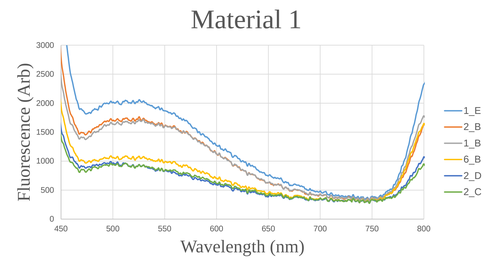
6_B 6_A

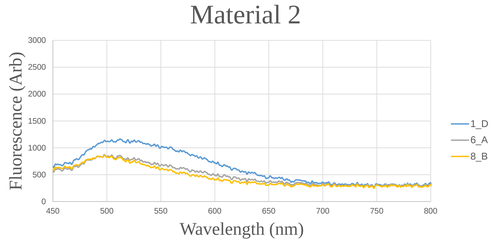


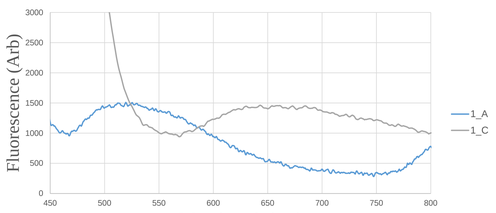
8_A and 8_B

For each region of interest, the tusk was excited with the selected black lights and the fluorescent spectrum was taken.

Results







Four main spectral zones were identified on the tusk, as shown by the spectra on the left. These indicate that there were, on the surface, four distinct preservation materials used.

The differing intensities of fluorescence indicate differing thickness of the preservation layers.

Material 1 was present in sections either thinner coatings of lacquer or areas known to have at least one layer chipped off. Material 2 was present in rougher sections, with visibly thicker coatings. Section 1_A and 1_C had multiple layers of the lacquer chipped off.

The difference in these two spectra could be explained by reading different layers of lacquer or the tusk itself.

Conclusion

These results show that the preservation techniques applied to the tusk are not uniform and therefore will require more care in restoring the tusk. By using the sections described here, the conservationists will be able to plan their efforts more efficiently.

Future Work

The spectra shown in this report indicated areas with significant differences in composition. However, in order to increase sample size, more spectra can be taken across the whole of the tusk. In addition, other methods can be used to identify the precise chemical makeup of the described areas.

Due to the limitations of the spectrometer and the probe, only the topmost layers of each section were analyzed. As the conservation project moves forward and layers are removed, additional scans could be done after each layer. This would allow for a closer inspection of all previous techniques and preservation materials used on the tusk.

Acknowledgments

University of Northern Iowa Museum
Nathan Arndt , University of Northern Iowa Anthropology Department
Roy J. Carver Charitable Trust

Work Cited

[1] Arndt, Nathan; Cruz, Jess. Preserving the Past: Scientific Study, Conservation, and Interpretation of the *Mammut Americanum* (American Mastodon). *University of Northern Iowa*, 2017.

[2] Howie, Francis M.P. Materials used for conserving fossil specimens since 1930: a review. *Studies in Conservation.* [Online] 1984**,** 29:sup1, 92-97, DOI: 10.1179/sic.1984.29.Supplement-1.92 (Accessed 2 September 2017).

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