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A resting place for eternity – a virtual reconstruction and preservation of a coffin lid fragment from Northern Upper Egypt dating from between the 22nd and the 25th Dynasties – a case study on modern scientific 3D documentation and reconstruction[1]

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Zusammenfassung
Der folgende Aufsatz behandelt die Erstellung einer digitalen 3D Rekonstruktion im akademischen Kontext. Es sollen die einzelnen Schritte, die es für eine auf wissenschaftlichen Methoden basierenden Rekonstruktion bedarf, vorgestellt und erläutert werden. Der Schwerpunkt liegt hierbei auf der quellenkritischen Arbeit und Bestimmung der einzelnen zu rekonstruierenden Elemente. Die technischen Schritte für die Erstellung des 3D-Modells werden anhand von begleitenden Online-Blog-Beiträgen näher erläutert. Ziel dieses Aufsatzes ist es zu zeigen, wie eine moderne 3D-Rekonstruktion begleitet von einer ordentlichen, quellenkritischen Dokumentation aussehen kann und somit einen wissenschaftlichen Diskurs darüber erst ermöglicht.

Abstract
The following paper deals with creating, in an academic context, a digital 3D reconstruction. The individual steps required for a reconstruction based on scientific methods will be presented and explained. The focus is on the source-critical work and the determination of the individual elements to be reconstructed. The technical steps for creating the 3D model will be explained in more detail in accompanying online blog posts. This article aims to show how a modern 3D reconstruction accompanied by proper, source-critical documentation can look like and thus enable a scientific discourse about it.

1. Introduction

<1> Today, 3D virtual reconstructions in archaeology are produced and published in ever-increasing numbers for various objects, ranging from the size of a city to small jewellery, often with astonishing details and great visuals. 3D applications are getting more user-friendly as well as approachable. The wish to simply show an ancient object rather than describe it, is high because one can reach a broad audience with 3D visualization. This is especially important for public science communication and gives insight into times long gone.

In the context of academic work, simply showing is not enough. One must document once's sources, decisions, and interpretations – in short: good old basics of academic work. This also leads us to the problems in terms of 3D reconstructions. We are not simply writing a text wherein we can add footnotes or annotations to make these aspects clear. A 3D application is

[1] We would like to thank the Cologne Digital Archaeology Laboratory (CoDArchLab) of the University of Cologne, in whose environment we have learned the techniques used in this paper and which gave us the opportunity to use these kinds of applications scientifically in the first place. Special thanks go to Sebastian Hageneuer from the University of Cologne, who supported us with helpful advice and constructive criticism.

We would also like to acknowledge the extensive help of Katharina Stövesand regarding the description of the coffin and her help with finding comparable coffins and literature.

Furthermore, we would like to thank the staff of the Foundation Rheinisch-Westfälisches Wirtschaftsarchiv zu Köln, especially Dr. Christian Hillen, who helped us to find archival information on Max von Oppenheim and his excavations and collections. Finally, we would like to thank the Egypt Exploration Society for providing us the rights for using their images.

often not suitable for the use of footnotes because 3D applications are tools made for the VFX (visual effects), movie and gaming industries which are interested only in a "good-looking" result, not the methodology leading to it. However, we, as scholars, are interested in precisely this way of creating knowledge and relying on footnotes or written interpretations to follow, discuss and exchange arguments about a specific topic. We lose this ability to some extent with plain 3D reconstructions. Therefore, it is essential to accompany a 3D reconstruction with documentation to allow discussions and academic exchange for this type of media. Otherwise, we will end up with many 3D reconstructions in the upcoming decades that look good but have only a minor chance of having their process of (decision-)making understood. Instead, we will create an extensive, new reconstruction from scratch, of the same object.

<2> In this paper, we want to describe our procedure as to how a digital 3D object can be created from photographs and be the basis for a virtual reconstruction while using academic sources to help with and solidify the reconstruction. While the process of planning and researching for this reconstruction will be documented extensively, the main focus of this paper is on the academic workflow; two accompanying online blogs will cover technical workflows. This work was part of an assessment in our course of studies in Digital and Computational Archaeology at the University of Cologne for the winter term 2019/2020. For this assessment, we were given only images of the artifact and did not have access to the object itself. Our task was to create a digital 3D object out of these images (3D documentation part), and to create a digital 3D reconstruction of the missing parts of the artifact (3D reconstruction part) while paying attention to scientific work and documentation.

<3> The artifact we will work on is an Egyptian coffin lid, which is part of the collection of the Archaeological Institute of the University of Cologne (Fig. 1).

The dimensions of the coffin lid are 62 cm in length and 54 cm in width. The lid is made from multiple wooden pieces, hewn wooden slabs, nails, and tenons. The coffin lid[2] is the only remaining part of a complete outer coffin; its lower two-thirds are missing. The lower end of the existing coffin lid part does not show any breaking points; it seems like the upper part of the coffin lid was deliberately sawn off.[3] The front or upward facing part of the lid shows a small face surrounded by a large wig with two small, crossed hands beneath it. The hands are lying on top of wooden slabs shaped like an upper-body part, including shoulders, on which the wig rests. Most of the upward-facing wood and parts of the sides of the coffin lid, show residuals of paint, plaster, and coloring. The coffin part has been painted black on the lower sides, and the wig shows remains of blue and white or yellow paint on the top. The condition of the paint cannot be defined decisively because the paint is brittle and the color could also have faded while the object was not properly stored. The face seems a little darker than the rest, with painted eyes and eyebrows. The hands have a red, almost imperceptible, grid pattern. The coffin lid shows wear and tear with fissures in the wood, and missing paint. Whilst we could not physically see the coffin part, because of restoration restrictions, it was possible to see some of the characteristics necessary for dating and locating the origin of the coffin.

[2] Opp.-Inv. Bl. 104, 21; Inv-Nr. 2127

[3] This often is the case with coffin lid fragments circulating on the art market. The lid in question was bought presumably in the first half of the 20th century by a private person, Max von Oppenheim, and not an institution. To what extend this transaction was legal or illegal, where the lid was bought and if the lid was sawn off before or after the transaction cannot be reproduced, but this practice is well documented for the art market and to some extend for a potentially trafficked object. For further details, see also https://www.britishmuseum.org/our-work/departments/egypt-and-sudan/circulating-artefacts (accessed 15.12.2021) and below for more details on the provenance of the object.

Figure 1: The remaining fragment of the coffin lid. This is also one of the images used for the SfM process, provided by Sebastian Hageneuer, University of Cologne.

<4> To create a digital 3D object from photographs, a Structure from Motion software[4] was applied in this case. Performing Structure from Motion (SfM) consists of a series of steps, after image acquisition, in a predefined mandatory sequence:

1. A “feature detection” is performed. This is an automatic recognition of the characteristic features of an object. These characteristic features of an object must be observable in at least three images and must also change in position due to the camera movement (Powlesland 2016:21). Without the features, the images cannot be matched, so that no reconstruction can occur. There are many different approaches to dealing with this, but now, an algorithm called Scale-Invariant Feature Transform (henceforth: SIFT) is considered to be the most effective approach (Lowe 1999, Lowe 2004). This results in the detection of the camera position, and a "minimal" or "coarse" point cloud is created; this represents the three-dimensional image of the object. This resulting "point cloud" is a structure from motion, i.e., it is a structure that has arisen from the camera motion (Nyimbili, Demirel, Seker & Erden 2016:3).
2. In the next step, a "bundle adjustment" is performed. This bundle block adjustment optimizes possible measurement errors and image distortions of the automatic detection of the object's characteristic features. Images are added to the algorithm one after another, so as to improve the initial estimate of features or key points. The algorithm also tries to solve the individual camera positions by triangulation (Carrivick, Smith & Quincey 2016:49-50). With the help of multi-view stereo algorithms (PMVS, CMVS), a dense

[4] We used Agisoft Metashape Version 1.5: https://www.agisoft.com/ (accessed 22.02.2021).

point cloud is created. This leads to an increase in points within the point cloud of the object's image. (Reinhard 2016:23).

3. Based on this dense point cloud, the "meshing", that is the construction of a polygonal mesh follows. The algorithm builds a mesh of triangles from these points. From the points in space, the point-cloud, an area mesh is created (Weßling, Maurer & Krenn-Leeb 2013:247).
4. Using the resulting polygon mesh, the "texturing" ("texture mapping") takes place. The photographs are placed on the surface mesh, and each triangle gets its own texture. The resulting texture becomes a 2D image, using "UV-mapping". A UV-Map is a 2D image with the corresponding texture coordinates of the 3D object. At the end of the process, a 3D object with color-fidelity is created (Willis, Koenig, Black & Castañeda 2016:7).

<5> Through creating a digital 3D object using Structure from Motion and Agisoft Metashape was time-consuming, the workflow itself was easy to understand and to follow. The finished 3D object was afterward imported into Blender and Cinema 4D to reconstruct the rest of the coffin.[5] Since the pictures of the coffin lid were fitted with calibrated photogrammetric non-coded cross-scales,[6] calculating the real-world size of the lid by Metashape was possible. The SfM-model already has the proper scaling when exporting.[7] The 3D object and textures were exported from Metashape to long-term storage data formats (.obj, COLLADA .dae, and Baseline TIFF), following the advice from the IANUS-project of the German Archaeological Institute (DAI) on favored long-term data storage[8] and imported into the respective 3D application. For the last process regarding the Structure from Motion 3D, all irrelevant faces of the object – such as the background the object lay on and the padding on the bottom of the object – were cut or deleted to display only the wooden structure of the lid.

2. Result of the SfM-process

<6> The SfM-model created in this way has a high level of detail and shows all artifact features. However, it also has a few limitations or problematic areas. First, the underside of the object is missing because it is too sensitive to be removed from its white padding base. Also, the lower edges of the model are visible, but some blurring occurs, both in the texture and in the polygon model. This is not material to the artifact itself (except for the tenons), however, the white base on which the coffin lid is placed makes it more difficult to separate the object from the base in the 3D application to prepare the reconstruction.[9] The preparation and deletion of the 'free-floating' faces was very time-consuming. As we got closer to the artifact, and because of deleting errors (i.e., cutting relevant parts of the coffin), this had to be repeated frequently. The last problematic point concerned the nail in the hole between both hands on the lower part of

[5] Since the core techniques of 3D-polygon-modelling are the same no matter which software is utilized, each of us worked in the software with which we were most familiar. The software versions used are Blender 2.8.7 and Cinema 4D R20 Education.

[6] http://culturalheritageimaging.org/What_We_Offer/Gear/Scale_Bars/index.html (accessed 11.02.2021)

[7] To obtain the right scale in the 3D-modelling software, one must remember to set the right measurement-world-scale in the chosen application if it does not happen automatically on importing the model.

[8] https://www.ianus-fdz.de/3d (accessed 11.02.2021).

[9] In such a case, the base should have been raised considerably (which was not possible here due to the fragility of the artifact), so that taking pictures from below the artifact would have been possible, making the tenons and the demarcation of the white base from the wood clearer. Similarly, this could probably have been achieved with an illuminated base, so that this area would have been better lit, allowing the camera to catch more details. This would also have prevented the smaller free-floating polygons e.g., above the head (at its lower edge) around the object.

the coffin lid. This detail has not been captured at the tip on three sides because the image coverage seems insufficient here, and no image could be taken from the underside.

Nevertheless, we are extremely satisfied with the quality of the model, especially the color representation and the level of detail (e.g., wood structure, flaked paint, dowels and plaster). This model clearly shows the strengths of SfM with its simple, quick, inexpensive and detailed implementation process, but also the weaknesses when an object has details that need to be covered from all sides. This issue is difficult to resolve with sensitive artifacts (like this one). However, it could have worked out slightly better if the model had been mounted on a tripod, even if this would not still be enough to cover the complete underside of the object.

<7> The final SfM-model with annotations of the main features can be viewed as an annotated 3D-object here: https://doi.org/10.18716/KKK/CL20.[10]

The created SfM model now serves as the primary source for the resulting reconstruction. However, since only the part of the lid from the head to just below the hands has been preserved, additional secondary sources (in the form of relevant academic literature and pictures of similar coffins for comparison) must be consulted. This is to realise the desired reconstruction of the whole lid from top to bottom and the actual coffin itself, so that as many areas of the reconstruction as possible can be documented and covered based on sources, other than being based solely on our interpretation. In doing so, we follow the basic statement of Simon James (1997: 25) that the only certainty about a reconstruction is that it is flawed, and the real question is how flawed it is.[11] To answer this question, we would like to present our findings and sources as transparently as possible to make an academic discussion possible.

3. Provenance

<8> The object in question, a part of an Egyptian outer wooden coffin, is an item from the collection of Max Freiherr von Oppenheim, which is found at the Archaeological Institute of the University of Cologne. We tried to discover more information about the origin of the artifact on the one hand to gather more details that could help us with the 3D reconstruction (like original excavation place, dating or comparable finds) and on the other hand, to discuss the provenance as to how the artifact found its way into the collection of the Archaeological Institute of the University of Cologne.

Max Freiherr von Oppenheim was born July 15th, 1860 in Cologne, Germany, and died November 15th, 1946 in Landshut, Germany. After traveling through Spain and the northern part of Africa, Oppenheim became an attaché at the German General Consulate in Cairo in 1896. Max Freiherr von Oppenheim is mainly known for his excavations at Tell Halaf, an archaeological site in north-eastern Syria, dating to the 6th millennium BCE. While working in Cairo, traveling through the historical area of Mesopotamia, and excavating at Tell Halaf, Max Freiherr von Oppenheim collected many artifacts for his collection.[12]

After World War II, parts of his collection remained in Berlin, while other parts were brought to Cologne. The artifact that this paper discusses is one of the items from the collection of Max Freiherr von Oppenheim, which is found now at the Archaeological Institute of the University of Cologne. In a description of the collection, it is listed as an upper part of a coffin lid. Its

[10] We have published the SfM model and the later reconstruction on https://www.kompakkt.de, which is a file hosting service created by the Department of Digital Humanities at the University of Cologne, also allowing to integrate meta data and on-object annotations.

[11] "Even if you follow the rules [of reconstruction], the only certain thing about any reconstruction drawing is… that it is wrong. The only real question is, how wrong is it?" James (1997:25)

[12] Biographic information is taken from the Max von Oppenheim Foundation (https://max-von-oppenheim.foundation/max-von-oppenheim/biografie/ accessed 25.02.2021)

height is given as 62 cm and its width as 54 cm, which fits perfectly with the dimensions of the coffin lid part in question.

<9> To discover more information about the coffin lid and its origin, the Stiftung Rheinisch-Westfälisches Wirtschaftsarchiv zu Köln13 was contacted. Dr. Christian Hillen helped us to find records concerning Max von Oppenheim's excavations and collections.[14] The coffin lid in question from had an inventory number, 2127. Two volumes are included in the archive of Dr. Kurt Erdmann,[15] who numbered and wrote down all artifacts in Max Freiherr von Oppenheim's private collection. This inventory is from 1942. The coffin lid can be found there with the same number (2127) and the same description as we had been given. The only other information gathered from the inventory list was the sequence of numbers. We then searched for these numbers to see if the coffin was classified with other artifacts that could help to discover the origin of the coffin. Number 2124 was a copper lamp, while numbers 2125 and 2126 were silver frames to hold stoneware jugs. Numbers 2128 and 2129 were blue and white plates from Korea, while numbers 2130 to 2133 were blue and white plates from China.

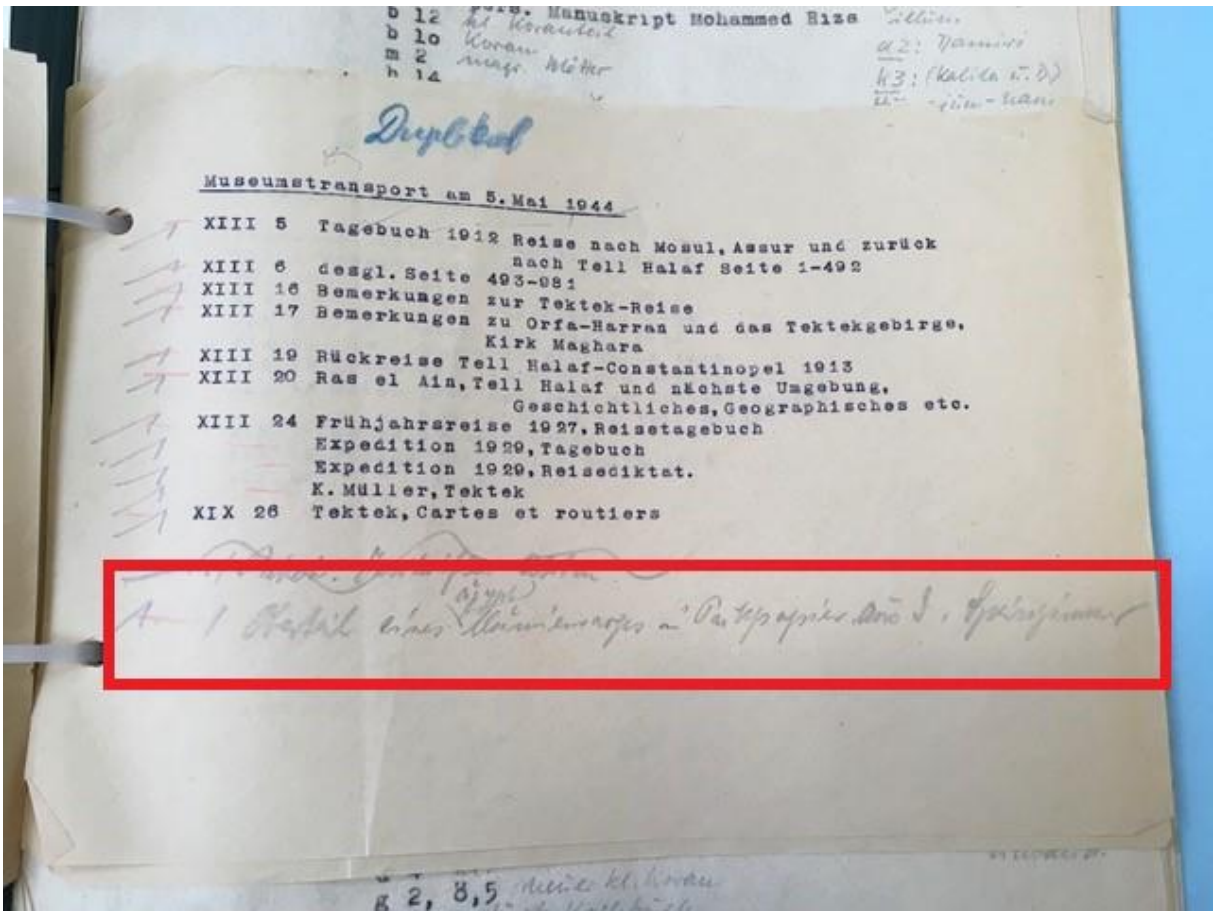


Figure 2: Bestand Abt. 601-92. Picture taken by Louise Tharandt at the RWWA

Unfortunately, the sequence could not help with identifying the origin of the coffin. However, the inventory shows that the process was done at the home of Max Freiherr von Oppenheim, with Dr. Kurt Erdmann going from room to room and sequentially listing all artifacts. This match the transport papers of the artifacts, which showed where the artifacts brought during the war, were to be stored (Fig. 2). One of these papers mentions an upper part of a coffin from the

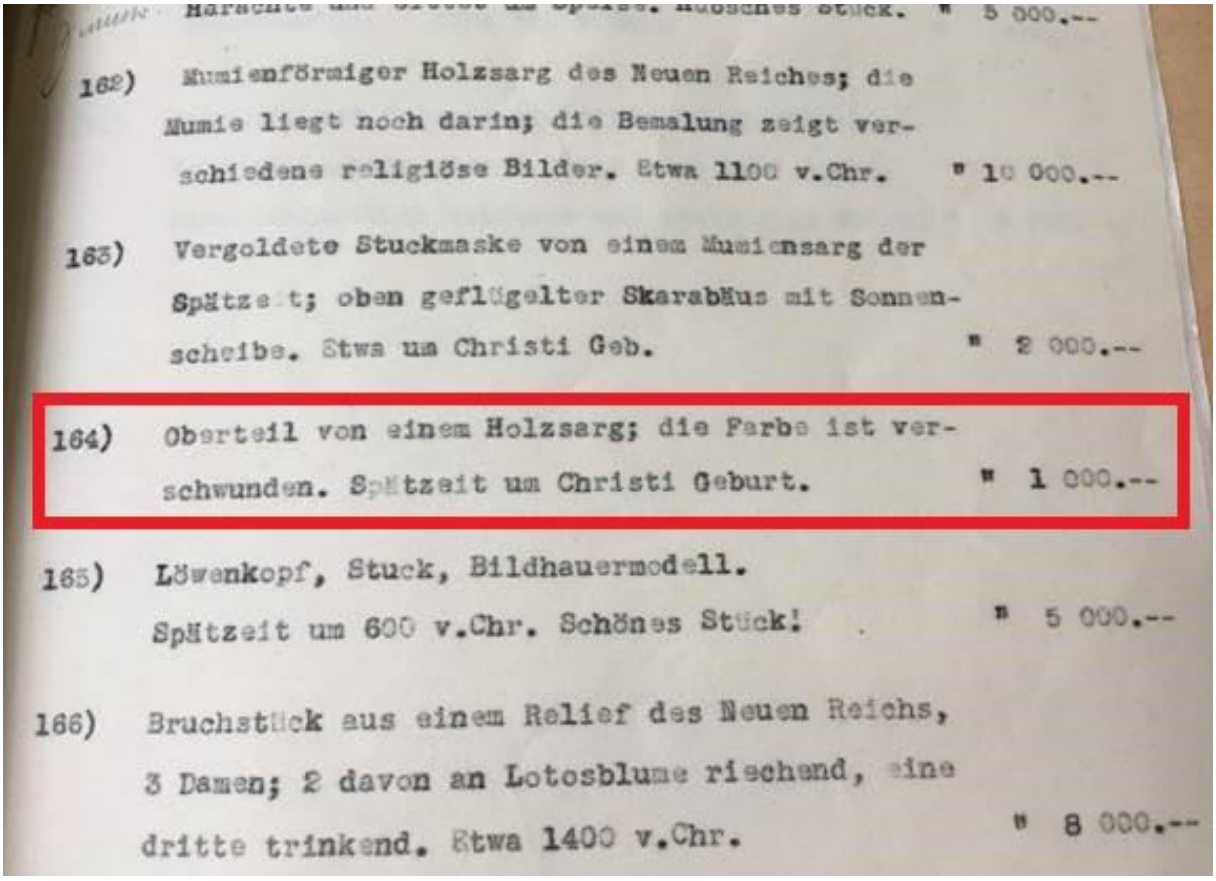
13 https://www.rwwa.de/ (accessed 11.02.2020)

14 Two inventories from the archive were looked through, Bestand Abt. 601 Nachlass Max von Oppenheim and Bestand Stiftung Max von Oppenheim (MvO-S)

15 Bestand Abt. 601-82

dining room ("Oberteil eines ägyptischen Mumiensarges in Packpapier aus dem Speisezimmer").[16] This would fit with all the plates numbered after the coffin lid.

At the RWWA, also a list from 1927 exists, which has a description of a coffin, matching the coffin lid we are dealing with in this paper: "Upper part of a wooden coffin; the color has diminished. Late Period around the time of Christ's birth." ("Oberteil von einem Holzsarg; die Farbe ist verschwunden. Spätzeit um Christi Geburt") (Fig. 3). Unfortunately, the numbering is different from the inventory list because it only covers the Egyptian artifacts with price estimates.[17]


162) Mumienförmiger Holzsarg des Neuen Reiches; die Mumie liegt noch darin; die Bemalung zeigt verschiedene religiöse Bilder. Etwa 1100 v.Chr. " 10 000.--

163) Vergoldete Stuckmaske von einem Mumiensarg der Spätzeit; oben geflügelter Skarabäus mit Sonnenscheibe. Etwa um Christi Geb. " 2 000.--

164) Oberteil von einem Holzsarg; die Farbe ist verschwunden. Spätzeit um Christi Geburt. " 1 000.--

165) Löwenkopf, Stuck, Bildhauermodell. Spätzeit um 600 v.Chr. Schönes Stück! " 5 000.--

166) Bruchstück aus einem Relief des Neuen Reichs, 3 Damen; 2 davon an Lotosblume riechend, eine dritte trinkend. Etwa 1400 v.Chr. " 8 000.--

Figure 3: Bestand Abt. 601-3. Picture taken by Louise Tharandt at the RWWA

<10> While Max Freiherr von Oppenheim was living and working at the German consulate in Cairo from 1896 to 1909, he subsequently bought artifacts and furniture for interior decoration, as seen in the pictures of his villa in Cairo.[18] However, there is no specific evidence at the RWWA of where, when, and what kind of artifacts Max Freiherr von Oppenheim bought at bazaars or from friends and visitors.

Even without more information about the origin of the coffin, the search through the records of Max Freiherr von Oppenheim at the Rheinisch-Westfälische Wirtschaftsarchiv was exciting and gave us a much better understanding of Max von Oppenheim himself and his collection. While provenance research alone could not help with the reconstruction of this coffin, the scientific research and comparison with similar coffins, which was based on several scientific sources, led to the reconstruction of the complete coffin.

[16] Bestand Abt. 601-92

[17] Bestand Abt. 601-3

[18] See https://max-von-oppenheim.foundation/max-von-oppenheim/biografie/ for pictures of the inside of Max Freiherr von Oppenheims villa.

<11> The coffin lid was also dated – at least from the 1920s and 1940s onward in the aforementioned collection inventories – to the Ptolemaic Dynasty (305-30 BC) (Fless 1997:63) or Late Period (525-332 BC). However, as we soon discovered while searching for comparable coffins and going through the literature, none of the features of our lid fit into the Ptolemaic Period or Late Period. If anything the features have a huge overlap with the features of Northern Upper Egypt coffins of the 22nd to 25th Dynasties (Third Intermediate Period, 1069-525 BC). Northern Upper Egypt is the northern region of Upper Egypt, which as Taylor (2009) describes originated with not only a political fragmentation in the Third Intermediate Period, but also the differences in the profile of the population and the material culture of the people. This led to referring to a north-south divide arising from the cultural and ethnic partition of Upper Egypt in the Third Intermediate Period (Taylor 2009:375).

Figure 4 a-e: a) 21st Dynasty Thebes, b) 22nd Dynasty Thebes, c) 25th Dynasty Thebes, d) Ptolemaic Era Coffin, e) Northern Upper Egypt Coffin, Sedment 22nd to 25th Dynasties.
Photo courtesy of the Egypt Exploration Society

To strengthen our dating, we collected and compared the features of these coffins with our lid.

4. Comparable artifacts

<12> Coffins have played a big part in the Egyptian afterlife culture. Most of the coffins examined, published and displayed in museums have beautiful decorations or have been elaborately manufactured (Martin 1991:140). Mostly, these coffins belonged to kings, priests or other wealthy people from the elite. Coffins that were not well made or very colorful were often overlooked when found in the late 19th and early 20th centuries. This makes it harder to find other similar coffins with more simple decoration and to compare them nowadays, primarily because these types of coffins were often sold to private collectors at this time. Most information about their provenance is now lost (Stövesand 2018:390 and see above). The interest in these simpler decorated coffins has grown in the last twenty years, and they have been examined, with the findings published.

The features we concentrated on to compare and define a possible provenance, or a rough estimate for dating (Taylor 2009:386-389) of the coffin were the hands – especially their presence on the coffin as separate wooden parts – the height and width of the lid, the broad wig especially in relation to the small face, the missing of depicted ears, the placement of the tenons

on the underside of the coffin lid and wood used as the material. The presence of hands added as separate carved pieces give a solid hint to its regional provenance.

<13> In Egypt, a significant shift in power and structure happened at the end of the 20th Dynasty and the New Kingdom with the death of Ramses XI and the beginning of the Third Intermediate Period (around 1069 BC; see Taylor 2010:220ff. for a political overview). This was also marked with a change in the burial tradition. Stone sarcophagi were no longer used, and with the 22nd Dynasty, the previously used highly decorated yellow wooden coffin (esp. Theban Elites) were discarded and replaced by much less elaborate decorations. Furthermore, the full cartonnage body container around the mummy was introduced (Cooney 2015:285).

The coffins dating from the 22nd to the 25th Dynasties consisted of an outer and/or an inner wooden coffin containing a cartonnage mummy case. The outer coffins are bigger to fit an inner coffin and the mummy. The coffin lid in question probably belongs to an outer coffin due to the size and style of the coffin lid (see Fig. 5).

Taylor (2009:376) describes the design of the coffins of the 21st Dynasty as mainly originating from Thebes, with anthropoid shaped and "brilliantly" (Taylor 2009:376) polychrome painted coffins on a yellow or white background and with hands crossed on the chest, often holding *djed* and *tit* amulets. The surface of these coffins is divided into rectangular fields and densely filled with deities and symbols; both the outside and the inside are painted (see also Fig. 4a). This changed drastically in the 22nd to 25th Dynasties, especially between Northern and Southern Upper Egypt.

<14> In Southern Upper Egypt around Thebes, wooden coffins remained masterfully crafted. They depicted the shape of the mummy, which was contained with a cartonnage mummy case, as far as possible. They were strongly three-dimensional; they had a protruding foot-case and no arms and hands (with a few exceptions). The outer decoration on the body surface also decreased considerably; usually, only a single vertical inscription remained (see also Fig. 4b and c), as well as the figure of a deity on the inside of the coffin lid (Taylor 2009:378).

However, the contrast is even stronger in the case of coffins from Northern Upper Egypt. Although these coffins still had an anthropoid shape, they were much simpler and, in some cases, more roughly worked than those discussed above. Decorations can only be found on the outside of the coffins and here almost exclusively on the lid, where only the face, wig, collar, and hands are decorated and elaborated; the body could also have one central vertical inscription, often crowned by a jackal lying down (Taylor 2009:379). The coarser method of making the coffin lid is defined by the almost flat surface except for the head and shoulder area, with flat wooden strips along the edges to give the impression of a slightly rounded body. The characteristic protruding foot-case like the South Upper Egypt coffins is also missing entirely or was rarely indicated by a flat board (Taylor 2009:386). This simpler method of manufacture has led to these coffins often being classified in Ptolemaic or Roman times (Taylor 2009:379) – just like the coffin lid fragment in Cologne.

<15> The faces of these coffins are strikingly small in relation to the broadly designed tripartite wig (Taylor 2009:387). Fless (1997:63) has also emphasized this characteristic for the fragment of the coffin lid in question and Taylor (2009:393f.) describes that this type of coffin has often been confused with Ptolemaic coffins. However, it is precisely the latter that have proportionately much larger faces (see Fig. 4d for an example) and this argues conclusively for a classification of these types of coffins into the 22nd to 25th Dynasties.[19] The classification of our coffin

[19] On the oversized faces on Ptolemaic coffins see Taylor (2009:396). The entire argumentation for dating is found in Taylor (2009:393-397). Dating is usually problematic because coffins and especially graves have been reused for several centuries, so that the accompanying archaeological material does not allow any statement to be made on the chronological classification. However, he does provide conclusive arguments

lid into this period becomes more certain if one continues to look at the design details; for the faces, yellow, red, or cream-white colors were used, with black and white eyes and black or blue eyebrows (Taylor 2009:387). The coffin lid from Cologne shows similar characteristics.[20] The most apparent distinguishing feature of coffins between north and south is the very frequent presence of the crossed hands on coffins from the North.[21] They are individually attached and are depicted without arms. However, they often have a decoration in the manner of a net pattern from the wrist to the root of the thumb or in the same manner as the pattern of the collar design (Taylor 2009:388f). This last detail makes it almost certain that our lid belongs to this group, as this pattern is well preserved on the back of the left hand and faintly preserved on the right. Unfortunately, it cannot be compared with the collar, which was decorated, as its details are no longer visible except for a reddish line under the chin.

<16> Thus, the lid of this coffin shows almost all the characteristics of the coffins from Northern Upper Egypt of the 22nd to 25th Dynasties (flat lid, added hands, head and wig, with the decoration only on hands, wig, face and collar). Only the inscription is not verifiable since this part of the lid is already missing. With the presence of hands and their decrease as details between the 22nd to 25th Dynasties (Helck 1984:448), an early dating of our lid into the 22nd Dynasty and not much later (Polz 1993:386f.) is almost certain.[22]

With this determination of the lid of the coffin, a reconstruction can now be created because some comparative examples for this type of coffin match our fragment in time and origin

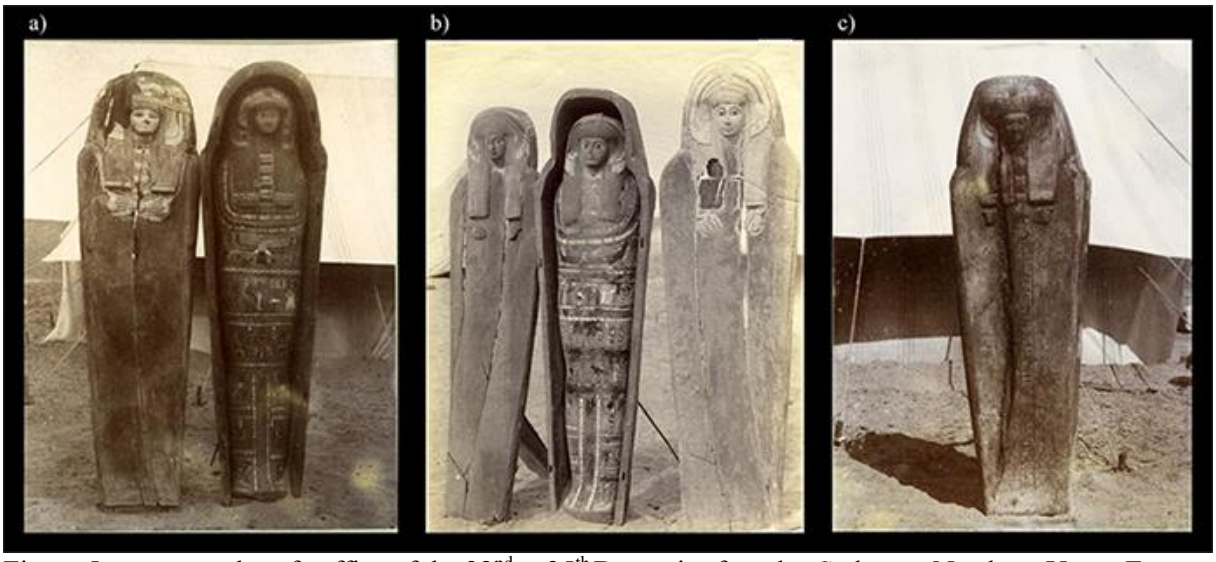


Figure 5 a-c: examples of coffins of the 22nd to 25th Dynasties found at Sedment, Northern Upper Egypt, entrance of the Fayyum. Photos courtesy of the Egypt Exploration Society

for the classification of coffins into the 22nd to 25th Dynasties, e.g., based on inscription texts and facial proportions.

[20] As said before, since we could not see the lid in person and had to rely entirely on color corrected photographs, for us the face color is a little difficult to determine. Fless (1997:63) assumes a brown color, but for us it seems to be rather plaster or stucco, which is yellowed and has lighter break edges. Rather, a cream-white color seems to have been the face color used, because between the eyebrows, in the upper right corner of the left eye socket and in and around the right eye there is a slightly darker shade than that of the damage part. The same on the dowels there.

[21] But less and less often as time goes on (Helck 1984:448).

[22] To highlight that our lid is not from the Ptolemaic era, we gathered two more examples of Ptolemaic dating from the British Museum. Most notable differences to the Cologne coffin lid (Opp.-Inv. Bl. 104, 21; Inv-Nr. 2127) are the exceptionally large faces and broad round shoulders as seen in Fig. 4d above: https://www.britishmuseum.org/collection/object/Y_EA22938, https://www.britishmuseum.org/collection/object/Y_EA6658 (both accessed 23.02.2021).

The reconstruction process with this kind of information was straightforward, and no special modeling techniques had to be used, just standard 3D-modelling approaches. The reconstructions were built using polygonal box modeling, meaning the 3D objects are made out of vertices, edges, and faces (Brunke 2017: 27).

5. Parameter for the Reconstruction

<17> With all this solid evidence for placing our lid into the category of coffins from Northern Upper Egypt from the 22nd to 25th Dynasties, we then had a further look at pictures of coffins from this period and on the description of the construction and features of the whole coffin in the academic literature (mainly Taylor 2009) so as to determine the features and parameters which the reconstructed lid and case must include.

Taylor (2009:386) describes these features for the overall main appearance, and we 'translated' them into steps and parameters of our reconstruction:

- made from small **pieces** of thin wood
- only **head, shoulders, and hands** as human features (covered by our SfM model)
- lid with a **flat surface**, slightly concave and **without protruding foot-case** (following the contour of the SfM model)
- **deep case, simply** constructed with straight sides, angled sides from shoulder to foot (foot width narrower than shoulder-width; see also pictures of other coffins above)
- **four to six tenons** and mortises as joints (two seen at the height of the hand positions in the SfM-model)

Taylor (2009:389) goes on and describes the more detailed features of the lid:

- **sparse** decoration
- the only decoration being on the **exterior** of the lid
- **the plain area** below wig and hands (as indicated by our SfM model)
- one **vertical inscription** with recumbent jackal on top

<18> Determining the coloring of the coffin needed some more attention. In comparison with images of similar coffins, many possible variations of some basic color schemes were visible. The base color on the body part of our coffin lid looks beige or faded yellow. A yellow coloring would fit because yellow is a well-attested substitute for gold, which means coffins from the 21st Dynasty imitated the appearance of this expansive material to suggest a link between the deceased and the gods. In the 22nd Dynasty, yellow connected the coffins to the sun and had a solar significance (Davies 2001:166). This led to our decision to show a base color on the reconstructed lid, but the coffin base will only show a wooden texture, as with most of the compared coffins and coffins of this type in general (see Taylor 2009:389).

Taylor (2009:392f), in addition also describes the following features:

- **plaster on the face, wig, and collar**; remainder optional. For us, just on these parts (see SfM model, esp. the space between the wigs and hands)
- rest of the coffin could be left unpainted. **Painted directly on wood**, as far as can be seen on the SfM-model and images (see SfM model, directly behind the right hand the peeled paint and wood underneath (links under paragraph 29)
- from our lid: color **darker creme-white**, nearly like **khaki**-colored or **faded yellow**
- black or blue inscription

<19> The final parameter-set was the measurements of the case, especially the depth. All the reference pictures we found of similar coffins with cases are top view images of the coffins. If the measurements were not given in the accompanying texts, but the scales nevertheless were shown in the images, it was possible to measure the length and width of the coffin. However,

the height of the cases was seldom given or shown. If it had been a three-dimensional publication, one could easily measure the missing values, which show another advantage of working and publishing in 3D (and how much more critical a thoughtful documentation and description is).[23] The height of the lid was quite simple to reconstruct because of the existent original 3D model of the coffin lid. We also had the width from the SfM scan, which shows the broadest part – the shoulders – of the coffin and lid. With this, we could reference the lid to the images of comparable coffins we had so that we ended up with a height between 190 to 196 cm. The depth required some guesswork. Eilas and Lupton (2018:177) published a study on two coffins from Northern Upper Egypt which are 200 – 400 years younger than our coffin and coffin types. Since this is the only indication we could find, we roughly used their findings around 25 to 30 cm as depth.

<20> With these kinds of described features and parameters, we ended up with controlled boundaries for our reconstruction. This was a good sign since it meant that most of our reconstruction would be based either on primary (what remains of the original object) or secondary (comparable objects from the same time and region) sources and not too much on our own interpretation and guesswork (Hageneuer 2019:206-210). We want to highlight that the preparation work is as much a part of the reconstruction (namely, the accompanying documentation) as the modeling itself.

6. Reconstruction

<21> The reconstruction process with this kind of information was straightforward, and no special modeling techniques had to be used, just standard 3D-modelling approaches. The reconstructions were built using polygonal box modeling, meaning the 3D objects are made out of vertices, edges, and faces (Brunke 2017: 27). Therefore, we will not go into the details of the single steps; for this, one can look at our accompanying blogs, where we documented our modeling and reconstruction process step by step and with pictures.[24] The reconstructions are placed on sketchfab[25] and kompakkt[26] (see information box under paragraph 29). Whilst the distribution of the information is not perfect, the division of technical discussion, viewable 3D reconstruction, and accompanying text stem from a university assessment, which was the basis of this paper. We ensured the websites could still be seen in the future by using the wayback machine[27] from archive.org. We saved the web pages for future use and to at least have snapshots of the websites. This is not the best way to preserve our documentation. However, these 3D models and workflow blogs were not initially designed for a more prominent publication, which is why saving the websites with the wayback machine is our solution for this publication.

<22> Nevertheless, we would like to recommend a more unified approach where ideally, the documentation of the technical workflows and source-critical documentation is integrated into the publication of the 3D model itself. Sadly, most 3D file formats do not have the capacity to hold so many texts and comments. An alternative would be to publish the final 3D model on a platform like kompakkt, where one can annotate directly on the 3D model itself (see the example on this reconstruction on the link under paragraph 29) and give it additional information in the form of metadata or links to, eg. documentation, published online. Another advantage of

[23] For example, most of the pictures used from the British Museum had all measurements (height, length, width) so that we could scale the sizes of the coffins accordingly in the comparison above (Fig. 4).

[24] https://archaeologywithblender.wordpress.com/blog-feed/ (Louise Tharandt), http://thevirtualarchaeologist.com/ (Daniel Hinz); both accessed 11.02.2021.

[25] https://sketchfab.com/ Platform allows users to display 3D, VR and AR content

[26] https://kompakkt.de/home Platform allows users to display images, videos, audio and 3D content

[27] https://web.archive.org/ a digital archive founded by the Internet Archive (https://archive.org) to preserve websites

kompakkt is that its servers are located and curated by the Department of Digital Humanities at the University of Cologne, and that this platform was built with long-term archiving and accessibility in mind. One can even order a DOI number through the university's service and its source code is available via GitHub.[28] For best practice, the accompanying documentation should also be stored in a repository with long-term accessibility in mind; most universities have such a service and can provide one with a DOI number. If we were to start a project from scratch and not have to deal with the structure imposed on us (due to the documentation and reconstruction being part of an assessment for the university), we would only create one document about the sources and the critical approach based on them with an appendix of general and special 3D modeling workflows used for the reconstruction. The final (single) 3D object would then be uploaded to kompakkt, annotated with the most important sources and parts that were difficult to reconstruct, and linked to said documentation, which would be uploaded to a repository and allocated with a DOI number.

In the following section, we only want to communicate some of our decisions which mainly concern texturing, the inscription, and the final presentation, since the other decisions are out of our hands and dictated by the sources. The depth of the case was the one major decision we had to make ourselves, but this was detailed above.

<23> As described before, a paint layer over the plain wooden planks can be seen on our lid. We, therefore, decided to add these two details and layered texture with a wood structure under a base paint layer in a khaki, yellowish tone made in Blender and Substance Painter. For the case, we used a brownish texture with fine wood grain similar to that of the lid fragment. Matching the color of the paint with that of the lid was quite tricky. It took some trial and error since the surface of the lid is pretty rough and has a very heterogeneous color gradient of many color shades so that one cannot simply pick the color from the lid itself.

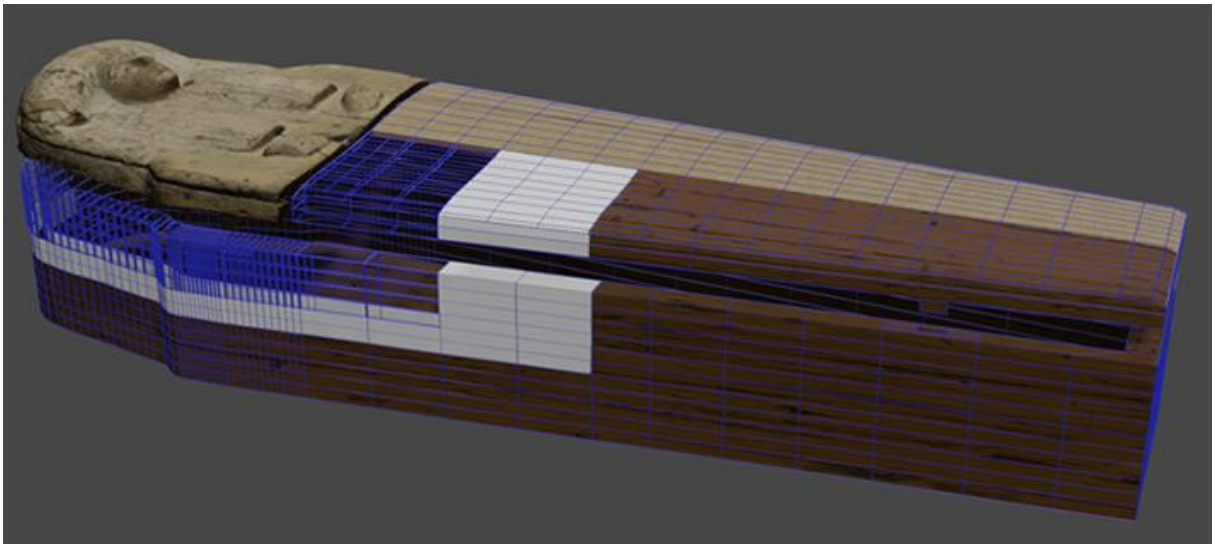


Figure 6: Reconstruction with underlying modeling and texturing steps (link see below Documentation)

The reconstructed coffin's texture and 'look' became an issue in itself. The capabilities of 3D modeling nowadays make it easy to reconstruct objects where it is hard to tell if it is an original object or a reconstruction, especially if one is using physically based materials (which mimic the correct physical properties of an object). We decided to leave a clear and visible 'break' between our reconstruction and the SfM model by using a plain color and a simple wooden texture. Making the difference between model and reconstruction obvious, is a practice used in many archaeological reconstructions and is used to show that the object is a reconstruction

[28] See http://archaeoinformatics.net/kompakkt-the-university-sketchfab/ (accessed 15.12.2021)

Brunke 2017: 31-33). We could also have added little details like dowels, dirt, imperfections, and more to achieve a more homogeneous look with the SfM model but decided against it to make the reconstruction and coffin lid distinguishable. The second approach to ensure that the reconstructed part is visible and recognizable to the viewer was to include a visible wireframe covering the reconstruction. The structure of the reconstruction was then highlighted by having small parts of the coffin shown as only a wireframe, another part only the plain 3D object without textures, and half of the lid with only wood texture to show the construction beneath the color (see Fig. 6).

<24> We also added an inscription in one reconstruction showing the whole coffin with textures (see Fig. 7). Most of the coffins from Northern Upper Egypt of the 22nd to 25th Dynasties had an inscription. On the case of our lid there are no visible remains of such an inscription because the part beneath the hands is already missing. Despite this, we added an inscription to give a visual alternative on how the whole coffin also could possibly have looked, since both makings (with and without inscriptions) are known from coffins of this period and region (see above, Fig. 5). The inscription was taken from such a coffin (again above, Fig. 5c). We also had chosen this example because it comprised all the visual characteristics one would expect from such an inscription: recumbent jackal, dark color, framed and carried out untidily (see Taylor 2009:391f).

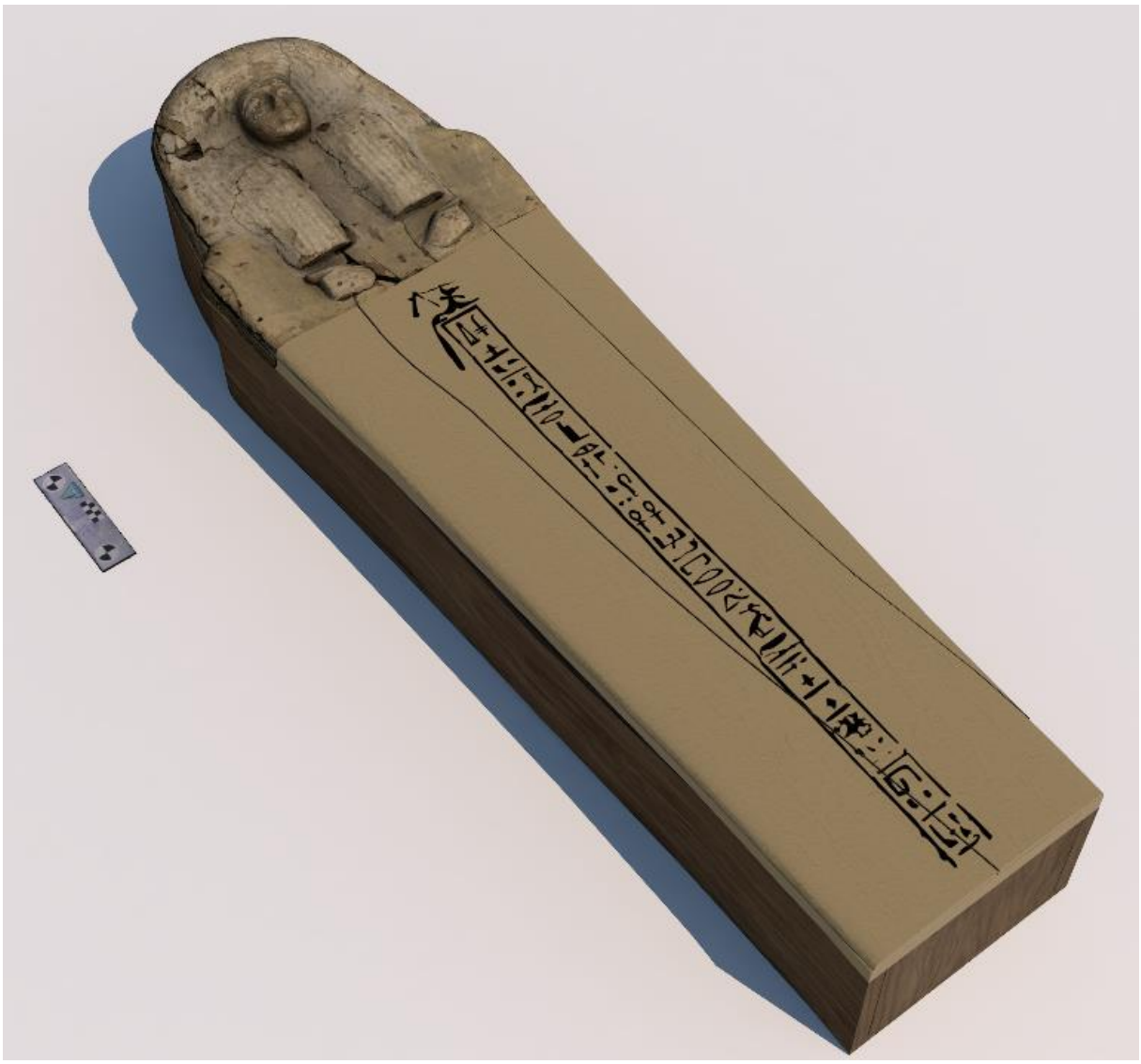


Figure 7: Reconstruction as whole coffin with exemplary inscription (link see below Documentation)

7. Discussion

<25> The 3D scan and model of the original coffin part and the subsequent reconstruction of the missing part of the coffin makes it easier for the public to get access to the artifact if published online, instead of having just a few 2D pictures or renderings of the object and reconstruction. Nowadays, the online presence of institutes and museums, to which such 3D documentation and scientific reconstruction can contribute, is important. Nevertheless, it is also essential to always publish the sources and vital information with these 3D objects so as to uphold scientific transparency.

A big problem in the archaeological field is that there are no actual guidelines for digital reconstructions. While charters like the London Charter from 2009[29] or the Principles of Seville from 2011 exists,[30] many published papers about 3D reconstructions all have their own principles on making specific original parts or reconstructions visible (for extensive examples, see Brunke 2017:35-38).[31]

Guidelines for 3D digital objects, reconstructions, and academic long-term usability would not only be helpful for those who build these objects but also for the museums and institutes that publish these models, especially today.

<26> One major problem of reconstructions is the pretty-picture-trap, which can occur when a (photo)-realistically reconstructed state is achieved by making the reconstruction look so good that it can easily be mistaken for reality, especially if it is published or exhibited without any reflection or documentation.[32] A pretty picture is more susceptible to a (manipulative) implication of truth than a written text, so in our opinion, special care must be taken when dealing with reconstructions, especially as modern technology makes the depiction of reality increasingly easy. This problem can be alleviated by identifying reconstructed areas and accompanying documentation, as we hope to have shown with this example.

However, a financial problem arises when extensive documentation is provided. For this task alone, we have spent about twice the time of the actual reconstruction on the documentation. Since Archaeoinformatics and Digital and Computational Archaeology are comparably young disciplines which only in recent years have become ordinary and equal courses of study to educate scholars making scientific reconstructions, their number is still too low to cover all reconstruction needs. Graphic designers still create many reconstructions coming from fields other than archaeology. Therefore, if one wants to receive proper documentation, the designer has to work in a team with a person educated in academic work and expertise on the topic of the reconstruction e.g. an Archaeologist or Egyptologist. This means not only does the designer need to be paid, but also the scientist must be financed to be heavily involved in this time-consuming task (and cannot work on other projects at this time). Thus, the fees for reconstructions are at least doubled (or even more). However, without such documentation, the scientific value and the scientific re- usability is, in our opinion, massively limited because of the footnotes of the reconstruction, i.e., the tracking of the steps and decisions that led to the result, are not available.

Despite these problems and difficulties, we think 3D reconstructions and 3D scans also offer many advantages if done correctly, i.e., made in a source-critical and academic way, not just as simple visual illustrations (e.g., for publications, museums, and other forms of public presentation) but also to provide easier access to the objects themselves (be it for interested laypersons or scholars). If reconstructions are made in such a way, this could also further the integration of 3D reconstructions into the scientific discourse.

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[29] https://www.londoncharter.org/ (accessed 16.02.2021)

[30] http://smartheritage.com/seville-principles/seville-principles (accessed 16.02.2021)

[31] Brunke draws the convincing conclusion that the high heterogeneity of established methods on highlighting reconstructed parts, uncertainty, and original archaeological record stems from the high diversity of datasets used for reconstructions and that scholars often use the method that fits their data best.

[32] See also Lanjouw 2016 for an overview on this topic and the state of 3D in archaeology.

8. Conclusion

<27> We hope that we have shown one way to enable a reconstruction guided by primary and secondary sources, including the primary source, to contribute directly to the reconstruction together with a 3D scan.

For reconstruction to be as near to the source material as possible and in parallel with thorough academic documentation, we think both skillsets – the skills of making a 3D model and the skills of academic workflows and education in the topic of the reconstruction – are needed. If it is not possible to find this competence in one person (which is mostly the case), teamwork between both parties is essential. This needs a willing scholar to participate in this and his or her employer or the financing institution to understand and support how vital such collaboration is for further scientific long-term usability. Reconstructions created in this way can more easily be discussed at a deeper level (the specific interpretations and decisions on individual elements of it and not just superficial on the overall visuals) because one now has something like footnotes, references, and sources which can be discussed. This could also allow the integration of 3D reconstructions more into the scientific discourse.

<28> In reviewing our methods and form of documentation, we would like to make some proposals on how to create such documentation and how to ideally, publish a 3D model. The 3D model itself should be made available in some form and not only as, e.g., 2D renderings so that it can be viewed from all sides. All information (= documentation) should be in one place, in the best scenario directly accompanied by the 3D model itself. If this is not possible, a feasible alternative would be a platform like kompakkt, where one can directly annotate on the object itself and give ideas and interpretations, for example on a specifically difficult part after it was uploaded. All the published information should then be made available long-term, so saving them in a repository and getting a DOI number would be the best approach. In cases where this is not possible (maybe due to imposed project-specific restrictions), a snapshot with archive.org of some kind of documentation (e.g., a blog or a website) would be an option.

We hope that in the future, more and more 3D reconstructions are made in such a way that they will no longer just have a primary value in visualization and preserving an object but also in preserving the ideas and thought processes which have gone into creating them.

Documentation

Where to find the content:

Description	Link	Paragraph
Archaeological Reconstructions The blog is part of a term paper and documents the technical workflow to reconstruct an Egyptian coffin, from partial Structure from Motion (SfM) model to complete 3D reconstruction. (Louise Tharandt)	https://archaeologywithblender.wordpress.com/ https://archaeologywithblender.wordpress.com/blog-feed/	21, 22, 23
Egyptian Coffin Reconstruction Complete 3D model of the reconstructed coffin, (Louise Tharandt)	https://skfb.ly/6ZvLD	22, 23

Archaeological Reconstructions The blog is part of a term paper and documents the technical workflow to reconstruct an Egyptian coffin, from partial Structure from Motion (SfM) model to complete 3D reconstruction. (Daniel Hinz)	http://thevirtualarchaeologist.com/	21, 22, 23
Egyptian Coffin Reconstruction Complete 3D model of the reconstructed coffin (Daniel Hinz)	https://doi.org/10.18716/KKK/CL20 https://kompakkt.de/entity/5e970066c74e5a08001f50db https://kompakkt.de/entity/5e97300b32213d01bbfa2ece	7, 22, 23

List of Figures

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Fig. 2 Inventory Abt. 601-92.
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Fig. 3 Inventory Abt. 601-3.
© Louise Tharandt (License: CC BY-NC-SA 4.0, https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode)

Fig. 4a Asset No. 338207001, Museum No. EA24789.
Wooden anthropoid coffin; painted detail on plaster; Hieroglyphic text.
© The Trustees of the British Museum.
https://www.britishmuseum.org/collection/object/Y_EA24789 (accessed 23.02.2021).
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Anthropoid wooden coffin, possibly designed for a woman, but inscribed with the name of Nesperennub, son of Ankhefenkhons, Opener of the Two Gates of Heaven in Karnak, Libationer of the Temple of Khons at Karnak.
© The Trustees of the British Museum.
https://www.britishmuseum.org/collection/object/Y_EA30720 (accessed 23.02.2021).
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Fig. 4c Asset No. 1613214324, Museum No. EA22813,b. Base and lid of the anthropoid wooden middle coffin of Nestawedjat.
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https://www.britishmuseum.org/collection/object/Y_EA22813-b (accessed 23.02.2021). (License: CC BY-NC-SA 4.0, https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode)

Fig. 4d Asset No. 32940001, Museum No. EA6677. Outer coffin of the priest Hornedjitef. © The Trustees of the British Museum. https://www.britishmuseum.org/collection/object/Y_EA6677 (accessed 23.02.2021). (License: CC BY-NC-SA 4.0, https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode)

Fig. 4e Ahnas Print 016. © Egypt Exploration Society. Courtesy of the Egypt Exploration Society

Fig. 5a Ahnas Print 012. © Egypt Exploration Society. Courtesy of the Egypt Exploration Society

Fig. 5b Ahnas Print 006. © Egypt Exploration Society. Courtesy of the Egypt Exploration Society

Fig. 5c Ahnas Print 016. © Egypt Exploration Society. Courtesy of the Egypt Exploration Society

Fig. 6 Reconstruction with underlying modeling and texturing steps. © Louise Tharandt (License: CC BY-NC-SA 4.0, https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode)

Fig. 7 Reconstruction as a whole coffin with inscription. © Daniel Hinz (License: CC BY-NC-SA 4.0, https://creativecommons.org/licenses/by-nc-sa/4.0/legalcode)

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