**Comparison of two ancient Egyptian Middle Kingdom statuettes from the Museo Egizio of Torino through computed tomographic measurements**

# Comparison of two ancient Egyptian Middle Kingdom statuettes from the Museo Egizio of Torino through computed tomographic measurements.

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ABSTRACT

X-ray Computed Tomography (CT) has a significant role as investigation tool not only in medical and industrial applications, but also in cultural heritage studies. One of the main reasons for such broad adoption of this method is its non-destructive capability to investigate the inner structure of precious and unique artefacts that would instead be damaged by traditional sampling procedures. Ordinary X-ray radiography is limited and gives only 2D images, while high-resolution X-ray CT imaging gives non-invasive access to three-dimensional (3D) information. This article focuses on the comparison of micro-CT results obtained from the analysis of two ancient Egyptian wooden statuettes representing offering bearers. The artefacts belong to the collection of the Museo Egizio of Torino as part of the funerary assemblage of Minhotep, discovered in the Asyut necropolis. For the analysis, an upgraded version of the X-ray imaging apparatus located in the Centro Conservazione e Restauro "La Venaria Reale" (CCR) was used, in order to reach a higher final resolution than the one already present and used at CCR. Thanks to this investigation, much information on the artistic technique was obtained and it was possible to highlight differences and similarities in the technical features of the two statuettes, acquiring elements to understand the specific contribution of micro-tomography in studying the finds and hypothesizing a common production method.

**Keywords**: Egypt; statuettes; comparison; Museo Egizio; tomography

## 1. INTRODUCTION

Accessing the inner structure of an object has been an ongoing problem in many disciplines. Historically, while a number of science fields could afford several micro-invasive analyses (e.g. biology, geology, materials science), this process was extremely limited for objects in the field of Cultural Heritage, being necessary to preserve the original materials of the artworks. The discovery of X-rays made it possible to see through matter non-invasively and the development of computed tomography (CT) to obtain three dimensional images. The capability of reading inside the objects boosted the chance of access to information supporting the study of the artistic technique. X-rays methods are based on the physical and chemical principles by which different materials and densities absorb the radiation (Kak & Slaney, 1987). The elemental composition of an object will determine the amount of X-rays from the incident radiation that are absorbed or scattered; the alteration of the transmitted beam is used to obtain an image of the inner components of the object. 2D images from X-ray radiography show overlapping spatial planes in the resulting image, making the examination of three-dimensional objects difficult and less clear. Tomographic analysis favours instead the interpretation of internal features, giving the possibility to reach a 3D visualization of the inner structure of the objects and allowing to determine the state of preservation and the manufacturing techniques of artworks (Casali, 2006; Morigi et al., 2010; Lang and Middleton, 2005).

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Fig.1. The analysed "Bearer" statuettes, frontal and lateral views after the conservation treatment (a: statuette A, n° inv. S. 08795; b: statuette B, n° inv. S. 8796)

Today, laboratory X-ray CT equipment is widely available and permits the study of many different archaeological and anthropological finds (Bettuzzi et al., 2015; Ngan-Tillard et al., 2018; Otte et al., 2013; Sanger, 2016), but sometimes synchrotron radiation is needed (Fiocco et al., 2018) to get a more detailed knowledge of ancient objects. The fixed X-ray imaging set-up installed at the Centro Conservazione e Restauro "La Venaria Reale" (CCR) was developed in the context of the neu_ART project (Nervo, 2013; Re et al., 2012) and optimized for DR and CT of large artefacts as, for example, furniture, wooden coffins and objects difficult to analyse in common/standard medical systems, e.g. soil blocks (Lo Giudice et al., 2017; Re et al., 2014, 2015, 2016). Since the works of art variability in terms of material, size, shape and state of preservation can be extremely wide, a recent upgrade of this set-up was performed (Vigorelli et al., 2020, 2021), allowing to reach higher spatial resolution, suitable for small objects, and consequently a better data interpretation. In the framework of this set-up upgrade, a comparison between the results of the CT measurements performed at CCR on two Ancient Egyptian wooden statuettes, from the collection of the Museo Egizio of Torino, is presented.

## 2. MATERIAL AND METHODS

The two painted wooden statuettes representing offering bearers (Fig. 1a,b) were found during the 1908 excavation season of the Italian Archaeological Mission, directed by Ernesto Schiaparelli, in the Asyut necropolis (Egypt). They were part of the rich funerary assemblage found in the "tomb of Minhotep" which included also another bearer statuette, three statues belonging to Minhotep and to Upuautemhat, a model of a bakery, boat models and numerous earthenware jars and bowls (Del Vesco, 2017; Kahl et al., 2019), most of which came from specialized workshops operating during the early Middle Kingdom, XII Dynasty (ca. 1980-1900 BCE). This type of equipment, composed by numerous wooden artefacts, models in particular, became, at the beginning of this period, the main element of tomb assemblages, generally placed within the burial chamber, according to ancient Egyptian religious beliefs. The statuettes here examined are the typical representation of a female "offering bearer", carrying a basket on the head, held in position with the left hand, and a poultry offering in the other hand, as also attested by an historical photo preserved in the Alinari archive, showing most of the finds from this tomb (Moiso et al., 2017).

Table 1. Comparison between some CT experimental details adopted for the analysis of the two statuettes.

| | Bearer A (S. 08795) | Bearer B (S. 8796) |
|---|---|---|
| Statuette dimension | 60 ×12.5 ×25.5 $cm^3$ | 44.7 ×14.5×20.5 $cm^3$ |
| Source-Detector distance (SDD) | 3.75 m | 3.73 m |
| Source-Object distance (SOD) | 3.51 m | 3.53 m |
| Magnification | 1.07 | 1.1 |
| Voxel dimension | 46 µm | 47 µm |
| Tube voltage | 80 kV | 80 kV |
| Tube current | 10 mA | 10 mA |
| Integration time | 1.75 s | 1.65 s |
| Scan phases (portions) | 3 | 5 |
| Projections/portion | 1440 | 1440 |
| Angular step | 0.25° | 0.25° |

The two statuettes object of this study belong to the same iconographic typology, so their appearance is very similar: both are positioned on a wooden base, with the left leg advanced, the right hand along the body carrying the animal offering, the left hand up to support a basket full of other offerings (as suggested by evidences on the surface) and have the same hairstyle of the wig with a long ponytail on the back. The pictorial treatment also presents similar characteristics, such as yellow skin, a white long dress and a white band on the forehead, a yellow basket with black geometrical decoration, a black wig, and others details.

Concerning their state of preservation, the first statuette (A, S. 08795) differs from the second (B, S. 8796) mainly by the lack of the two arms, while the feet and the animals carried in the right hand are missing in both the artefacts. Beside this, the difference of the two wooden bases and the anchoring system appears evident: in statuette B, the base is thicker and, despite the lack of feet, it is possible to see the 'footprints' left by their ancient presence, as a gap in the base preparation layer, unlike statuette A. Taking these aspects into account, we can assume that probably the base of the statuette B is original, while further studies, as the CT analysis, were needed for the base of the statuette A. Another difference regards the basket-head junction of the statuettes, i.e. wooden dowels


Fig.2. Radiographic images of the two bearers, frontal view (a: statuette A; b: statuette B; yellow arrow: wooden dowels for the basket-head junction of statuette A, absent in statuette B)

for the statuette A, which cannot be found to the naked eye in statuette B. Due to breaks in the dowels of the statuette A before the conservation treatments, the tomographic analysis was carried out separately for the basket and the body (3 scan phases), while for the measurement of statuette B took place on the entire figure (5 scan phases).
The analysis was carried out at the CCR, with the upgraded equipment for X-ray imaging investigations, that include a General Electric Eresco 42MF4 X-ray source, improved with a high resolution flat panel detector Shad-o-Box 6K HS by Teledyne Dalsa, whose pixel dimension of 49.5 μm makes it suitable for analysis of small object. The reconstruction of the CT sections in both cases was made using a filtered back-projection algorithm (Brancaccio et al., 2011; Kak & Slaney, 1987) by means of two non-commercial softwares developed by the University of Bologna (Martz et al., 2009)and by Dan Schneberk of the Lawrence Livermore National Laboratory (USA). All the details of the instrumentation used are reported in (Vigorelli et al., 2020), where the results obtained from the tomographic analysis of the statuette A are also described. In (Vigorelli et al., 2022) instead, all the other diagnostic investigation performed on statuette A and their interpretation are illustrated.
The experimental details of the CT measurements of both the bearers are reported in Table 1.

## 3. RESULTS AND DISCUSSION

Starting from the analysis of the radiographic images (Fig. 2), it can be seen that the entire surface of the statuette B appears more homogeneous to X-rays absorption than in the statuette A, where areas with different radiopacity over the entire volume of the body can be noticed. This issue reflects the presence of small-size wood portions applied to the main one with wooden dowels (for example in correspondence of the wig and right breast) and the application of some material to favour the attachment of the two pieces and to fill the irregularity of the two surfaces in contact in statuette A. The absence of this feature on the Bearer B suggests the choice of a different wooden material and, perhaps, a better capability in carving without damages to correct in the structure: infact, modelling materials applied to cover defects in carving combined with the use of multiple pieces of wood assembled, also of limited dimension, could be considered an evidence of a different manufacturing. Furthermore, from the analysis of radiographs, it is possible to notice an important difference in the realization of the basket-head portion of the two statuettes: in statuette A the evidence of a junction of two different blocks by means of wooden dowels can be seen (Fig. 2a), absent instead in the statuette B. For the latter, this detail suggests the carving of the two portions from a single piece of wood, noticing continuity in the wood vessels. In general, the characteristic wood growth rings and vessels are very well distinguishable in the different tomographic slices (vertical and horizontal). For statuette B, it is also possible to notice the presence of the pith, some knots and some fractures due to wood carving,


Fig.3. CT vertical slices of statuette B (a: entire figure; b: detail of the basket; c: detail of the body) in which the hole caused from the pith detachment is clearly visible (red arrows: pith; green arrow: knots; blue arrow: thicker preparation layer; orange arrow: crack).

(Fig.3b-c, Fig.4a, Fig.5a-b), an aspect to consider during the conservation treatment. Moreover, the presence of the central pith, extended through almost the entire height of the statuette (Fig.2) (a detail emerging from the CT vertical sections of

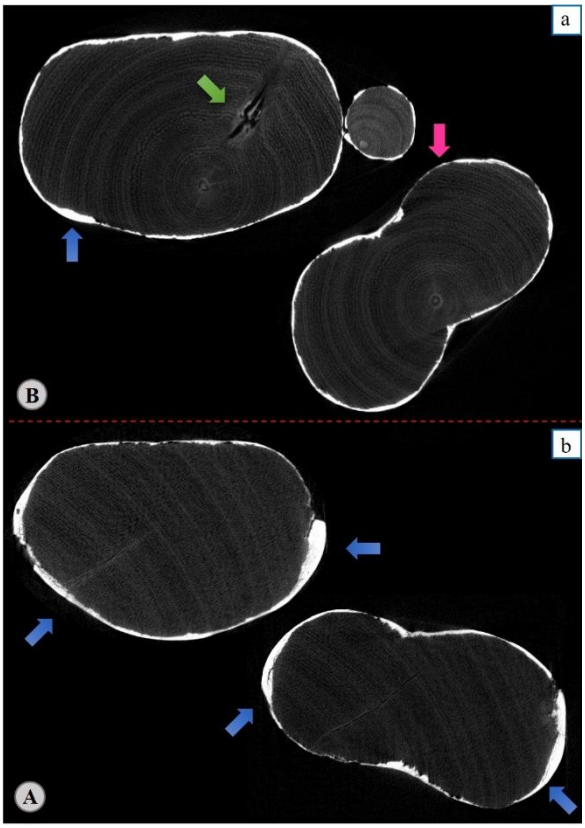


Fig.4. CT horizontal slices of the two statuettes (a: statuette B; b: statuette A) in which the preparation layer is visible (pink arrow: lack of material; blue arrow: thicker preparation layer; green arrow: defects).

bearer B) suggests the use of a single wooden block for the realization, confirming the same hypotesis based on the absence of dowels junctions.

As regards the assembly between the basket and the head, starting from the upper portion, the tomographic reconstructions of the statuette B confirm the absence of wooden dowels, used instead in the statuette A (Fig.5b). Some wooden dowels in bearer B can be instead observed for the junction of the left hand with the basket and of both arms with the body (Fig.5a-d), together with a material (possibly the same used for preparation) applied to ensure a better hold of the pieces; this is not found instead in correspondence of the different dowels used in statuette A (Fig.5e,f), probably due to the perfect adherence of the inner elements in their place.

Analysing the lower part of statuette B, some areas with thinner or absent preparation layer can be noticed (Fig.4a), in correspondence with gaps visible even to the naked eye. As for the insertion of the legs into the base, from the radiographic results of statuette A (the tomographic analysis was performed only from the top to the hips of the figure) it is possible to distinguish two holes made to accommodate the end portions of

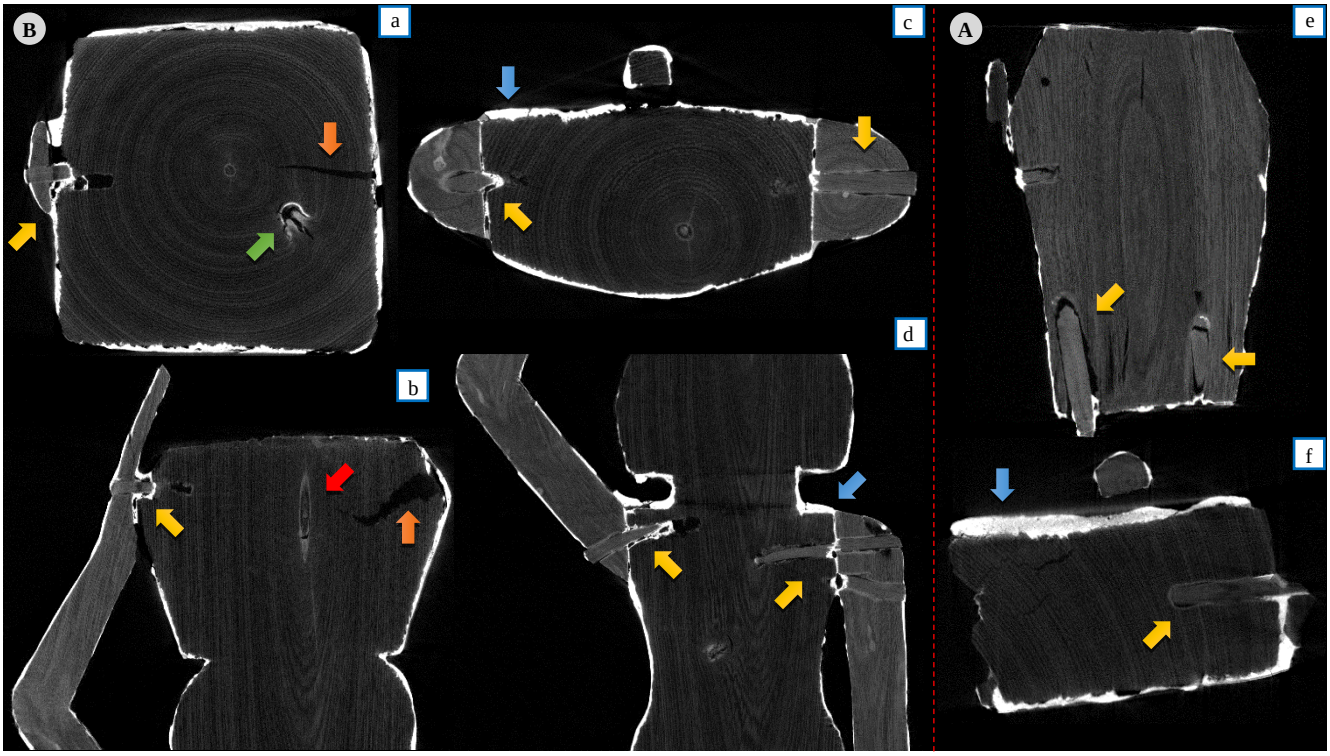


Fig.5. CT horizontal and vertical slices of the two statuettes (a-d: statuette B; e-f: statuette A), where the use of wooden dowels is visible (a-b: visualization of the basket; c-d: junction of the arms; e-f: slices of basket and shoulders respectively). Green arrows: defect; orange arrows: cracks; blue arrows: thicker preparation layer; yellow arrows: wooden dowels, together with filling material in a-d; red arrow: wood pith.

the legs, fixed by means of a filler material with a higher radiopacity than the wooden material (Fig.6), applied in occasion of a previous intervention; these holes have been realized in elements made of different wood that were added to make up for the loss of original material in the base (Fig.7). The tomographic analysis of the same part of statuette B shows very clearly the insertion of the right leg in the base via its hole, fixed with the application of a radiopaque material, clearly distinguishable from wood (Fig.8).

Concerning the left leg, missing of the last part, the CT analyses evidently show the insertion of a wooden element, applied in a previous intervention to support the leg, in the still existing original hole functional to the assembly and, during this treatment, filled with a radiopaque material. It is not to be excluded that both the filler materials detected could belong to the historical intervention, and not to the original technique, observing similar features in their density and morphology.

The presence of air bubbles inside the matrix, absent in the original materials (Fig.8c,e), seems to confirm this. Finally, also in the base it is possible to see the wood growth rings and some defects, such as knots and internal cracks; in this case it is possible to notice the presence of two piths, one of which is detached, as found in the body of the statuette (Fig.8a,b). This peculiar characteristic suggests the origin of this block from a branched trunk, possibly the part immediately before the separation in two branches.

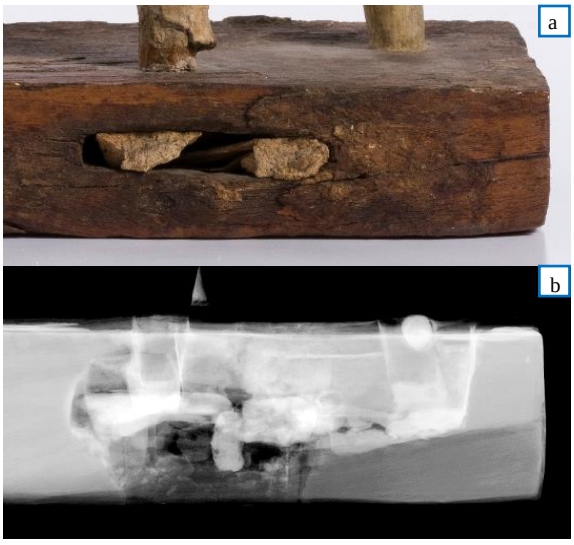


Fig.6. Detail of the statuette A base (a: visible light picture; b: radiographic image)

Fig.7. Detail of the statuette A base, in which the different wooden material is visible (yellow arrow).

The preparation layer, generally applied to receive painting materials and to regularize the wooden surface, is immediately recognisable observing the different tomographic sections. Unlike what was observed for statuette A, the preparatory layer of bearer B shows in general an homogeneous thickness (0.7-1 mm), except in a few points where it reaches 2.3 mm (Fig.4a). This might be caused by the presence of a less homogeneous wood material and structure underneath. This feature, different from what was seen on statuette A, where in many parts volumes were modelled with this material, is to be considered: in combination with other slight differences emerged, extremely significant for the study of the artistic technique, it can be a clue of the technical approach of the sculptor. From the evaluation of the resulting attenuation coefficient's values, it can be supposed that the type of material is the same used for the statuette A, a feature that will be further investigated through other diagnostic methods.

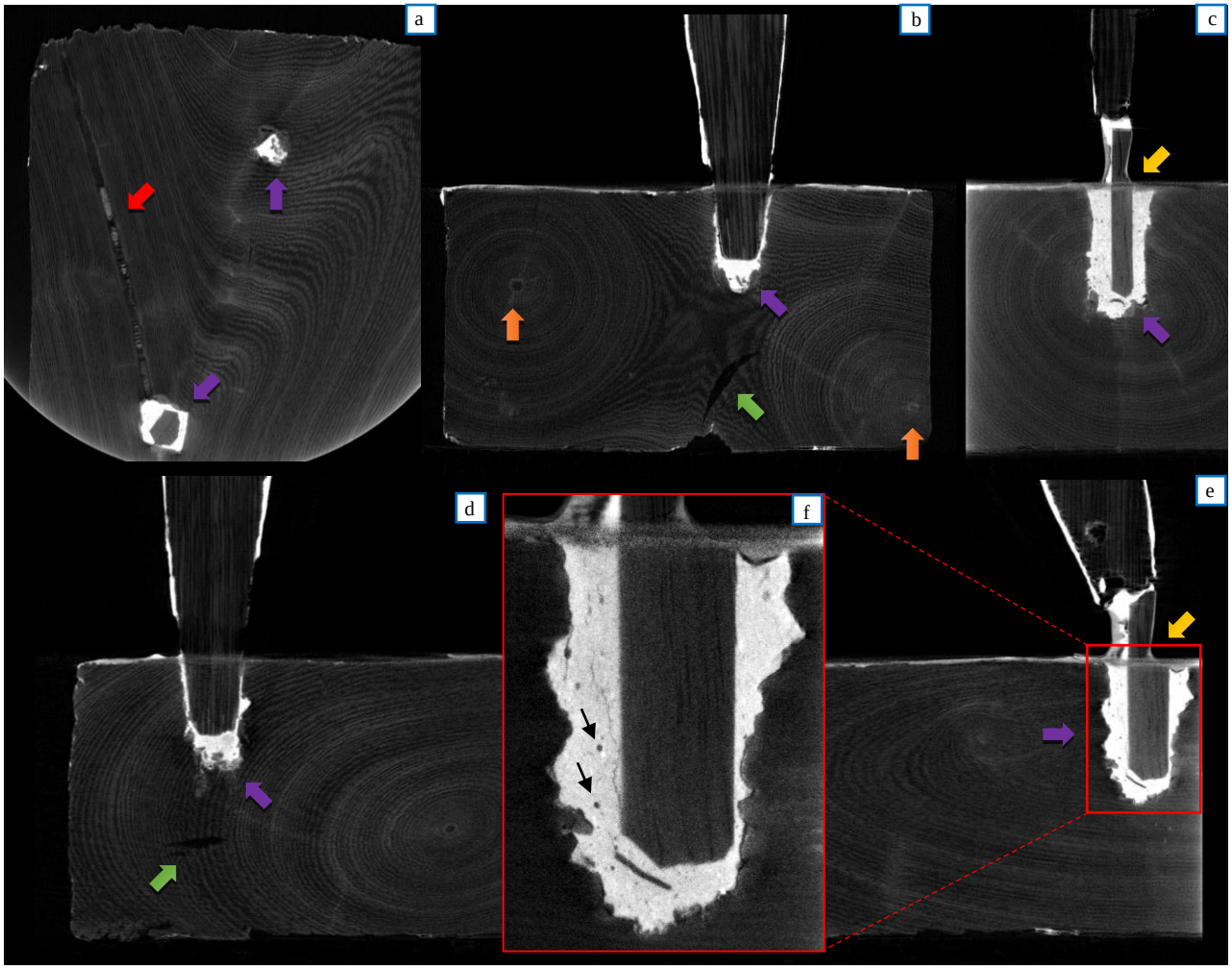


Fig.8. CT slices of the statuette B base; a: horizontal slice; b-e: vertical slices in which the insertion of the right leg (b and d) and the left leg (c and e) are visible; f: a particular of the filler material where air bubbles are visible (black arrows); (red arrow: pith hole; green arrows: defects and cracks; purple arrows: filler material inside the legs holes; orange arrows: double pith; yellow arrows: wooden dowel).

## 4. CONCLUSION

Thanks to the upgraded set-up located at CCR, i.e. the use of a high resolution flat panel detector, it was possible to perform DR and CT analysis of two small ancient Egyptian statuettes from the collections of the Museo Egizio of Torino. The small pixel dimension and the high integration time of the flat panel permitted to obtain useful information on these wooden artefacts, about the characteristics of the wooden structure, artistic technique and previous interventions. Most of the evidences came out from tomographic measurements that allow to obtain more useful information about the inner structures and specific features of the two finds. Despite the same provenance and iconography of the artefacts, as concerns the artistic technique some important differences can be found, such as: statuette B is carved in one solid wooden block, unlike statuette A, in which the basket and the body are two separated pieces; the preparation layers have different thicknesses and contribute in a different way to the realization of the volumes (more homogenous and thin in statuette B, used also for modelling in statuette A). In both the bearers some knots and inner breaks are visible from CT slices, with the further presence in statuette B of a hole caused by the wood pith detachment. In addition, the CT images reveal that both the finds have undergone some previous interventions that regard principally the legs area. In conclusion, the importance of underlining similar and different features in terms of assembly, modelling technique and materials used could suggest possible different hands in the realization of the objects. As starting point for future systematic

studies, these specific characteristics could contribute in the correct understanding of finds coming from the same context, but not necessarily produced by the same artisans. In the future, if it will be possible to apply the same investigation strategy to the other wooden artefacts and statuettes belonging to the same context, analogies and differences in terms of materials, manufacturing techniques and state of preservation will support the Egyptological study aiming at the possible reconstruction of different workshops active in Asyut in the early Second Millennium BCE.

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