



Short communication

Revealing the history of a Mongolian shrine by virtually unrolling Buddhist Dharanis

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ABSTRACT

Mongolian Buddhist shrines (mong.: *gungervaa*) come in a variety of designs, just as the concept of shrines exists across different religions. These shrines are protective containers for icons, such as images or statues of Buddhist teachers, deities, saints, or revered clergy. The central figure is usually surrounded by relics from high-ranking lamas as well as decorative offerings presented by worshippers. Since *gungervaa*s are inherited within the family and offerings are added constantly, they can accumulate diverse sets of items over several generations. It is therefore important to examine and analyze the composition inside and understand each single component. One type of object that is found in *gungervaa*s are Dharanis (spell scriptures). Physically opening these tiny paper scrolls wrapped in silk poses a risk to their preservation, so it is generally not the preferred method. A non-destructive method is needed to decipher the written messages inside. X-ray tomography provides a way to examine the interiors of these fragile objects. By creating a three-dimensional virtual copy, it was possible to analyze and manipulate the content using computer software without harming the scrolls. Finally, text from inside the Dharanis scrolls was successfully extracted and translated.

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Introduction

In the Mongolian collection of the Ethnologisches Museum Berlin, there is a unique wooden shrine known in Mongolian as a *gungervaa* [1,2]. It measures approximately 55 cm in height, 40 cm in width, and 25 cm in depth. The front of the shrine features an ornate frame with a pane of glass, through which the figure of a lama, a teacher in Tibetan Buddhism, can be seen. The lama is surrounded by small paintings, decorative offerings, and various relics. The shrine was likely to have originally been part of a triptych.

The known story of the shrine's biography begins with Sven Hedin. Hedin was a Swedish geographer and explorer, who led the Sino-Swedish Expedition between 1927 and 1935 [3], which included approx. 60 men, 300 camels and 40 tons of luggage. He referred to the expedition as the "wandering university" because it included scientists from various disciplines in Sweden, Germany, and China. The team studied the meteorological, topographic and prehistoric conditions in Mongolia, the Gobi Desert, and Xinjiang [4,5]. Another important name in this context is Waldemar Haude [6,7], the German meteorologist on the expedition, who came into

possession of the *gungervaa* under still unknown circumstances. For some reason, he considered the shrine such an important piece that he handed it over to his German friend Ferdinand Lessing in Beijing after the expedition ended [8]. Lessing, a Sinologist and Mongolist with a special interest in Tibetan Buddhism, was curator of the East Asian collections at the Ethnological Museum in Berlin [9]. He took the precious gift home to Berlin and exhibited the *gungervaa* in an exhibition on the folk life of Mongolia in 1934. To this day, the *gungervaa* in Berlin is the only known example of this type of shrine in a museum collection in the west and in Mongolia. Usually taken apart and stored separately according to their components, no known composition of such a shrine stayed intact.

The Berlin shrine has suffered some losses and no longer exists in the arrangement in which it entered the museum in 1932. Four gilded bronzes and a small painting have been missing since the Second World War. However, >20 small items remained in the shrine and have been analyzed. Nevertheless, essential questions about the provenance of the *gungervaa* and the original arrangement of the multiple items inside this wooden box remain unanswered until today.

An opportunity to shed more light on these questions presented itself in three tiny scrolls wrapped in yellow silk (Fig. 1a) found inside the *gungervaa* (Fig. 1b). The goal of the research presented

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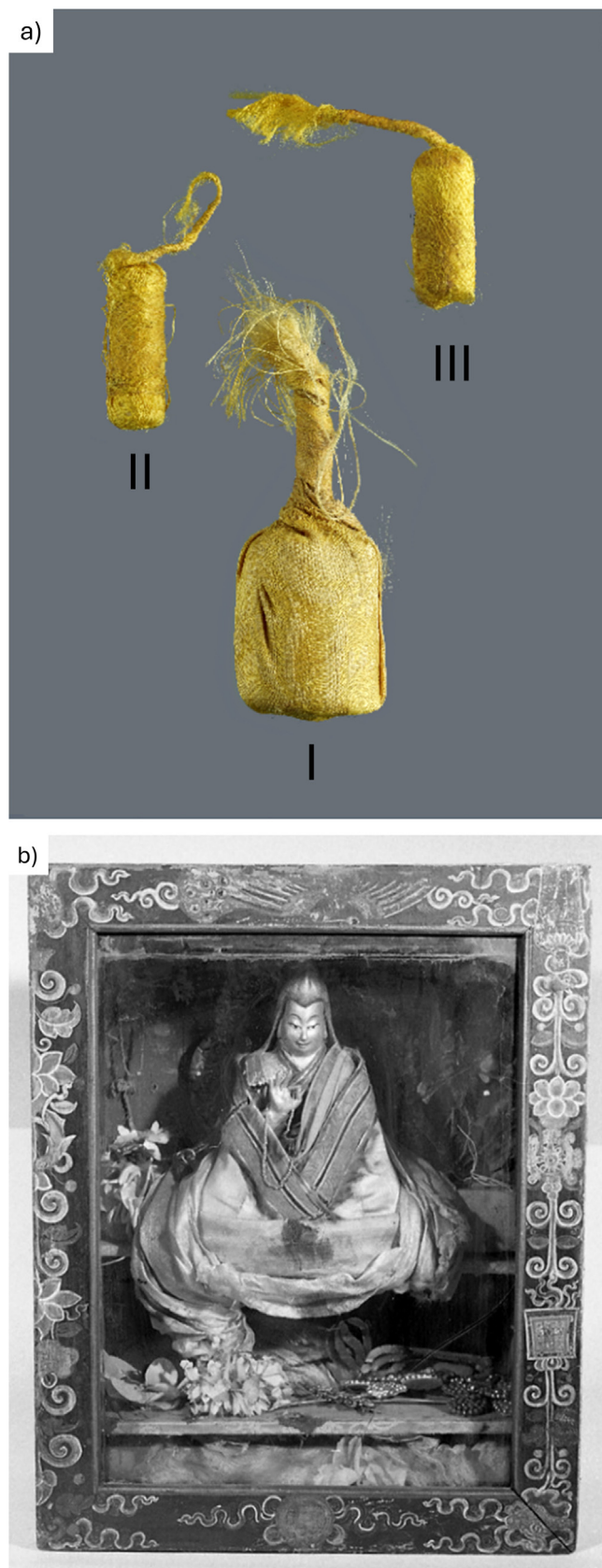


Fig. 1. a) Three tiny scrolls were found inside the shrine. ©Staatliche Museen zu Berlin, Ethnologisches Museum / Martin Franken. b) Inv. #: I D 34310 Mongolian shrine. ©Staatliche Museen zu Berlin, Ethnologisches Museum.

here is to extract the information contained in these scrolls without altering their material condition by unrolling them.

The current X-ray tomography technique provides very detailed insights into matter and objects. This method is non-destructive, thus the objects to be examined will not be manipulated or damaged during the process. It is therefore possible to safely obtain information from inside the objects. Comparable techniques have already been applied to other folded and rolled objects [10–13] and have been successfully applied to ancient papyri fragments from Elephantine Island [14–15]. In that study, the first characters could be identified and read from inside folded papyri without physically opening them.

The scrolls from the *gungervaa* are Buddhist Dharanis, tiny paper scrolls containing mantras or prayer texts, occasionally with additional information. They were commonly inserted in stupas and metal sculptures during consecration ceremonies and can be interpreted as Buddhist text relics [16]. The language of Dharanis includes both meaningful and meaningless content, making it unclear whether these texts might contain information useful for dating the shrine or for determining the provenance of the *gungervaa*. However, physical unwrapping and unrolling was not an option for ethical reasons according to international museum standards in conservation [17]. Instead, interdisciplinary solutions were explored, and X-ray tomography scanning was chosen.

Research aim

The aim of this research is to present virtual unrolling and unfolding technologies to other fields of research and interest. Considering that the information cannot be obtained safely by other methods, the aim is also to spread awareness of the existence of this method to the community. A larger user base leads to more data, which subsequently can be used for further optimization of the method.

Method

To access the content of the scrolls without manually opening them, synchrotron tomography was employed. Synchrotron tomography is an advanced imaging technique that uses hard X-rays to create detailed 3D representations of objects at microscopic scales. This method is widely used in materials science, biology, engineering and cultural heritage for non-destructive analysis of internal structures. The three scrolls were scanned at the electron storage ring BESSY 2 in Berlin, Germany, using the imaging beamline BAMline (Fig. 2a) [18]. The monochromatic beam energy was set to 35 keV to achieve sufficient contrast and low dose on the object. Like most other imaging beamlines at synchrotron storage rings, BAMline is limited in its field-of-view, so the scrolls had to be scanned at different height positions. After reconstruction, all sub-volumes were combined to one volume showing almost the entire scroll at a high volumetric resolution (isotropic voxel size of 3.6 μm). For each sub-volume a stack of 2570 projections was taken over 180°. An example of a reconstructed slice is shown in Fig. 2b.

For the scans, the scrolls were carefully taken out of their boxes for transportation and mounted in the field of view of the detector (pco.edge 5.5 camera with 40 μm CdWO₄ scintillator and magnification optics behind the scintillator). The measurements were taken under normal air atmosphere and ambient pressure.

Amira software (by Thermo Fisher) was used to unroll the scans of the scrolls [19–20]. The procedure is illustrated in Fig. 3a, which shows a single cross-section of scroll “I”. The course of the paper needed to be marked manually (orange line). To simplify this

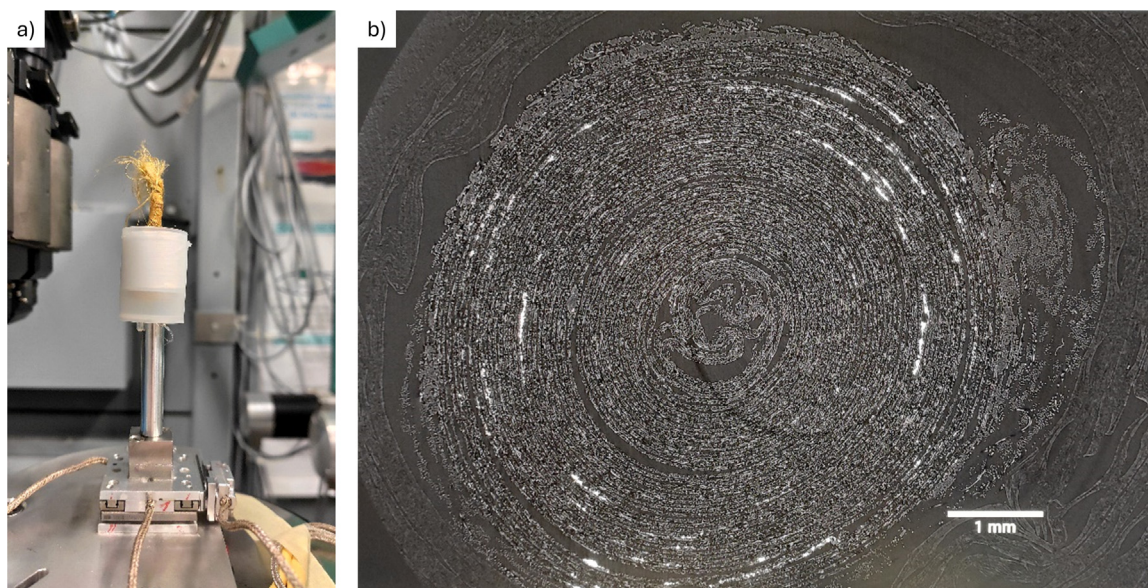


Fig. 2. a) Scroll inside synchrotron X-ray beam at BAMline, BESSY 2 [18]. b) reconstructed cross-section of a scroll. Areas that contain metal appear bright, while the paper of the scroll is shown as light gray in color, and air in dark gray.

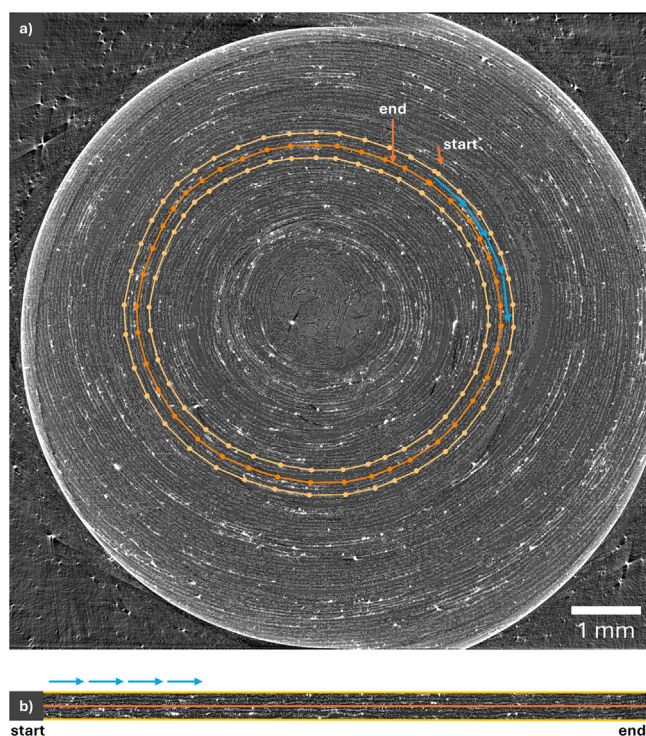


Fig. 3. a) Cross-section of a reconstructed slice. The course for the virtual unrolling needed to be created manually in several slices of the 3D volume. b) Cross-section of unrolled and flattened volume.

time-consuming process, the line was widened to cover more than one layer at the same time. The extended areas are represented by the yellow lines. This procedure needed to be repeated at several heights in the 3D volume of the scroll. Finally, the unrolled 3D volume included several layers, but, due to the unrolling transformation, appeared as flat lines (Fig. 3b). In the end, the individual layers needed to be separated to single layers by suitable reslicing tools. This step was done using Fiji/ImageJ [21].

Results & discussions

The dimensions of the scrolls, including the silk wrapping, are $50 \times 18 \times 18$ mm for scroll “I”, $30 \times 7 \times 7$ mm for scroll “II” and $30 \times 7 \times 7$ mm for scroll “III”. The wound paper inside the silk package is clearly visible. Bright spots represent metal-containing particles, which originate from ink. The bright sphere-like structure at the outer areas in Fig. 4 originates from limited field-of-view artifacts due to the small field-of-view of the detector system and is not related to the information of the objects. The cross-section images show the spiral-like structure that was created by rolling the paper. Additional material without any text is wadded in the center of each scroll, presumably to simplify the rolling process. Nevertheless, the rolling was carried out very delicately and precisely, which can be easily recognized by the neatly wound layers. Also, the material thickness is thin and even, which indicates that the paper is of good quality.

The writing and characters can be identified by the light gray values. Firstly, there are bright spots presumably showing metal particles in the ink. Secondly, the ink appears to have seeped into the paper. This can be seen in Fig. 4d, h and i, which show magnifications of reconstructed slices. Particularly close to bright spots, the paper appears brighter than in other areas. Consequently, there must be even smaller particles of the ink inside the paper substrate.

The length was calculated based on the inner and outer diameter of the rolled paper and number of whorls. The very tightly wound papers were shown to reach lengths in excess of 80 cm. The exact values are provided in Table 1, whereby ‘spacing between whorls’ means the distance between neighboring papers. A spacing of zero indicates touching layers. Up to now, it was not possible to reliably separate touching layers by algorithm, as is necessary to automatically extract written letters. At touching points, the trace would be lost, leading to misinterpretation of the characters in the unrolled volume. The complex process of virtual unrolling is currently undergoing further optimization [29].

Using the method described above, it was possible to partly unroll scroll “I” and to make characters visible. Characters are only legible in the virtually unrolled image. An excerpt is shown in

Table 1
Geometry of the scrolls taken out of the tomographic scans.

object	thickness of paper / μm	spacing between whorls / μm	number of whorls	length of paper /cm
ID 34310, scroll ("I")	20–40	0–70	48	86.0
ID 34310, scroll ("II")	20–40	0–240	26	32.6
ID 34310, scroll ("III")	10–40	0–90	49	51.0

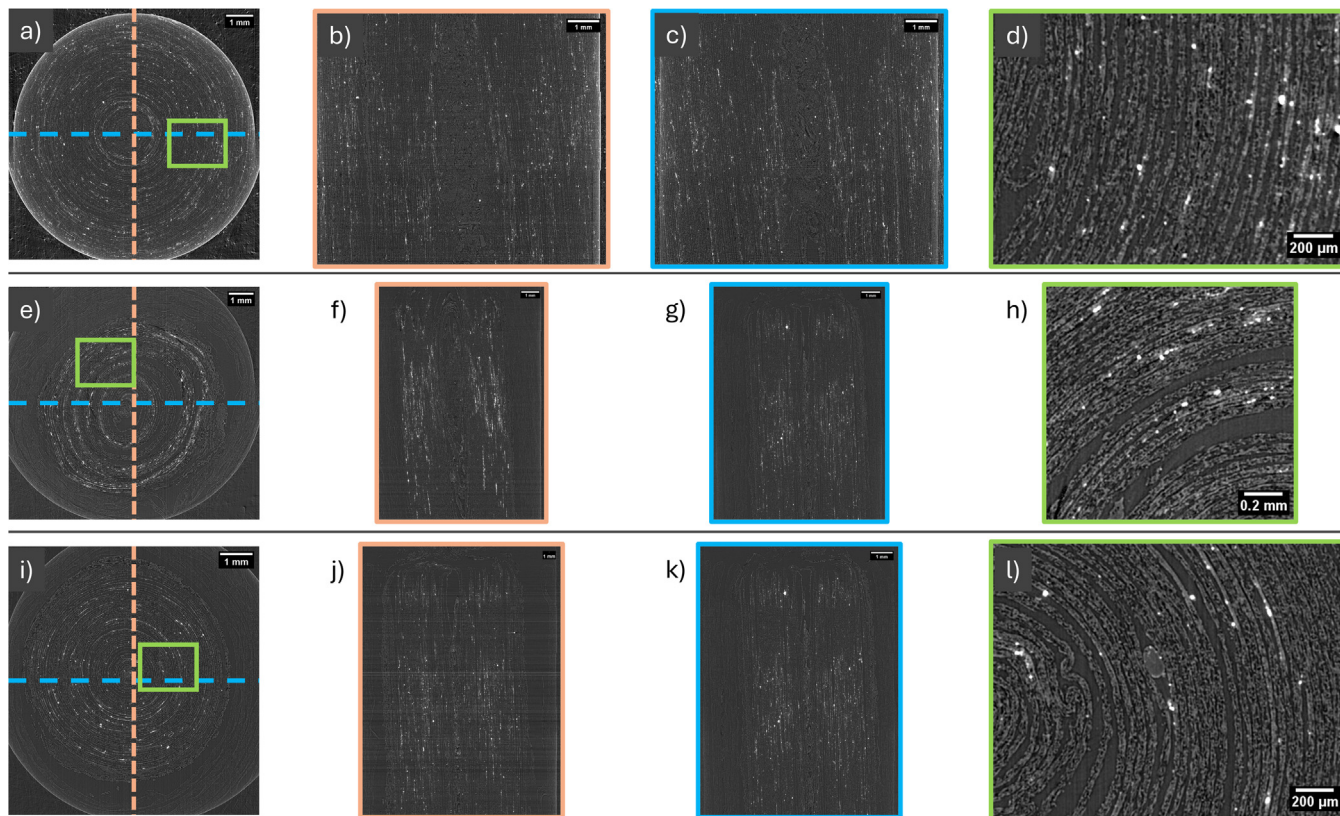


Fig. 4. Cross-sections and magnification of scroll "I" (a-d), scroll "II" (e-h) and scroll "III" (i-l). The first column contains orientation information for the details on the right. The second column (brown) shows cross-sections overviews of the following subfigures. The third column (blue) shows vertical slices of the scrolls, while the fourth column shows horizontal slices. The last column (green) gives magnification.

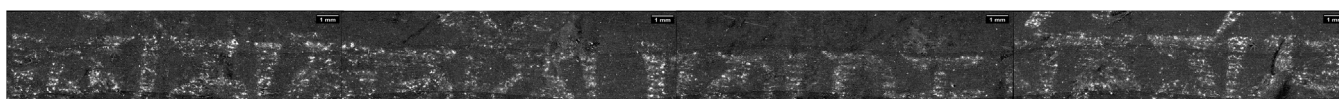


Fig. 5. Text is visible in unrolled volume "Om mani padme hum".

Fig. 5. In addition, information on material properties, such as thickness or mass density, could be obtained, which can serve as new starting points for further research regarding remaining questions about the shrine as described below.

The characters of the script have been identified as Tibetan but have not been further classified. The language used is Sanskrit. Further research is needed to determine if this combination was widespread or specific enough to point in a particular direction [22].

One inscription was translated as "Om mani padme hum", which is the oldest and still the most popular mantra of Tibetan Buddhism. Dharanis have been passed down over the centuries in the form of very precise mass prints, making it extremely difficult to categorize and date them [23]. Only when more sections of the scrolls can be visualized and more specific texts come to light will there be a chance to gain new clues through textual analysis.

The very fact that it was possible to visualize characters indicates that the ink used, whether it is black or red, must contain a

certain amount of metallic phases since only metal can cause such attenuations of X-ray radiation. That is interesting, because Chinese ink traditionally consists of a mixture of soot as a black pigment and animal glue as a binding agent [24]. The same basic recipe with variations has been used in Asia for centuries with a wide variety of constituents added for different reasons [25]. Yael Bentor even states that "Dharani, besides being relics of the Dharma, can cross into the category of physical relics when they are written with ink mixed with the bodily relics of various lamas" [26]. Technical (scientific) studies since the 1930s have identified differences in particle size and the composition of various inks. Further research may help to determine the temporal and geographical origins of the Dharani [27–28]. However, the chemical composition, and thus the type of ink, cannot be detected by this method. It is unclear whether the metal originates from the soot or whether it is a pigment with a different chemical composition that contains more metallic components than expected based on literature.

Not much can be said about the paper of the tiny scrolls. On the revealed section, three staggered letters can be recognized, which are trimmed on the lower edge. It is not yet clear whether these are individual, overlapping sections of different papers or a single piece.

Conclusion

In this project, non-destructive X-ray tomography combined with computer software was applied to virtually unroll Dharani scrolls and to extract information that could not be accessed by conventional mechanical techniques. It is shown that characters and also whole sentences – here: “Om mani padme hum” – can be extracted from rolled Buddhist scrolls by this method without opening them physically. We were able to prove that metal containing ink was used and that the scrolls were wound very tight and carefully. Despite continuous development, the method is still labor-intensive and cannot yet be used as a standard [29]. Nevertheless, it offers unique opportunities to unroll or unfold scrolls where promising texts are expected. It is only through the collaborative, interdisciplinary efforts of museum conservators, cultural and natural scientists, and other stakeholders that new methods can be developed to obtain information without compromising the material and spiritual integrity of cultural objects.

Statement

During the preparation of this work the authors used MS copilot to improve the readability of individual text passages. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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