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Non-destructive investigation of a time capsule using neutron radiography and X-ray fluorescence

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ABSTRACT

Non-destructive analytical techniques are becoming increasingly important for the study of objects of cultural heritage interest. This study applied two techniques: X-ray fluorescence and neutron radiography, for the investigation of a capped, tubular metal object recovered from an urban construction site in Gore Park, Hamilton, Canada. The site is an urban park containing a World War I commemorative monument that underwent renovation and relocation. Historical documentation suggested that the object buried underneath the monument was a time capsule containing a paper document listing the names of 1800 Canadians who died during WWI. The purpose of this study was to assess the condition of the object, and to verify if it was what the historical records purported. XRF analysis was used to characterize the elemental composition of the metal artifact, while neutron radiography revealed that its contents were congruent with historical records and remained intact after being interred for 91 years. Results of this study demonstrate the value of non-destructive techniques for the analysis and preservation of cultural heritage.

1. Introduction

The primary challenge for investigating materials of cultural heritage interest is in the need for non-destructive methods of analysis. Data regarding the physical condition, and chemical and structural properties of objects in archaeology and art provide important information to researchers to develop protocols for their appropriate handling, presentation, storage, and conservation. Therefore, the availability of non-destructive imaging and materials analysis techniques to assist in the characterization of such objects are of great value to heritage specialists. Neutron radiographic (NR) imaging has been used for heritage science applications to image museum quality metallic objects for information on structure and condition. Some successful examples include Lehmann et al. [8] investigation of 14th–15th century Tibetan Buddha statues, analysis of 8th century BC Etruscan bronze figurines [4], and other examples in Lang and Middleton [7], and Rant et al. [13]. In addition to the information that imaging can provide about the condition, internal features, and manufacturing technologies of an object, elemental characterization techniques are also used for the identification of raw materials, alloys, pigments, gilding, or surface treatments. This information is especially critical for assessing the condition of an object, and developing protocols for handling and conservation. As a result of recent improvements in portable technologies, handheld XRF devices are now used almost routinely in museums and for research on archaeological collections [3,5,9–12,14–16]. For this study, we used a combination of XRF and NR to assess the condition, composition, and contents of an object suspected to be a time capsule that was recovered from a historic site in Hamilton, Ontario, Canada.

2. Time capsule

Nray Services Inc. has worked in collaboration with cultural heritage researchers at McMaster University on a series of unique, non-destructive examinations of objects including Greek and Roman coinage, early 16th C Spanish Basque metal trade goods, and paintings attributed to Vincent Van Gogh and Alexander Rodchenko from the McMaster Museum of Art permanent collection. Recently, an object purported to be a time capsule was recovered from a construction site in Gore Park, Hamilton, as part of an initiative to upgrade a cenotaph and World War I memorial site originally constructed in 1923. In partnership with specialists in

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Fig. 1. Gore Park and cenotaph, downtown Hamilton, Ontario.

the City of Hamilton Cultural Heritage Division, XRF analysis and NR imaging were conducted to assess the elemental composition, condition, and authenticity of the object. Upon the discovery of the tube, Hamilton Public Library archivist Margaret Houghton confirmed information from a May 1923 Hamilton Herald news article describing the unveiling ceremony and the placing of a scroll inside the cenotaph. A.R. Lancefield, the Canadian Club president at the time stated: "This is no empty tomb. Within its depths lies a scroll bearing the names of 1800 Canadians who gave their lives in the cause for right and freedom" [6]. Fig. 1 shows the cenotaph in Gore Park prior to its relocation.

The object was an 11″ × 2″ cylinder with threaded caps on each end. Fig. 2 shows the tube and its corresponding neutron radiographic image. Wax and paper residues remained on the external surface of the object, as well as some visible areas of copper oxidation. Upon recovery the cylinder appeared to be airtight and intact. As with most objects of heritage interest, preservation is paramount, and in the potential context of a time capsule it was critical to refrain from opening the object. Opening the object would risk causing irreparable damage to the contents inside. The research goals were twofold: to confirm what was inside the tube without damaging or opening it while preserving its condition, and, to determine the composition of the metals to develop a protocol for its handling and preservation. In this circumstance, the application of NR imaging and XRF analysis for elemental characterization were a combination of techniques well suited to achieve this end. The following sections describe our application of these methodologies.

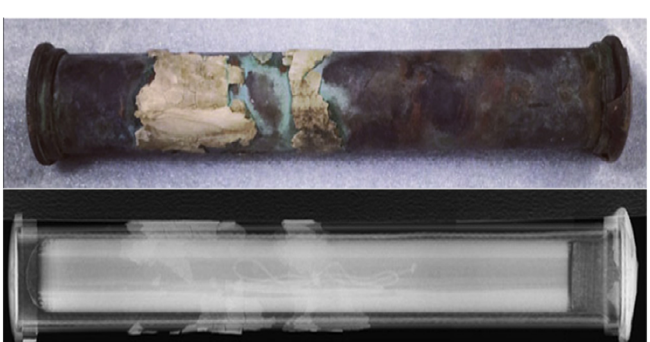

Fig. 2. Time capsule tube (above) and corresponding neutron radiograph image (below).

3. Elemental characterization via X-ray fluorescence

X-ray fluorescence is a technique used often by cultural heritage specialists for the non-invasive chemical characterization of objects of interest. An advantage of this technique is that it does not require a sample to be removed, ablated, or homogenized for analysis, which is of great value in the interests of preservation. However, in comparison to other techniques such as neutron activation analysis, X-ray diffraction, SEM-EDS, or LA-ICP-MS, it can be comparatively less precise and accurate for some applications. XRF is a near-surface analysis technique whereby samples are bombarded with X-rays powerful enough to dislodge inner K-shell electrons from their respective shell configurations. The target atom becomes unstable, and outer L- and M-shell electrons replace inner-shell vacancies. The energy that is emitted, or fluoresced, during this process corresponds to an X-ray characteristic of that element. Those energies are measured by a detector and sorted by a multi-channel analyzer to produce a qualitative and quantitative spectral representation. The equipment used for this application was an Olympus Innov-X Delta Premium model portable XRF device. This instrument is equipped with an Au anode as the excitation source, a SDD detector, and operates at 40 kVp and 0.1 mA. It is programmed with a series of modes, each applying different voltage, current, and filter combinations customized for different material types. The mode selected for this work was Alloy–Precious Metals, which is optimized for determining