A symbolic homecoming. 3D digital imaging of Greek vases from the MHNC-UP

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ABSTRACT: One of the most interesting Portuguese-German diplomatic relations is associated with the imprisonment of a ship in Lisbon during World War I. Bringing this centenary story, which took place between 1914 and 1927, back to light seemed appropriate due to its strong symbolic charge: some of the pieces contemplated in the events we will soon be remembering are symbolically returning home. The subject is not new, however, as it has already been the subject of a number of publications, including by one of the proponents of this study. But the approach presented here is naturally different, as it falls within one of the themes under discussion at this meeting, 3D digital analysis methods and techniques. This approach has already been considered several times by another of the proponents of this study, one of which included four Greek vases from different productions and periods from the Museum of Natural History and Science of the University of Porto (MHNC-UP) that we will be discussing.

1. INTRODUCTION

One of the most interesting Portuguese-German diplomatic relations is associated with the imprisonment of a ship in Lisbon during World War I. Bringing this centenary story, which took place between 1914 and 1927, back to light seemed appropriate due to its strong symbolic charge: some of the pieces contemplated in the events we will soon be remembering are symbolically returning home. The subject is not new, however, as it has already been the subject of a number of publications [1][2][3], including by one of the proponents of this study [4][5][6][7]. But the approach presented here is naturally different, as it falls within one of the themes under discussion at this meeting, 3D digital imaging and analysis methods and techniques. This approach has already been considered several times by another of the proponents of this study [8][9][10], one of which [11] included four Greek vases from different productions and periods from the Museum of Natural History and Science of the University of Porto (Museu de História Natural e da Ciência da Universidade do Porto – MHNC-UP) that we will be discussing.

Hence, the main objective of this article is to highlight how 3D imaging and computational methods in archaeological and conservation studies can contribute to a better comprehension of ancient pottery. Furthermore, we aim to understand production and filling standards, the potter's skills, and trading issues, as well as to demonstrate if a vessel has the ability to perform certain functions, as exemplified next.

1.1 A FATE OF HISTORY

Let's briefly return to a fascinating story that frames the presence of the pieces under study. It was the result of the historical upheavals at the beginning of the past, which led to Portugal's participation in World War I, due to economic problems and pressure from England. In this context, on 24 February 1916, Portugal seized all the German and Austrian merchant ships that had sought refuge at the beginning of the conflict, and on 9 March formally entered the conflict. Among the six or seven dozen vessels seized was a 3245 tonne steamer registered in Hamburg and owned by Hapag, the Cheruskia. This was no ordinary seizure. This vessel was transporting valuable cargo to the Berlin museums: 412 boxes containing materials from the excavations in Assur by the well-known German archaeologist Walter Andrae (1875-1956). By decision of the Commercial Court, these goods were put on the list of prisoners of war and deposited at the Lisbon Customs House until the end of the conflict. From that date onwards and after José Leite de Vasconcelos refused to house the collection in the Portuguese Ethnological Museum (now the National Archaeological Museum), due to an alleged lack of space, Augusto Pereira Nobre, rector of the University of Porto between 1919 and 1926, and who had been appointed Minister of Instruction in 1920, had the collection transferred to the University. The importance of the collection did not go unnoticed and it was offered for study to renowned French Assyriologists François Thureau-Dangin and George Conteneau. According to Andrae, in his memoirs, this study yielded no results because the 412 or so boxes containing the materials were not accompanied by inventory lists [12].

The diplomatic adventures and misadventures that involved tough negotiations with advances and setbacks to get the material back are well known. In his memoirs, Andrae recalls an episode that particularly moved him: in a private conversation he had with the Kaiser, informing him of the retention of the Assur finds in Portugal, the latter, unrealistically and without any sense of reality at the time, angrily replied that he would send a warship to Porto and bomb the city!

In 1925, in the context of Andrae's second stay in Portugal, accompanied by the German minister plenipotentiary in Lisbon, E. A. Voretzsch, an agreement was reached for the return of Assur's possessions in exchange for other objects selected and offered by the Berlin museums (Staatliche Museen Preußischer Kulturbesitz). This second stay would bring back good memories and some pleasant experiences, in particular a friendly relationship with the Berlin family living in Portugal, Michaëlis de Vasconcellos [12]. In June 1926, eight years after the war, the objects were finally returned, and the following month the crates arrived by sea and river in Berlin, having been unloaded at Kupfergraben, directly in the south wing of the new building, where the excavation diaries were kept [12]. Soon, in January 1927, a selection of objects from the Berlin museums with archaeological and ethnographic collections from Europe, Africa, South America, Central America and Oceania arrived in Portugal.

It is in this context that the MHNC-UP has a small archaeological collection of Greek vases, distinguished, however, by the great variety of productions and decorative styles, namely Mycenaean, Beotian, Corinthian, Attic Black and Red Figure Attic, Lucanian, Apulian and the so-called gnathia technique. In a letter to Carlos J. Michaëlis de Vasconcellos, dated 21 October 1925, he expressly mentioned his concern for careful selection for teaching purposes.

2. MATERIALS AND METHODS

From this small group of twelve specimens from the MHNC-UP, we will focus on four Greek fine-wear vessels that were the object of 3D imaging and analysis, dating from 6th to 4th c. BCE and representing different productions (unknown archaeological site provenance) (Table 1): a Corinthian globular *aryballos* (MHNC-UP-020052), an Attic black-figure shoulder *lekythos*, Group of Vatican G 52 (MHNC-UP-020053), an Apulian red-figure *lekanis*, Circle of the Patera Painter and the Baltimore Painter (MHNC-UP-020058, lid and vessel; probable production area: Taranto / Daunia) and a Gnathian cup-*skyphos*, (Morel, Shape F-4242) Laurel Spray Group (MHNC-UP-020060).

Inv.ID	MHNC-UP-020052		MHNC-UP-020053	MHNC-UP-020058 (vessel)	(lid)	MHNC-UP-020060
Shape/style	Corinthian globular *aryballos*		Attic black-figure shoulder *lekythos*, Group of Vatican G 52	Apulian red-figure *lekanis*, Circle of the Patera Painter and the Baltimore Painter		Gnathian cup-*skyphos*, (Morel, Shape F-4242) Laurel Spray Group
Period (BCE)	c. 575-550		c. 550-500	c. 330-320		c. 330-300
Provenance (before 1925)	Berlin State Museums			Berlin State Museums		Berlin State Museums
References	[4][11][20][24]		[4][11][21][24] [25]	[4][11][22][24]		[4][11] [23][24]
3D system	SL	CT	SL	SL	SL	SL
Scans/slices	23	560	35	41	44	24
KB	3,661	10,999	8,038	47,927	28,121	23,692
Vertices	91,426 [a]	295,215	200,766 [a]	1,196,641	702,267	591,146
Faces	182,78 [a]	590,430	401,456 [a]	2,393,286	1,404,530	1,182,296
Weight (g)	82.3		130	587.4	502.65	148.7
Width (mm)	61.7		66.85	293.5 209.2 [b]	209.78	156.2 96.5 [b]
Height (mm)	67.1		141.29	104.8 98.5 [b]	100.1	68.5 61 [b]
Length (mm)	61.4		66.32	207.4	211.4	95.8
Mesh volume (mm^3)	45,279.3 [c]		- [d]	330,490.9	292,038.4	82,812.1
Density (g/cm^3)	1.8 [c]		- [d]	1.8	1.7	1.8
Max. filling height (mm)	62.8		140.5	88.6	94.3	58.4
Max. filling vol. (cm^3)	64.4 [c]		- [d]	1,006.2	754.3	211.9
Centre mass [xyz] (mm)	-1.5 [c] 29.2 [c] 0.3 [c]		- [d] - [d] - [d]	1.9 55.9 2.7	1 57.3 -0.3	-1.1 30.9 0.3

Table 1: *Short description and main measurements of the 3D models of the vessels. (a) mesh is not watertight, (b) excluding handles, (c) from CT-derived 3D model, (d) not computed because the mesh is not watertight. Values are rounded to one decimal place.*

2.1 3D IMAGING

Different imaging methods, techniques, and resolutions may reveal, distort, or conceal specific features of the object. This issue is of great importance when analysing, namely, forming and painting techniques, or even natural, animal, and anthropic surface alterations that have occurred over the centuries.

The four vessels were digitised at MHNC-UP, with a portable structured white light scanner (SL), Breukmann smartSCAN3D-HE: with two colour cameras, 250 mm stereo field of view (FOV), 129 µm lateral resolution, 1024 mm operating distance, 211 x 159 mm^2 maximum FOV, and 120 mm depth of measuring volume. The system has values according to standard procedures for estimation of accuracy [13]. Within this study, these settings represent an optimal compromise between time available, required level of detail, and computational resources. The Corinthian globular *aryballos* was also digitised with a helical computed tomography (CT) scanner, at the Veterinary Hospital of Porto, specifically to assess its inner structure and morphology and to visualise significant technological and functional features.

2.2 ANALYSIS FROM 3D DATA

A brief morphological description and analysis of the vessels is presented, making the most of a small set of analytical tools to (i) compute and characterise global and local features of each 3D digital model (e.g. topological and basic linear and volume measurements, centre of mass, contact surface of the base, capacity, and wall thickness; curvature analysis is also used to differentiate surface texture regions by detecting and characterising subtle technological, functional, and conservation marks); (ii) generate automatically scientific illustrations. For further technical and methodological details see [11]. As earlier mentioned, these parameters can provide clues about the production, transportation, trade, and use of the vessels.

2.3 DIGITAL DATA LIFECYCLE

Following the research data management plan, several relevant attributes were documented in detail during the entire data lifecyle and added as descriptive, administrative, and structural metadata to every collection and vessel, while the standard operating procedure was added as technical metadata to each vessel. Linked Open Data (LOD) [14] and FAIR data principles [15] were applied whenever possible [16]. In the spirit of Open Science [17][18], selected data generated during this study was deposited in Zenodo [19], an online repository, with unique and persistent identifiers assigned to the digital resources and under a CC usage license [20][21][22][23].

3. RESULTS AND DISCUSSION

Table 1 shows a few basic descriptions and main measurements of the SL- and CT-derived 3D models of the vessels. Within this study, mesh holes were filled in order to generate watertight meshes and enable to compute the volumes and capacities of the vessels – except for MHNC-UP-020053, whose interior could not be completely digitised by the SL scanner due to occlusion. The material density was calculated by the ratio of its mass per unit volume; an offset plane parallel to the base plane of the vessel was used to calculate the filling height, inner volume, and maximum filling volume without dropping; the centre of the coordinate system was set at the centre of the 3D model's base.

Figure 1 displays the isometric and orthographic views of the SL-derived 3D digital surface models of the vessels. The image texture/colour of the vessel's painted decoration is not displayed in order to make the geometric features highly readable. Whereas Figure 2 shows automatic illustrations from the same 3D digital models – except for the profile of MHNC-UP-020052, which was generated from the CT-derived model. The first reflective symmetry is orthogonal to the most distinctive geometric feature, such as handles. The contact surface between the bases of the vessels and a horizontal plane is indicated in Figure 3, which enables to assert the consistency with the overall shape of each vessel while helping to maintain its stability when standing up. Both MHNC-UP-020052 and MHNC-UP-020053 are stable when standing up, but a closer examination revealed that the lid from the Apulian red-figure *lekanis* when used as a container and the Gnathian cup-*skyphos* are not entirely stable, as some areas of the base are not in contact with the horizontal plane.

Figure 1: *Isometric and orthographic views of the SL-derived 3D digital surface models of MHNC-UP-020052, MHNC-UP-020053, MHNC-UP-020058, and MHNC-UP-020060. Note that the vessels do not share the same scale in this figure.*

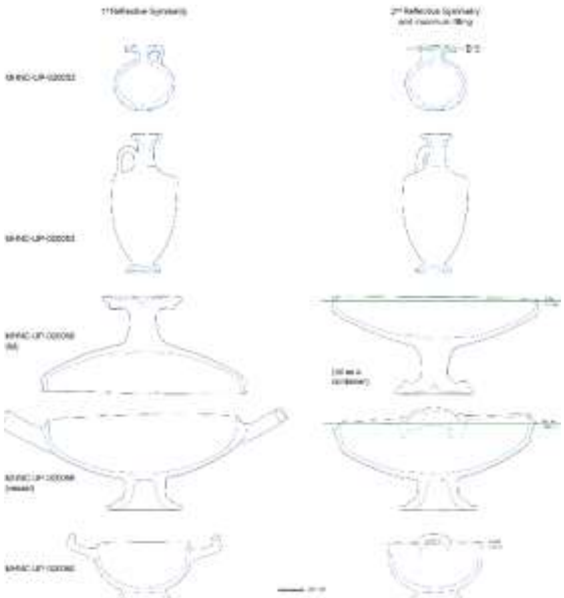

__Figure 2:__ Automatic illustrations of the 3D digital models of the vessels. All profiles were generated from SL scan, except for MHNC-UP-020052, which was generated from CT scan. The 1st reflective symmetry is orthogonal to the most distinctive geometric feature, such as handles. Silhouette (black line), inner cross-section (blue line), and maximum filling height/volume (horizontal green line). Every vessel shares the same scale.

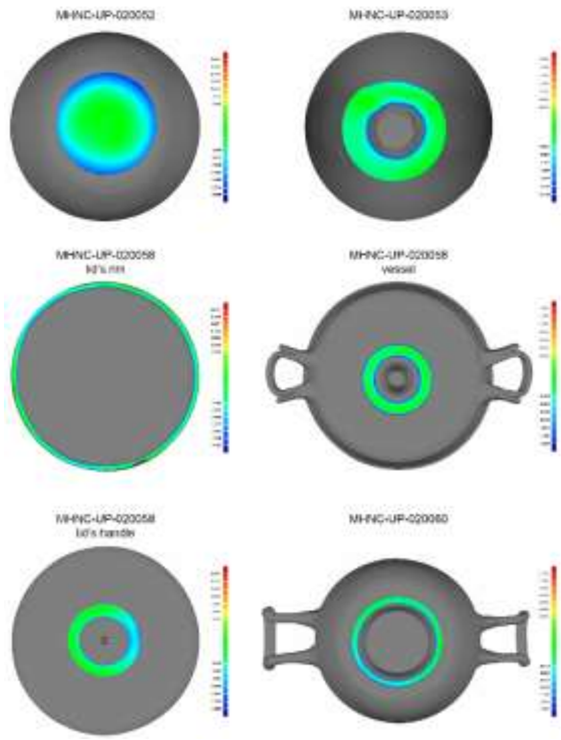

__Figure 3:__ Colour map showing the contact surface between the bases of the vessels and a horizontal plane (bottom views): a) MHNC-UP-020052; b) MHNC-UP-020053; c) MHNC-UP-020058, vessel; d) MHNC-UP-020058, lid's rim; e) MHNC-UP-020058, lid's flat knob handle (i.e., lid working as a container); f) MHNC-UP-020060. Contact (green), far (light blue), and farthest (dark blue) surface areas. The horizontal plane is set as invisible for higher readability of the colour map.

3.1 CORINTHIAN GLOBULAR *ARYBALLOS* (MHNC-UP-020052)

The *aryballoi* were typically produced to contain perfume or oil, for athletes at the baths. The MHNC-UP-020052 has a globular wall decorated with three warriors (or hoplites) to right, with spears, helmets, and round shields (Fig. 4). Tongues on the upper part near the handle; dotted line on the rim. Short handle runs from the rim to the shoulder, externally decorated with a zigzag motif.

__Figure 4:__ Corinthian globular aryballos (MHNC-UP-020052).

The CT imaging of this vessel makes visible significant technological and functional features, besides revealing hidden details – the most significant of which is shown in Figure 5. Wheel-throwing was confirmed as the primary forming technique by: (a-d) the spiral pattern of ridges and grooves up and around the walls, formed as the potter's fingers pulled the clay on the wheel; (a, e-f) the oblique orientation of elongated inclusions and voids in the clay paste/matrix (characteristic of pulling the clay on a fast wheel), and the orientation of inclusions and voids parallel to the walls. The cavity (c) almost reaches the outer surface of the vessel, making this area particularly fragile, which is a concern for conservators. The protuberance at the centre of the inner surface of the vessel's base was rather unexpected, giving rise to some hypotheses, e.g., to serve as a structural function by strengthening the thin base of the vessel or by making the *aryballos* more stable; help consolidate sediment deposits at the bottom of the container in order to prevent sediment mixing into the perfume/oil when poured; make the container easier to clean prior, by facilitating the removal of sediments; decrease its capacity (with possible trade implications). Or was it simply formed as the potter's fingers pulled the clay on the wheel, "with the two elongated hollows representing the impressions of fingers”, thus suggesting a “hasty and/or inexpert execution” [26]?

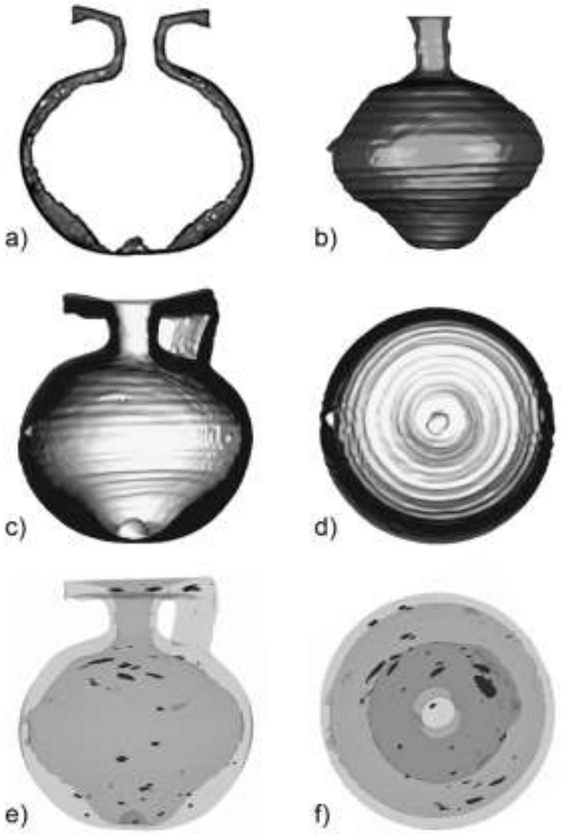

Figure 5: CT scan of MHNC-UP-020052. a) Frontal tomographic negative image from the original vessel; b) filling volume; c, d) lateral and horizontal sections from the generated 3D digital model; e, f) lateral and top views (with transparency) from the generated 3D digital model, exhibiting voids in dark grey. External and internal structures and features: examples of spiral ridges and grooves, voids, cavity, protuberance.

3.2 ATTIC BLACK-FIGURE SHOULDER LEKYTHOS, GROUP OF VATICAN G 52 (MHNC-UP-020053)

Shoulder *lekythoi* were usually designed to hold oil or perfume. The MHNC-UP-020053 has a curved wall with a naked young man running to the left, flanked by two young men standing, dressed in a himation; the one on the right holds a spear (Fig. 6). A piece of clothing hangs on the wall next to the young man on the left. On the shoulder, a three-leaved plant element, flanked by four ornamental dots; an ivy leaf on each side. Added red on the hair, on the pieces of clothing hanging from the hands of the young men, on the lower part of the scene and on the neck. The rim, the handle, the lower part of the wall and the base of the vase are in black. Small semi-circular handle that runs from the neck to the shoulder.

***Figure 6:** Attic black-figure shoulder lekythos, Group of Vatican G 52 (MHNC-UP-020053).*

3.3 APULIAN RED-FIGURE *LEKANIS*, CIRCLE OF THE PATERA PAINTER AND THE BALTIMORE PAINTER (MHNC-UP-020058)

Originally, a *lekanis* could have had a wide variety of utilitarian and symbolic functions, such as being a container for cosmetics or small items of adornment, or being offered as a dowry or grave goods. It consists of two parts: a low vessel with two handles (arranged horizontally and upright that run from the lower part of the vessel) and one foot, and a lid with a flat knob handle. Both parts of this Apulian red-figure *lekanis* have survived. The MHNC-UP-020058 has two handles, a stem and a foot, and its lid has a stem and a flat knob handle (Fig. 7). This *lekanis* has a curved wall, with the lid decorated on one of its sides with an effeminate winged Eros sitting naked on a rock with outstretched legs, holding a phiale with fruits in his right hand. On the other side, a female figure sitting on rocks with a sakkos, dressed in a peplos and a himation that rests on her left shoulder and holding a phiale with fruits in her right hand. Flanking both scenes, palmettes motifs and beneath the handles laurel leaves and rays; wave motifs on the rim and radial motifs on the lid handle. Added white on the fruit and on the rock.

When turned over, the lid can also act as a container, i.e. a secondary function. As expected, the maximum volume of the vessel is larger than that of the lid (Table 1). Interestingly, the vessel and the lid have different densities, which may suggest that different types of clays were used, or were prepared in a different manner, or that the material is non-homogeneous (e.g. natural or intentional admixture of distinct types, amount, volume, and distribution of mineral/organic matrix, or inclusions, to improve the structure of the fabric), or it may just indicate the presence of voids – further archaeometric techniques would be needed to characterise their fabric and perhaps infer their provenance. The wall thickness of the vessel and the lid increases consistently from top to bottom (Fig. 8), demonstrating the potter's skills on the wheel (i.e. wheel-throwing as the primary forming technique). Curvature analysis was set to ±0.4 and revealed that the finishing texture (fine-grained fabric) of the inner surface of the vessel is different to that of the lid. The inner surface, more likely exposed to people's gaze, displays a smoother surface and the lid shows a light rough pattern (Fig. 9). This parameter is relevant as it may help to confirm the primary intentional uses of each part of this specific vessel.

Figure 7: *Apulian red-figure lekanis, Circle of the Patera Painter and the Baltimore Painter (MHNC-UP-020058).*

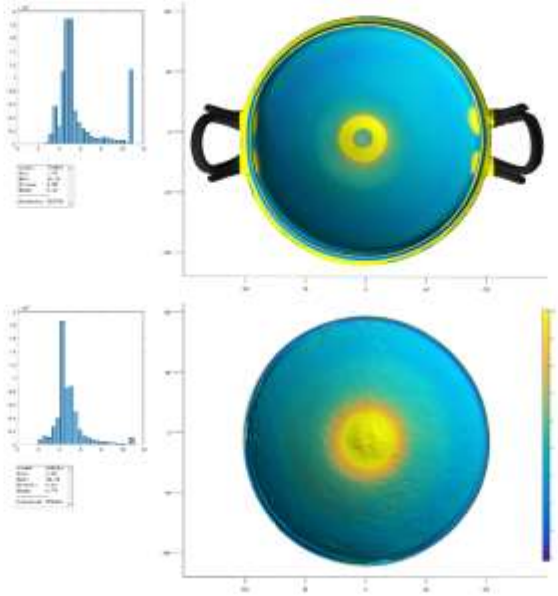

Figure 8: *MHNC-UP-020058: top view of the vessel (top) and bottom view of the lid (bottom). Colour map showing a detail of the variability of the wall thickness of the body – from blue (thin) to yellow (thick), corresponding to low to high values of the thickness; grey tone indicates unselected areas. Automatic quantitative and qualitative data of the wall thickness: the joining of the handles and stem to the body of the vessel and the lid are indicated in yellow.*

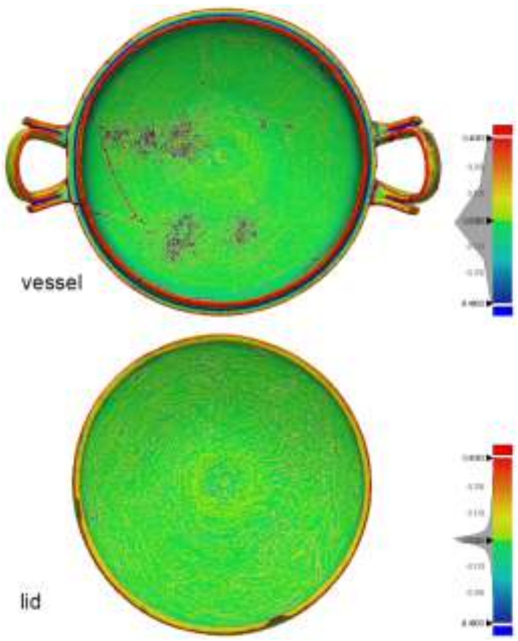

Figure 9: *MHNC-UP-020058: top view of the vessel (top) and bottom view of the lid (bottom). Curvature analysis of the inner surfaces: lines revealing previously fragmented areas; rough pattern suggesting anthropic use-wear (possibly worn), although one should not discard natural wear. The colour map is from red (convex) to blue (concave), corresponding to high to low values of the curvedness, whereas green colour indicates planar patches.*

3.4 GNATHIAN CUP-*SKYPHOS*, (MOREL, SHAPE F-4242) LAUREL SPRAY GROUP (MHNC-UP-020060)

Typically, Gnathian cups were small drinking cups. The MHNC-UP-020060 consists of a small hemispherical vessel with two handles and a foot (Fig. 10). It has a curved wall decorated with two bands outlined by two concentric lines beneath the rim. The first line is decorated with an egg pattern and the second one with red bands flanked by two yellow ones. The body is decorated with grape bunches between three vertical ivy branches, all in added white. On the other side, double line, above and below, with ivy leaves. There is a reserved space between the cup and the foot. Upright handles that run from the mid-wall.

Figure 10: *Gnathian cup-skyphos, (Morel, Shape F-4242) Laurel Spray Group (MHNC-UP-020060).*

Once again, the wall thickness of the body increases consistently from top to bottom (Fig. 11), revealing the potter's skills on the wheel. It is also possible to detect underdrawing traces from the use of a pointed tool, such as a cane or a stiletto.

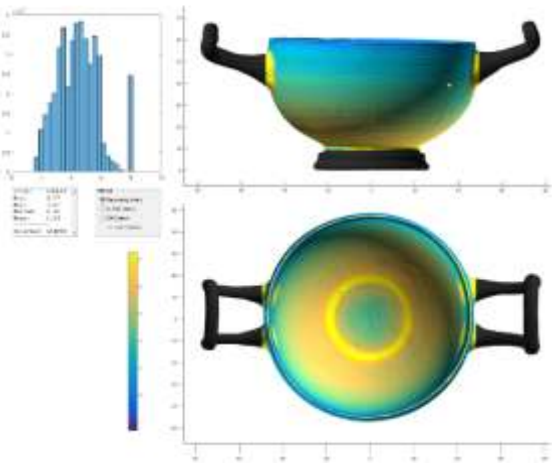

Figure 11: *MHNC-UP-020060: front (top) and top (bottom) views. Colour map showing the variability of the thickness of the body of the vessel – from blue (thin) to yellow (thick), corresponding to low to high values of the thickness; grey tone indicates unselected areas. Some underdrawing traces are visible; the joining of the handles and foot to the body of the vessel is indicated in yellow.*

4. CONCLUSION

This article has briefly highlighted that using 3D imaging and computational methods in archaeological and conservation studies can contribute to a better comprehension of ancient pottery. Moreover, the non-contact and non-destructive nature of the approach, from structured light and computed tomography scans to digital data analysis, renders it of particular value in cultural heritage best practice. Although the SL-derived 3D digital surface models were not produced to the highest possible quality of the system, the accuracy, resolution, and precision of the measurements were high enough to fulfil the aims of this work. The CT imaging of one of the vessels enabled the documentation of its inner structure and morphology, and the visualisation of significant technological and functional features, as well as revealing hidden details. A preliminary characterisation and analysis of four vessels was presented, making the most of a small set of analytical tools. Different methods and techniques have been used to compute and analyse distinct and representative features of 3D digital models of archaeological objects as well as to generate scientific illustrations. Three-dimensional data produced stimulating results as they enabled the extraction of meaningful morphological, technological and functional information from distinct archaeological artefacts. Although the results presented are preliminary, they contribute to the current body of knowledge in pottery studies. Another thing that makes ancient pottery special is that vessel shapes show great typological and morphological variety over time and space. However, we are well aware that quantifying and interpreting chronological or geographical (dis)continuities of such features would undoubtedly require a much larger dataset.

In short, digital imaging and computational methods and techniques enabled to document, measure, analyse and visualise features beyond the limits of conventional tools. Even though a 3D digital model does not provide a complete representation of the object, it should be understood as a powerful tool, potentially with valid data, for cultural heritage research and conservation that complements other analytical techniques and fields of knowledge [8][27].

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