

THE SARCOPHAGUS OF SETI I —  
RE-MATERIALISATION

Factum Foundation  
For Sir John Soane Museum London  
Made possible with support from  
Jeffrey and Veronica Berman

SIR JOHN  
SOANE'S  
MUSEUM  
LONDON





Fig. 1. Recording at the Sir John Soane's Museum, London.

The recording of the Sarcophagus of Seti I was carried out in 2016 in Sir John Soane's Museum. The facsimile was made in summer 2017 in preparation for the exhibition *Scanning Seti: The Regeneration of a Pharaonic Tomb*. A multi-disciplinary team made up of engineers, photographers, sculptors and restorers took part in the challenge of recording, and then fabricating the facsimile of the sarcophagus. The challenge of re-materialising the Sarcophagus was overcome using a novel technique known as elevated printing, developed by Océ (a Canon Company) through a research project known as Project Eiger<sup>1</sup>.

The project sits within the framework of the larger body of work carried out by Factum Foundation for Digital Technology in Conservation<sup>2</sup>, dedicated to the safeguarding and dissemination of cultural heritage by means of digitisation and the creation of high-resolution digital archives. These archives are fundamentally important for study and condition monitoring as well as re-materialisation giving rise to high-quality copies and facsimiles. As a result of this approach, both public and specialists are able to enjoy and learn from our cultural heritage without harming the original object.

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1. Océ - a Canon Company.(2013). See: <https://www.oce.com>. [Consulted 25 November 2017]

2. Factum Foundation (2009). See: <http://www.factumfoundation.org> [Consulted 22 November 2017].

## DESCRIPTION OF THE SARCOPHAGUS

The Sarcophagus of Seti I is 284.4 cm long, 111.8 cm wide and 81.3 cm in height. It is made from Egyptian alabaster with thicknesses ranging from 4.5-11.4 cm; the alabaster is semi-translucent, with ochre and sienna tones and is heavily veined in many areas with both white and coloured veins. The alabaster was once white, turning honey coloured through contact with London's pollution. The surface is covered inside and outside with relief carving that was once infilled with Egyptian blue paste. This fell out in England or was removed by over-vigorous cleaning. Some traces of blue can still be found but these are mainly C19th additions.

The simple beauty of its form and the nobility of the material is complemented by the simplicity of the carvings from the Book of Gates<sup>3</sup>. These cover the interior and exterior surfaces of the sarcophagus, culminating in the imposing image of the goddess Nut carved into the interior of the piece. This high level of detail on these incisions were difficult to reproduce in the facsimile. This project aimed not only to capture a digital model<sup>4</sup> of the sarcophagus, but to obtain a copy that was as close as possible to the original which will be useful for monitoring its condition.

A monograph entitled *Sir John Soane's Greatest Treasure: The sarcophagus of Seti I* by John Taylor and Helen Dory was published to accompany the exhibition *Egypt Uncovered: Belzoni and the tomb of Pharaoh Seti* (October 2017 – April 2018). The facsimile of the sarcophagus and all the fragments of the lid was included in the exhibition *Scanning Seti* at the Antikenmuseum in Basel (October 2017 – May 2018). A book entitled *200 Years in the Life of the Tomb of Seti I* was published by Factum Foundation in October 2017 that contains Belzoni's description of the discovery of the tomb and its journey to London in 1823.

## RECORDING THE SARCOPHAGUS

The Sarcophagus was recorded in-situ at the Sir John Soane's Museum using photogrammetry, a non-contact methodology. The full high-resolution data necessary to generate a detailed digital model were obtained in five days. The work was done by Pedro Miró and Manuel Franquelo from Factum Arte together with Ferdinand Saumarez Smith from Factum Foundation, with additional help supplied by personnel from the museum. A total of 4500 images were taken with a Canon 5DSR mounted on a motorised slider with two flashes positioned at 45° with respect to the camera. Given the difficulty of photographing the interior of the sarcophagus, a number of images were taken by hand, employing a ring-flash that allowed the operator to maintain the lighting constant.

The images were pre-processed at low-resolution prior to the high-resolution processing with Reality Capture software made by Capturing Reality (Bratislava). This is the only photogrammetry software that is able to process this number of high-resolution images - the result is a digital model composed of 2.7 billion polygons that reveals the unusual beauty and complexity of the sarcophagus.

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3. The Book of Gates is an Egyptian funerary text dating from the New Kingdom era, and appearing in many tombs from the period. It describes the passage of the deceased through the underworld together with the Sun God in the night-time hours of Duat.

4. The digital model can be viewed on the Sir John Soane's Museum website (2017). See: [http://explore.soane.org/?\\_ga=2.224654746.1635165188.1516532862-526808955.1516532862#/section/sepulchral/sarcophagus-of-king-seti](http://explore.soane.org/?_ga=2.224654746.1635165188.1516532862-526808955.1516532862#/section/sepulchral/sarcophagus-of-king-seti). [Consulted on 15 November 2017].

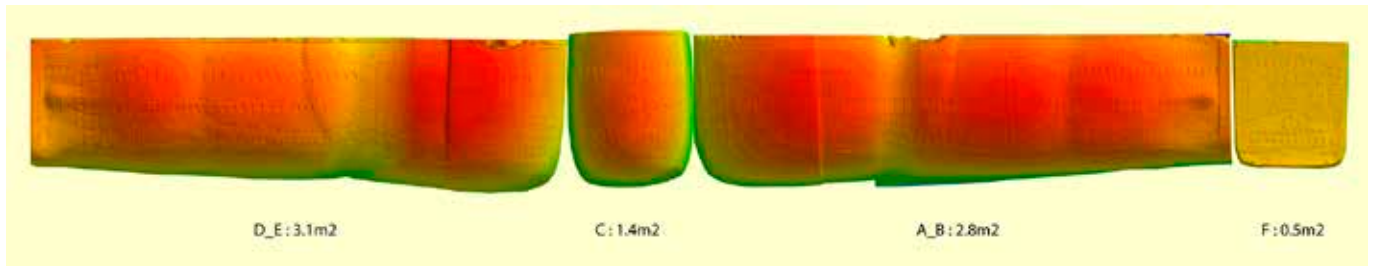


Fig. 2. Rendered 'Shaded depth map' - visualisation with artificial colours generated from relief data.

## REPRODUCING THE SARCOPHAGUS

Factum has developed various methods and techniques that allow for the reproduction of the most diverse materials. In this case, we used a method which combined CNC<sup>5</sup> routing with a seven-axis robot together with Océ's elevated printing technique. This second technique had been used in the past as part of the process of making facsimiles, but never as a final surface for an object. This new methodology is known as *elevated printing*. It was created by Project Eiger based on Océ's experience with photocopying. The production of the first photocopiers or Xerox printers was a revolutionary moment in the recent history of printmaking.<sup>6</sup> A simple way to understand elevated printing is by thinking of a normal colour printer – it is printing on a flat surface in layers that are about 5 microns in depth. If you print thousands of layers one on top of the other a relief surface can be built up – resulting in a colour print with physical body. Océ's new printer with UV cured ink can produce a 3D surface that is about 1.5 cm in depth and with dimensions up to 2.4 x 1.4 meters.

The system is based on the use of photosensitive acrylic inks, which react immediately to UV radiation such that the polymer is immediately cured. This allows the rapid superposition of layers of ink, whose thicknesses can vary between 2 and 40 microns – these strata result in the emergence of a relief surface that very exactly reproduces colour and 3D data. The maximum thickness of Océ's plates is usually 5mm, but a combined effort on the part of Océ and Factum engineers has enabled the printing of sheets up to 1.5 cm thick specifically for this project.<sup>7</sup>

Starting from the basis that Océ's elevated printing technology produces a sheet material with a relief surface, the Factum team worked with the idea of employing a base material with the complete form of the sarcophagus and then distorting the surface so that when it is mapped onto this 3D form it has the exact character and look of the carved surface of the sarcophagus. A high-density polyurethane was carved on a 7 axis CNC robot in sections and joined into one form by hand. A 'skin' was generated from the Océ plates, which reproduced the 3D data from the sarcophagus, with perfectly registered colour.

This approach required a great effort on the part of the 3D and workshop teams at Factum Arte who had to contend with a new working methodology in order to generate the files for printing 3D and colour together and later find a way of attaching the Océ plates to the polyurethane base.

5. CNC: Computer Numerical Control

6. Xerox Graph: invented by Chester Carlson in 1937, based on the principle that UV light destroys electrostatic charge. A charged surface is selectively rendered without charge by means of UV light - the charged area attracts a fine powder of pigment covered in resin, which is then fused using heat.

7. The Elevated Printing Technology works best when the thicknesses of the plates are less than 8mm. For this project, it was decided to work with plate thicknesses between 13 and 15 mm, given the difficulty in manipulating the plates in order to adapt them to the matrix.

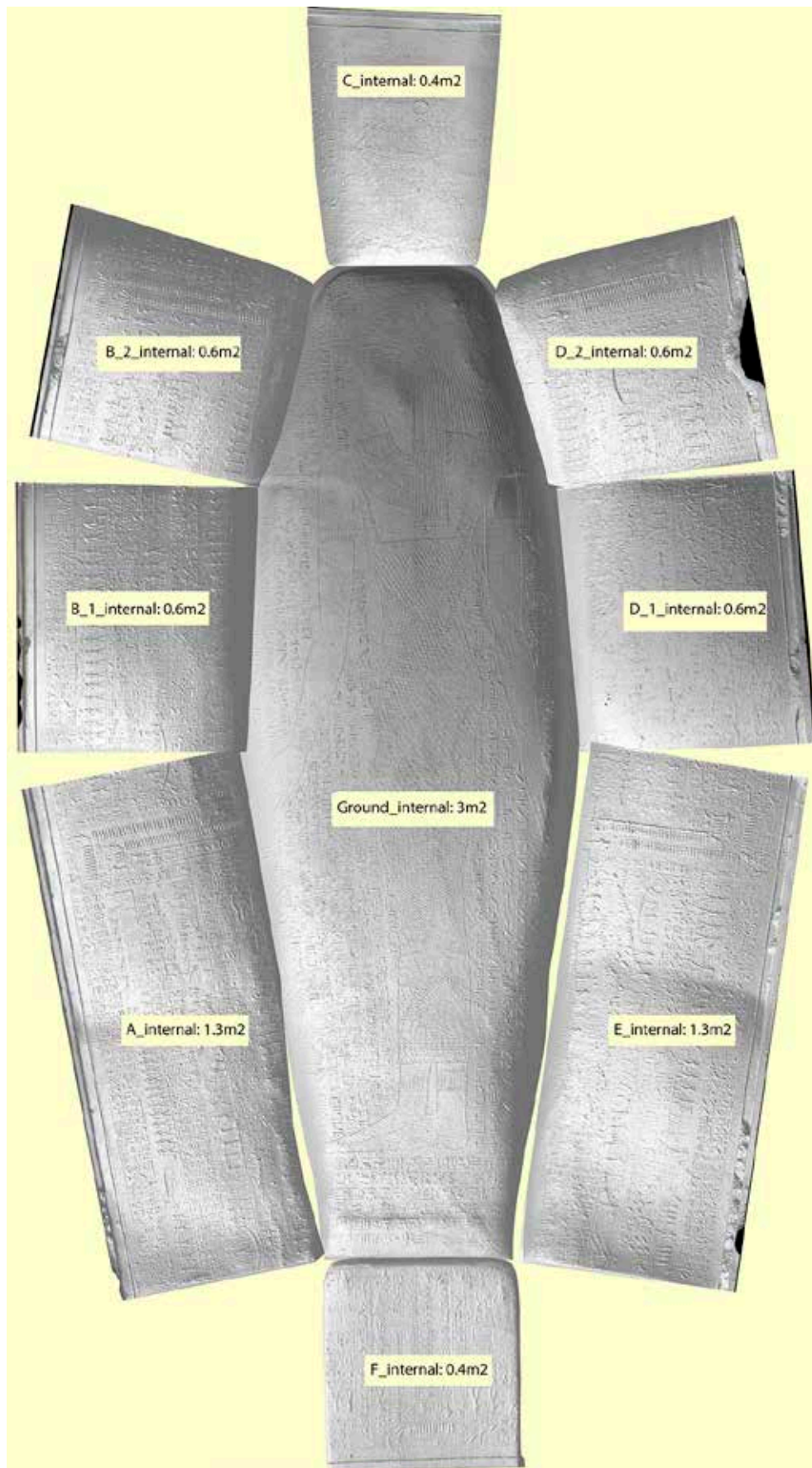


Fig. 3. Visualising the principal 'planes' of the interior and exterior of the sarcophagus, generated from the 3D model as orthophotos with depth and rendered information. Here the exterior of the sarcophagus is flattened.

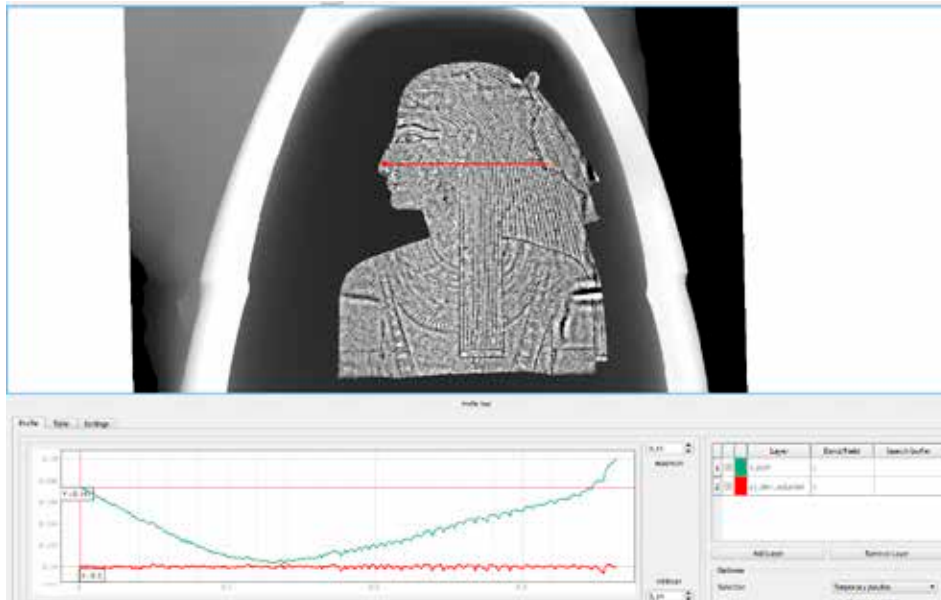


Fig. 4. Extraction of superficial bas relief by means of algorithms and GIS tools.

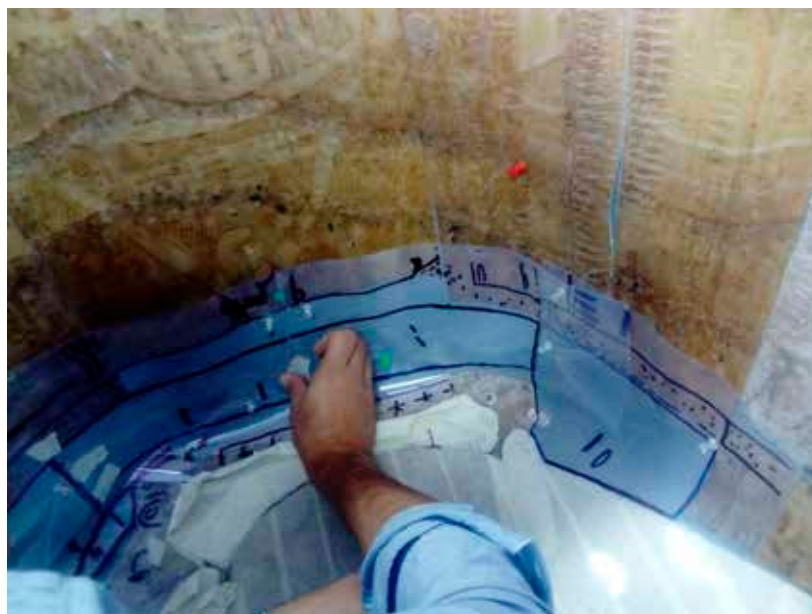


Fig. 5,6. Example of pieces resulting from the 'plane' of the exterior top section of the sarcophagus in strips adapted to the shape of the acetate models. The manual adjustment technique for developing these pieces was carried out using templates and acetate models.



Fig. 7. Example of pieces from one of the exterior flanks of the sarcophagus, in strips adapted to the shapes obtained by means of physical modelling in acetate. Checking the plates prior to adhesion to the polyurethane base (grey surface).



Fig. 8. Process of gluing the plates to the exterior of the sarcophagus. Here a total of nine Océ plates were fixed to the base.

Engineers at Factum employed a variety of algorithms together with GIS<sup>8</sup> tools in order to obtain the superficial bas-relief of the sarcophagus, configuring the basic data for the 'skin' from the height-map files for relief and bitmap for colour. These files were provided in a format that could be printed by the team from Project Eiger. Within the suite of software used is Global Mapper, a GIS tool with which our engineers were able to maintain the depth data of the bas relief on the sarcophagus without distortion. This was necessary because the bas relief extended over curved surfaces - in order for the printed surface to be correct, it was necessary to translate the depth information from its plane to the printing plane of the machine (see Figure 4).

However, the difficulties did not end with obtaining the bas relief files. It was also necessary to correctly 'cut' the 'skin' of the sarcophagus, such that after printing it would be possible to perfectly adapt the Océ plates to the convex and concave forms of the base. In order to facilitate this process, and prior to printing the files, the Factum team produced templates in acetate and paper that enabled one to test each piece together with the base (see Figures 5 and 6). In some sense, this verification process can be likened to that followed by a pattern maker. Despite the rudimentary nature of the work and the fact that it took a long time, the team were rewarded by a set of plates perfectly adapted to the curved surfaces of the sarcophagus.

It was a process similar to making a large 3D jigsaw puzzle (see Figure 7). The process began the production of the sarcophagus itself. The plates belonging to the sides of the exterior of the sarcophagus were attached first. Once these had been fixed onto the polyurethane base, the next archives were generated, checked by means of the templates, corrected if necessary, sent to print, and finally attached. The work was carried out progressively until we had generated the final set of files - the upper and lower files.

Océ plates were glued onto the sarcophagus whilst the production of new plates was ongoing; new plates were checked and adjusted against those that had already been fixed to the base (see Figure 8). An 'Araldite' epoxy resin with 24 hours catalysis time

8. Geographical information system.



Fig. 9,10. Removing the protective covers and reintegration by means of acrylic putty and re-touching with paint.



Fig. 11. Colour reintegration and retouching. The filled joints need to be integrated into the surface.

was used to glue the plates, which were held in position, due to the impossibility of using clamps, with a system employing screws and washers. These maintained the pieces in place (see Figure 8) whilst exerting the pressure required to ensure that the plates had been correctly fixed to the surface. They were aided by means of metallic tape and a large number of thumbtacks, which were used to align the heights in the joints between pieces, thus avoiding the appearance of steps or any unevenness between adjoining plates.

All these elements were later removed, together with the protective covering. The protection was kept in place during the process of fixing the plates to the internal structure. The process of integration between the surface and the shape took about 6 weeks. This was followed by filling the joints between the plates with an acrylic putty to unify the surface. These joints were retouched by hand by a team of skilled restorers using traditional restoration techniques – watercolour and acrylic paint applied by hand with a paintbrush. The process to reproduce this fantastic copy was finished with the application of natural waxes which sought to generate the varied gloss of the original alabaster.

During the production of the facsimile there were as many questions than there were answers. The procedure was being invented, adapted, applied, corrected and repeated until time had run out. As with all innovation, there was hesitation and uncertainty as well as moments when enlightenment and invention produce remarkable innovations.

The mixture of mapping software and photogrammetry software made the separation of the surface and the skin possible. The elevated printing technology developed by Océ allowed for the surface to be printed without any loss of information (the elevated printing is capable of printing higher resolution 3D data than we can record). As the recording and output technologies are developed the process of making facsimiles will improve. But the technology is always dependent on skilled people who understand materials and the way they can be mediated and transformed. This approach is capable of helping to preserve, archive, share and study the world's heritage. The work to record and replicate the Sarcophagus of Seti I has been a great success. But using this data a new research project has started... to digitally restore the Sarcophagus and to study the texts which make it one of the most important Pharaonic artefacts.



Fig. 12. Facsimile of the sarcophagus of Seti I, exhibited at *Scanning Seti: The Regeneration of a Pharaonic Tomb*, Antikenmuseum, Basel.

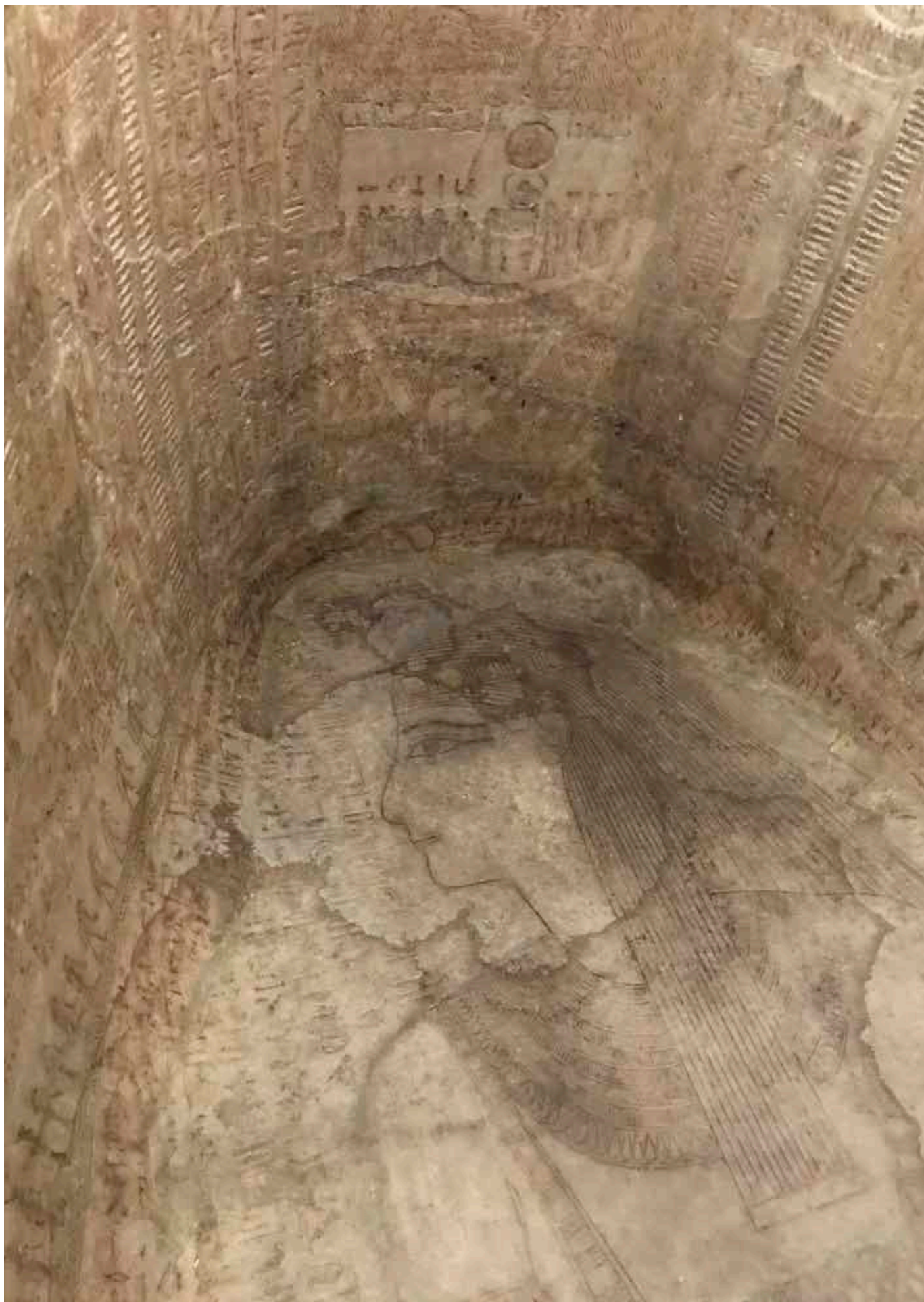


Fig. 13. Detail of the goddess Nut at the inside bottom of the facsimile of the sarcophagus.

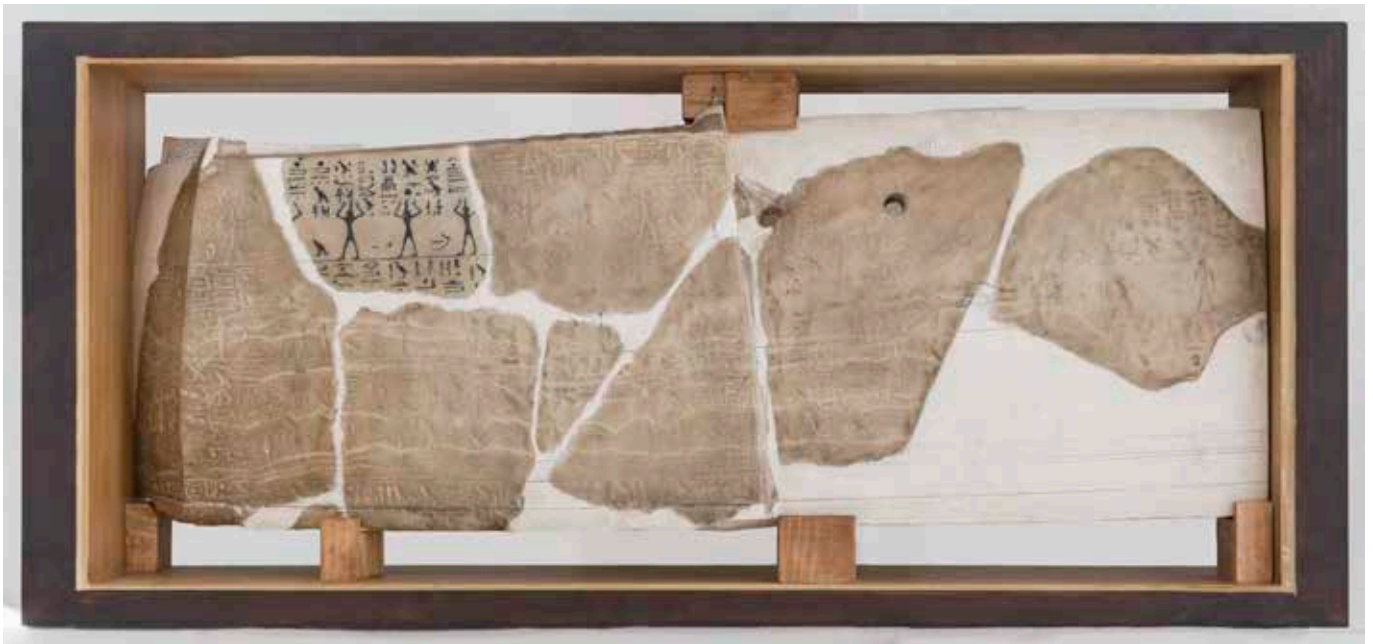


Fig. 14. Facsimile of the sarcophagus lid fragments recorded at the Sir John Soane's Museum, London.



Fig. 15. Facsimile of the sarcophagus lid fragments recorded at the Sir John Soane's Museum and the British Museum, London.



Fig. 16. Front and back facsimile of the sarcophagus lid fragment recorded at the British Museum, London.



Fig. 17. Front and back facsimiles of the sarcophagus lid fragments recorded at the Sir John Soane's Museum, London.