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Revealing the biography of a hidden medieval manuscript using synchrotron and conventional imaging techniques

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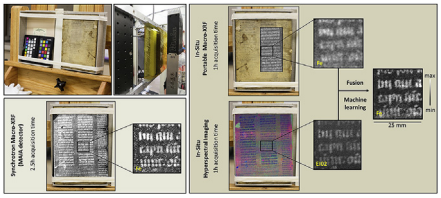
HIGHLIGHTS

- A comparative study of *in-situ* conventional and synchrotron imaging techniques for revealing hidden manuscript.
- The fusion of portable XRF and hyperspectral, an innovative solution for compositional imaging of wide fields of view.
- Application to real cases: a deeper insight into ancient manufacturing and historical context of the hidden library.

GRAPHICAL ABSTRACT



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ABSTRACT

Reading the content of hidden texts from ancient manuscripts has become an increasingly important endeavor thanks to the variety of non-destructive analytical tools and image processing routines available for this task. In this study, portable macro X-Ray Fluorescence (MA-XRF-tube), Visible Hyperspectral Imaging (HSI) together with Synchrotron based macro X-Ray Fluorescence (MA-XRF-SR) are combined with signal processing methods to reveal the biography of a degraded manuscript recycled as binding material for a 16th century printed edition of Hesiod's *Works and Days*. The analytical techniques allow visualizing the hidden text, revealing passages from *the Institutes Justinian*, a 6th century A.D codification of the Roman Law, with further marginal comments on medieval Canon Law. In addition, the identification of the materials (*e.g.* pigments, inks) part of the original manuscript together with their sequence of use are revealed: i) the preparation of the parchment using a Ca-based preparation layer, ii) drawing of ruled guide lines, using a Pb-based pen or ink, iii) writing of the main text using a rich Fe-gall ink with modulating color pigments (Hg-, Cu- and Pb- based) and iv) addition of two types of comments to the main text, one of the ink used for the comments being a Fe-gall ink rich in Cu.

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1. Introduction

The way manuscripts were preserved and treated through time can affect their legibility by partially or fully occluding the original text. Several factors related to their manufacture, storage, use or aging can lead to physical, chemical or biological degradation of the text support, and ink that constrain and limit our full reading of the information [1,2].

Recycling of parchment and paper has been one of the primary agents of damage for written texts throughout the history of bookbinding. During recycling the original information is voluntarily hidden or removed, as the parchment is formed into other objects, such as cartonnage [3], or made into a new manuscript support, such as a palimpsest [4]. Physical modification of the support by washing or scraping off the original text, folding, gluing, *etc*., together with natural degradation processes, may result in a brittle and fragile structure which could be damaged if one attempts to physically access the remaining written information. Moreover, even if accessible, the remaining text can be further occluded by additional writing, painting or staining of the surface related to its new use. Thus, reading the primary text on these compromised parchments often requires enhancing the legibility of their content.

In this study, a parchment repurposed as the binding material for the book "*Hesiodou tou Askraiou Erga kai Hemerai*" - the Greek poet Hesiod's Works and Days - has been examined. This version of Works and Days, now housed in Charles Deering McCormick Library of Special Collections at Northwestern University Libraries, was printed in Venice in the early 16th century and is of particular interest for its employment of a *slotted parchment* binding [5], named for the slots cut into the parchment sheath following exactly the shape of the book spine as illustrated in Fig. 1a. For this specific binding, the parchment cover was usually attached to the book board using animal glue. In combination with the alum-tawed skin patches used to protect the raised supports of the book, this particular structure provided a refined and easily flexible cover with a unique durability. These advantages resulted in the *slotted parchment* binding being a common choice for book bindings made in Venice from 1490 to 1670, where it represented an alternative to leather-based bindings which involved heavy gluing or stretching steps.

Among *slotted parchment* bindings, the recycling of earlier manuscript parchments was a common practice, typically borne out of frugality. In more than half of the recycled parchment, the ink of the text was removed from the outside surface to provide a uniform color as well as an elegant, albeit plain appearance [5]. However, the ink of the writing present on the inside surface of the parchment was not removed, and, with time became partially visible as illustrated in Fig. 1b. This effect, also called "burn-through", is commonly attributed to the use of iron gall ink, the writing ink of choice for documentation from the Middle Ages to the twentieth century. Produced by the reaction of gallic acid with an iron salt, the initially colorless solution oxidizes when applied to paper and exposed to air forming black-colored ferric gallate complexes. With time, the acidity of the ink and the presence of soluble and mobile iron ions accelerates the oxidative breakdown of the parchment surface [6]. While the deterioration caused by the iron gall ink on the binding of the Northwestern Hesiod allows for a visual demarcation of the written area, individual words or letters cannot be read.

For the recovery of this textual information a number of imaging and image processing modalities were explored (*e.g.* X-ray imaging, multi-spectral imaging in the UV, infrared and visible domains, reflectance transformation imaging and terahertz time domain spectroscopic imaging). These imaging techniques have previously offered enhanced legibility of hidden texts together with additional information about the physical characteristics and condition of the document [1,2,7–13]. Building on these previous studies, two non-destructive and non-invasive analytical techniques were chosen to recover the hidden writing from the Northwestern Hesiod: Hyperspectral Imaging (HSI) and X-ray Fluorescence (XRF) Imaging.

Visible HSI imaging allows the cover to be examined using diffusely reflected light. The overall acquisition time necessary for scanning areas with high spatial resolution is relatively short [14], and is thus suitable for the study of large object. This technique has proven successful in enhancing the hidden and damaged writing in other historic documents [4,15–20] based on the light absorption properties of the materials being imaged. In particular, the increase

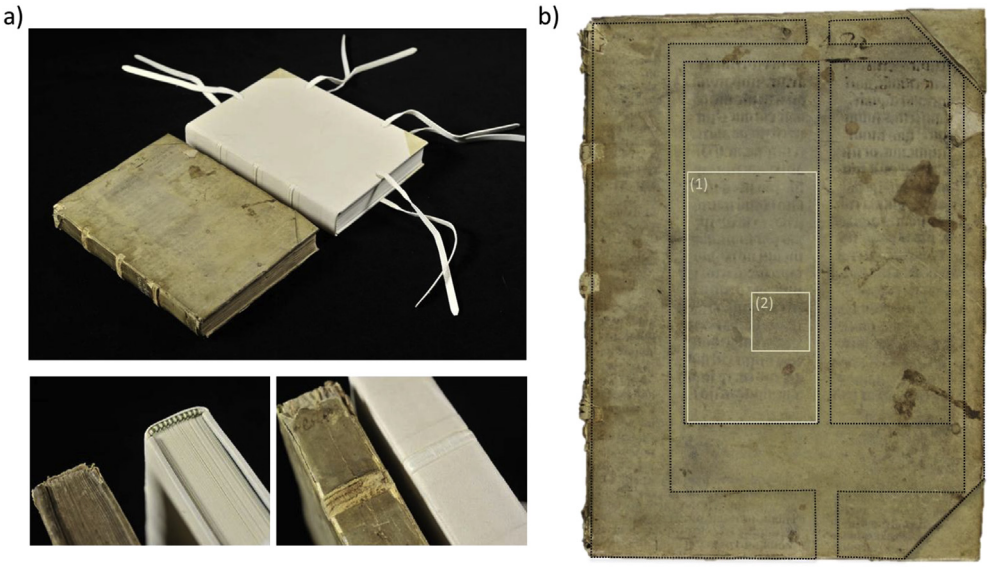

Fig. 1. a) Visible pictures of the original binding and of a facsimile following Venetian bookbinding tradition (image credit: Scott W. Devine); b) Visible picture of front side of the book cover (size: 21.4 cm H x 15.6 cm W x 2.3 cm D) – (1) and (2) refer to area analyzed by MA-XRF portable instrument and HSI, the results of which are presented below; the dotted line shapes highlight the presence of written areas defined by preliminary visual observations.