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The ceramic finds from Guadalupe, Honduras: optimizing archaeological documentation with a combination of digital and analog techniques

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ABSTRACT

The ceramic finds from Guadalupe, Honduras:

Optimizing archaeological documentation with a combination of digital and analog techniques

Franziska Fecher, Markus Reindel, Peter Fux , Brigitte Gubler, Hubert Mara, Paul Bayer, Mike Lyons

Archaeological projects are often faced with processing unwieldy amounts of ceramic material on-site. This documentation and analysis has traditionally required hand drawing of diagnostic sherds and vessels, which is extremely time-consuming, especially when faced with complex forms. The Guadalupe Archaeological Project operates in northeast Honduras with the aim of characterizing the local culture of the Cocal period (AD 1000–1525). During investigations, the project systematically compared the benefits of traditional hand drawing techniques with more modern approaches, such as 3D modelling and 3D data processing, in order to develop an effective workflow for on-site documentation. Using a combination of structured light scanning, traditional drawing, and the automated generation of profile drawings in the 3D software GigaMesh, we were able to streamline our work by applying the appropriate technique on a case by case basis.

KEYWORDS

Central America, Honduras, Postclassic period, ceramic drawing, structured light scanner, 3D modelling, Digital Archaeology

FRANZISKA FECHER, MARKUS REINDEL, PETER FUX, BRIGITTE GUBLER, HUBERT MARA, PAUL BAYER, MIKE LYONS

The ceramic finds from Guadalupe, Honduras

Optimizing archaeological documentation with a combination of digital and analog techniques

1 Introduction

1 Archaeological investigations in remote inaccessible regions with poor technical infrastructure often pose a challenge for project organization and logistics. While many of these challenges have to be solved during surveys, excavations and restorations, the documentation of archaeological finds has its own specific conditions and limitations. The detailed documentation and analysis of various materials is very time-consuming. In most archaeological projects and according to the modern cultural heritage regulations of the countries where the projects are carried out, archaeological finds may not be exported in large quantities. Therefore, the analysis must be performed near to where they were found. Due to the often great distances between the studied regions and a researcher's home country, travel expenses and the cost of transport and accommodations abroad are high. As the detailed documentation and analysis of archaeological finds is a bottleneck in most archaeological projects, solutions to this problem have been sought for many years with the goal of finding methods for faster processing of archaeological material on site or at least carrying out the most important steps of the documentation process near the research region. One of the solutions is digital 3D documentation of the objects on site, while the other steps of the archaeological analysis can be carried out off site.

2 The Guadalupe Archaeological Project operates in northeast Honduras (Fig. 1) and is, in many respects, a typical example of such an archaeological research project in which the processing of large quantities of finds is a challenge that had to be solved as part of the archaeological work. The discovery of well-stratified layers of a myriad of diagnostic ceramic fragments allowed archaeologists to investigate a little-known pottery phase of northeast Honduras with a single pottery collection, thus closing an important gap in the poorly understood prehistory of the region. It was, however, necessary to develop an effective workflow for the documentation and analysis of the fragments on site, as the laws of the Honduran government do not allow the export of materials to other countries in large quantities.

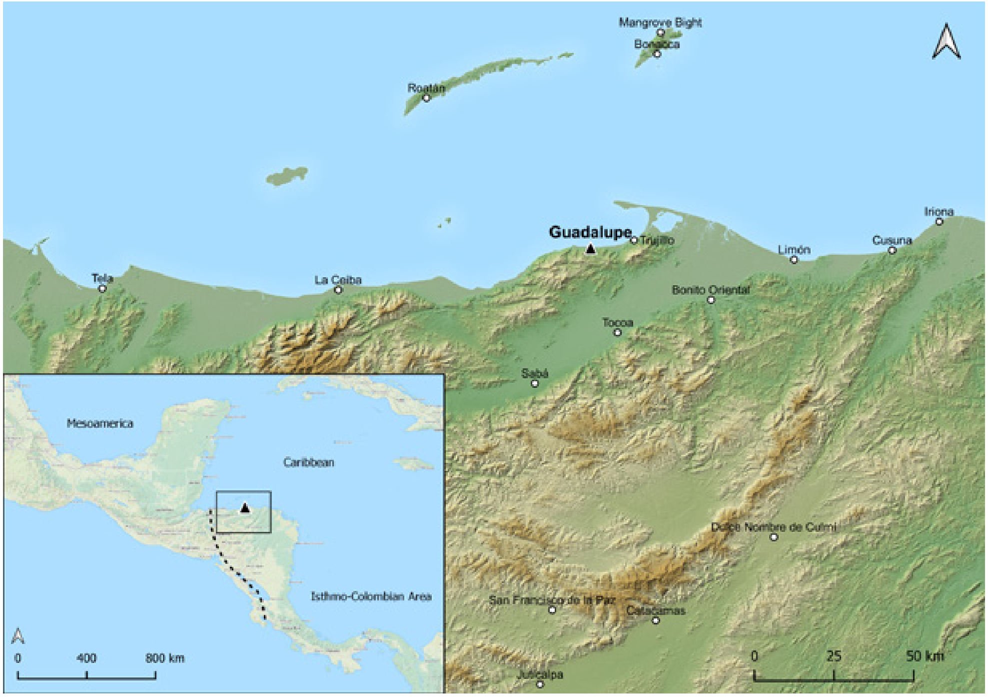

Fig. 1: Map of northeast Honduras with the location of Guadalupe. The dotted line on the inset map indicates the border between the culture areas of Mesoamerica and the Isthmo-Colombian Area

3 As part of the Central American Isthmus, Honduras adopted a special role in pre-Hispanic America. The territory of modern Honduras functioned as an interaction zone between the culture areas of Mesoamerica and the Isthmo-Colombian Area. In spite of this unique situation, archaeological investigations in Honduras have been focusing on the western Mesoamerican part, especially on the Maya city of Copan. In contrast, little is known about cultural developments in the eastern part of the country. Although some projects (see below) have provided important information on pre-Hispanic developments in the region, many fundamental questions remain unanswered.

4 In order to contribute to the understanding of local cultural developments and external connections of the region, archaeological investigations have been carried out in Guadalupe, northeast Honduras, since 2016. Excavations have yielded an extensive number of ceramics that are suited to improve the existing typochronology. Yet the documentation of the ceramics as the basis for establishing a chronology is complex and time-consuming. In this paper, we compare different techniques in order to find the best method for documenting and studying a partly unknown and extensive ceramic assemblage. We present traditional hand drawing methods as well as digital methods, such as 3D scanning and structure from motion. Comparing the methods in terms of precision, speed and effort led to a newly developed workflow presented in this article.

2 The Guadalupe Archaeological Project

5 If we look at a map of Honduras in which regions that have experienced intensive archaeological work are marked (Fig. 2), two things stand out: 1) A large part of the country has not yet been investigated and 2) these uninvestigated regions are concentrated in central and eastern Honduras. This situation has different causes. Concerning the first point, Honduras is, in archaeological terms, one of the least investigated countries of Central America. Until the mid-20th century, research has mostly been carried out by foreigners, a situation that changed with the foundation of the Honduran Institute of Anthropology and History (IHAH) in 1952. Even so, national archaeology in Honduras is lacking compared to other countries. Aside from the Maya city of Copan, which has been a research focus since the mid-19th century, only two archaeologists, Oscar Neill Cruz, head of the IHAH archaeology department, and his colleague Ranferi

Juárez, manage archaeological investigation. An anthropology study program was only introduced in 2013. Monument protection, preservation and the corresponding infrastructure are not well established. As a result, public awareness of archaeological remains is weakly formed and the notion that the Classic Maya culture is the nation's only cultural ancestor is widespread among the public despite the fact that archaeologists have long shown that the Maya only settled in a small part of what is today western Honduras.

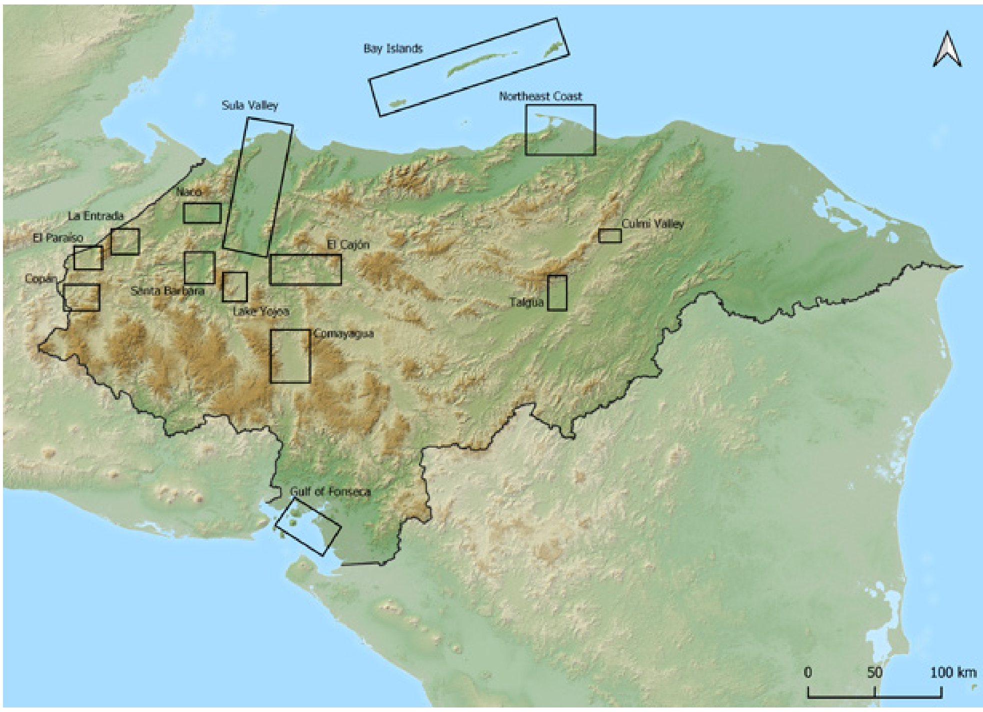

Fig. 2: Map of Honduras. Areas where major archaeological projects have been carried out are marked

6 This leads us to the second point, which is rooted in the history of archaeological research. The western part of Honduras belongs to Mesoamerica, a culture area that has been defined by its development of complex civilizations. The eastern part of the country in contrast belongs to the Isthmo-Colombian area where, for a long time, cultures have been seen as inferior as they are presumed not to have reached a level of state organization (Sheets 1992). This view has led to the concentration of research efforts in western Honduras. However, even though research in eastern Honduras has been limited, several projects have contributed valuable information to the understanding of pre-Hispanic cultural developments.

7 Until the mid-20th century, eastern Honduras was mainly investigated by means of short-term expeditions often motivated by museums. Few publications exist from this time. Notable exceptions include the detailed monographs by William D. Strong (Strong 1935) and Doris Stone (Stone 1941). While these early scholars didn't have a precise notion about the depth of the cultural remains they were studying, the first chronology was developed in 1957 by Jeremiah Epstein (Epstein 1957). He defined the Selin (AD 300–1000) and Cocal (AD 1000–1525) phases. The first long-term project carried out in northeast Honduras was directed by Paul Healy in the 1970s (Healy 1974, Healy 1978a, Healy 1978b, Healy 1984). He was able to expand and refine the existing chronology with his discovery of formative vessels in the Cuyamel caves, adding the Cuyamel phase (1350–400 BC) to the known chronology. The typology was again revised by Carrie Dennett based on material excavated in the Cocal-phase settlement of Rio Claro (Dennett 2007). The IHAH's efforts were directed towards studying the prehistory of the Islas de la Bahía, Olancho and the north coast (e.g. Hasemann 1977; Véliz – Willey – Healy 1977). Another key project was conducted by Christopher Begley

(Begley 1999), who created an extensive data set for the Olancho region by registering and studying sites in the Culmi Valley. Recent discoveries in the Mosquitia revived interest in the archaeology of northeast Honduras (Fisher et al. 2016). However, there are still many fundamental questions about pre-Colonial cultural development that remain unanswered.

8 Cave finds from Cuyamel and Talgua still represent the only indications of settlement in early periods. There is a gap of 700 years (between 400 BC and AD 300) where literally nothing is known about human occupation in eastern Honduras. Information on burial customs, subsistence, settlement functions, architecture, etc. is limited and we are just starting to understand local cultural processes. Another fundamental question concerns the position that northeast Honduras had as a region within the spheres of influence of Mesoamerica, the Isthmo-Colombian Culture Area, and the Caribbean. To what extent did inhabitants of northeast Honduras interact with groups from neighboring regions and what did these interactions consist of? In order to answer these questions, basic research is needed to improve upon our current base of understanding.

9 Beginning in 2016, the Guadalupe Archaeological Project has been addressing these questions through excavations and surveys on the northeast coast of Honduras (Reindel – Fecher 2017; Reindel – Fux – Fecher 2018). The focus of the investigation is the Cocal-phase settlement of Guadalupe. The project is jointly financed by the German Archaeological Institute and the Swiss-Liechtenstein Foundation for Archaeological Research Abroad, and operates in cooperation with the University of Zurich, Museum Rietberg Zurich, the Honduran Institute for Anthropology and History, and the Universidad Autónoma de Honduras[1]. The aim of the project is to characterize the local culture during the Cocal period by investigating the settlement and its surroundings, including studies on settlement function, subsistence and material culture. On this basis, supraregional issues such as adaptation to coastal systems and integration into long distance exchange are to be clarified.

10 The modern village of Guadalupe is located on the northeast coast of Honduras about 15 km west of Trujillo. It is one of several clearly visible, yet unstudied sites found along the narrow coastline, which is limited by a chain of mountains to the south. Behind this mountain chain, the fertile Aguan Valley, used today intensively by the palm oil industry, extends from west to east where it widens to become the Mosquitia. The archaeological remains of Guadalupe are largely overbuilt by modern

Fig. 3: Mound in the backyard of the primary school of Guadalupe

1 Additional funding was provided by the UZH Alumni (Fonds zur Förderung des akademischen Nachwuchses).

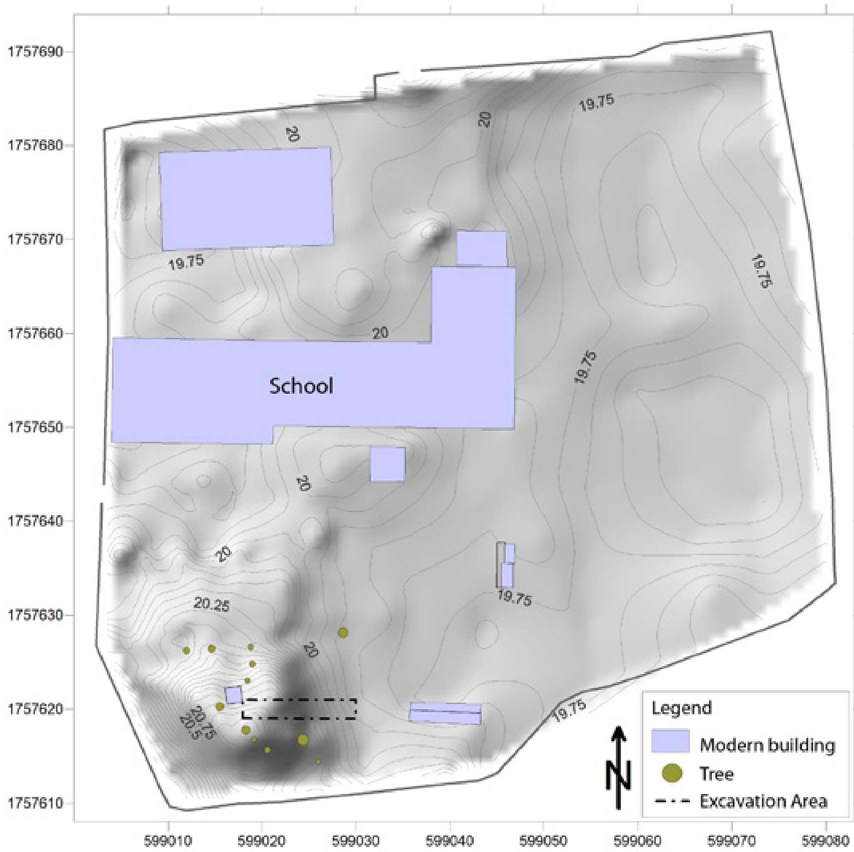

Fig. 4: Topographic map of the school area

constructions, but ceramic concentrations on the surface and dark humic earth are evidence of pre-Hispanic human activity. The best preserved architectural remains are located in the backyard of the local primary school (Fig. 3, Fig. 4). The earthen mound is 1 m high and has a diameter of 20 m. In order to clarify the stratigraphic sequence and the function of the mound, a 2 m x 12 m trench was excavated from the center of the mound to its periphery (Fig. 5).

11 Radiocarbon dates show an occupation ranging from at least AD 1000 until the arrival of the Spaniards at the beginning of the 16th century. Several occupational layers date to the Early Cocal phase (AD 1000–1400) as is evidenced by post holes, clay floors, pits and fireplaces. Imprints on clay fragments (bajareque) clearly indicate that reed was used for the construction of buildings using a wattle and daub technique.

Fig. 5: Excavations in 2018

12 At a later point, the location was used as a burial ground. Several burials were found in the periphery of the mound (Fig. 6). Stratigraphically associated with the burials is an approximately 1 m thick accumulation of pottery sherds mixed with animal bones, stone implements, obsidian blades and prestige objects, such as jade beads and metal items (Fig. 7). The presence of ocarinas and ladle censers indicate ritual activities (Fig. 8). The nature of the ceramic sherds, which are broken into large fragments and lie in conjunction with one another, suggest an intentional deposit. It is very likely that these accumulations of objects are the remains of ritual activities and feasts that were associated with the burials.

13 Descriptions of such feasts can be found in ethnohistoric reports of the Paya, who were most likely to have inhabited portions of northeast Honduras before the Spanish arrival. Conzemius (Conzemius 1927) writes that in the event of a death, it was common to hold celebratory feasts three, nine and thirty days after the passing, while the main feast was celebrated one year later. The author describes these feasts as

Fig. 6: SfM 3D model of one of the burials found in 2019

Fig. 7: Ceramic concentration

Fig. 8: Ocarinas excavated in Guadalupe

boisterous events during which a lot of food and drinks, mainly the fermented maize beer chicha, were consumed. While evidence of ritual feasting has also been found in nearby settlements, a very similar situation, namely the association of broken pottery with burials, is reported from the highlands of Costa Rica (Hoopes – Chenault 1994).

14 Aside from these valuable insights into local cultural practices, the finds contribute to our understanding of external relationships. Obsidian, jade and metal finds are particularly well-suited for this purpose. Half of the obsidian fragments found in Guadalupe (n = 355) were analyzed under the direction of Geoffrey Braswell (Stroth et al. 2019) and were able to be assigned to geological sources. Obsidian was imported from Güinope (63%) and La Esperanza (34.5%) in Honduras, and Ixtepeque (2.5%) in Guatemala. A technological study by Luke Stroth (Stroth 2018) showed that obsidian blades were produced in Guadalupe from Güinope polyhedral cores, whereas finished blades reached Guadalupe from Ixtepeque and La Esperanza, indicating that Guadalupe was integrated into a far-reaching exchange network. It is likely that the obsidian from Ixtepeque reached Guadalupe via maritime trade, which was firmly established in neighboring Mesoamerica during the Postclassic period (AD 1000–1525). It was probably the same route over which jade found its way to Guadalupe. The analysis of eight specimens under the direction of Ulrich Glasmacher (University of Heidelberg, Germany) showed that all of the greenstone objects found in Guadalupe are jade (Fig. 9). The closest and as of yet only known jade source in Central America is located in the Motagua Valley in Guatemala, thus it is very likely that the jade was imported from there. Metal objects, including two copper bells and a tin-bronze needle, indicate connections to Mesoamerica where bells were highly praised exchange items during the Postclassic (Fig. 10).

Fig. 9: Jade objects from Guadalupe

15 Although preliminary interpretations of Guadalupe's finds suggest long distance exchange relationships, the limited number of imported specimens also indicates that the inhabitants of Guadalupe were involved in more of a sporadic exchange. In

Fig. 10: Photography and SLS 3D model of a copper bell

contrast, close ties with the inhabitants of the Aguan Valley in the south and the Islas de la Bahia to the north must have existed. Material culture in these regions share a great number of similarities. Ceramics are especially similar in their formal and decorative execution. They are almost exclusively decorated with incisions and appliqués with very few examples of painted pieces. Forms consist of tripod dishes, hemispherical and composite silhouette bowls, as well as large jars and vases. Handles and hollow supports executed in animal or human motives are typical. The amount and quality of the ceramics found in Guadalupe allows us to improve upon and complement the existing typology.

16 The archaeological evidence recovered from the Guadalupe site to date, in particular the results of analyses of various classes of artifacts, have shown that the research region has important potential for improving our understanding of the cultural history of northeast Honduras. The analyses of representative materials illustrate the extensive economic and cultural contacts of the Guadalupe region in all directions. The obsidian, jade and metal objects showed that materials from important raw material sources were used in southern Honduras, Guatemala and probably even Mexico. Based on specifically selected diagnostic pottery finds, it could be shown that Guadalupe was part of a wider cultural region in northeast Honduras that extended up to 150 km inland to the south, at least to the Islas de la Bahía to the north and to the Mosquitia to the east.

17 On the other hand, the investigations carried out so far have shown how limited our knowledge of the ceramic phases characterizing the excavated settlement layers of Guadalupe is, namely the Cocal phase and the preceding Selin phase. In order to get a more detailed picture of the pottery inventory and to better understand the cultural history of northeast Honduras, it is necessary to examine the respective pottery finds in more detail. The numerous pottery artifacts recovered from the Guadalupe settlement form an ideal material basis for achieving this goal. With the ceramic artifacts from a single excavation site, we will be able to document a large portion of the spectrum of forms and decoration types of the Cocal phase as well as at least part of the preceding transition phase between the Selin and Cocal phases. This great potential justifies the intensive and detailed documentation and analysis of the Guadalupe pottery finds.

18 Painted decoration on Guadalupe ceramic material is very rare, while figurative applications or complex incised decorations dominate the decorative elements. Thus, the documentation of such decorative forms by hand drawing is very time-consuming, but important for a thorough analysis of the objects, as they have a high diagnostic value. Since the objects may not be exported, expensive long-term campaigns in Honduras would be necessary solely for the documentation of the archaeological material. In the context of the investigations, repeated checks of the material are necessary for a complete and detailed documentation. This translates to a considerable logistical effort.

19 In view of these logistical and financial challenges in combination with the scientific significance of the artifacts, the members of the Guadalupe project discussed several strategies to achieve a faster and more economic methodology for the processing

of the ceramic material. While Franziska Fecher, Markus Reindel, Peter Fux and Mike Lyons were in charge of the excavation and the processing of the archaeological finds, specialists in manual scientific drawing techniques and specialists in digital 3D documentation were invited to develop optimized documentation methods. Brigitte Gubler, a professional scientific illustrator specialized in archaeological drawing and lecturer at the Lucerne School of Art and Design, tested the documentation of various types of ceramic objects by hand drawing. Hubert Mara, computer scientist at the Interdisciplinary Center for Scientific Computing (IWR) at the University of Heidelberg is a specialist for 3D documentation and surface analysis of archaeological objects. Together with his assistant Paul Bayer from the University of Graz and with the support of Laura Edvesi from the Digitization Center of the University Library of Heidelberg, Hubert Mara developed a workflow for the documentation of ceramic objects using structured light scanners. The details of both methods and the discussion of the advantages and disadvantages of each are presented in the following sections.

3 Documentation of Guadalupe's ceramic material

20 The first subsection provides a detailed description of the hand drawing process. In the next subsection, a set of objects that were documented digitally is described. Finally, a comparison of the two methods is presented and their pros and cons are discussed.

3.1 Hand drawing

21 Drawings of archaeological finds are a fundamental tool and a point of reference for comparative archaeological analysis and interpretation. They are an integral part of the recording procedure and complement photographic images and written descriptions. In order to ensure comparison between archaeological finds with the help of drawings, it is necessary to produce true-to-scale drawings following the same standards. Therefore, various basic principles and rules, which are internationally valid, have been established for the graphic documentation of archaeological finds (Hodges 2003: 466). This same approach facilitates research by identifying and comparing similar finds.

22 The main feature of archaeological drawings is the orthogonal projection, i.e., a find is projected at right angles to a coordinate plane, similar to the principle of a technical construction drawing, often with several views. Generally, finds are drawn at a scale of 1:1. Thus, all the measurements can be clearly read from the drawing; the true scale of the object is guaranteed. The drawing of the archaeological find unites all measurable, visible and reconstructable information about the object. Thus, exterior and interior views, profile view, three-dimensionality, surface structure, decoration, cross-sections, completions, etc. can be combined in a single drawing.

23 A further characteristic of archaeological as well as scientific illustration in general is the principle of correct illumination. In guidelines for drawing archaeological finds, it is often mentioned that the light source should come from the upper left in order to present all objects coherently and uniformly in the same lighting. The decisive reason for lighting from the upper left however is the illusionistic three-dimensional appearance. When looking at pictures, we are used to interpreting the three-dimensionality (i.e. volume and surface texture) correctly when the source of light comes from the upper left at an angle of about 45° to the object. A well-known example for three-dimensional perception is the representation of the relief on maps. On satellite images, it's often difficult to read the three-dimensionality correctly if there is no corresponding cast shadow. This means that when drawing archaeological finds, the source of light is directed – either actually observed or perceived in the illustrator's mind – in a way that

the light and, above all, the shadow areas best support the three-dimensional form of the object and its decorations. Additional indirect light sources in the form of reflectors, such as white paper, which for example emphasize a light edge within the shadow area, increase the effect of plasticity. Knowing how light molds form and using direct and indirect light sources such as reflectors, details can be individually processed to achieve the best possible plasticity and legibility.

24 The creation of archaeological find drawings requires an exact observation of the object (form, volume, material, surface, decoration and positioning), an understanding of the function and an accurate, aesthetically appealing graphic reproduction using lines and tonal values. The drawing is clear and unmistakable. Diagnostic potsherds, such as rim, wall and base sherds, as well as entire vessels, are represented or reconstructed according to the following rules.

25 Positioning of rim sherds: The rim sherd must be oriented in order to define the stance in the original, unbroken vessel. To do this, it is held vertically, resting upside down on the rim edge and rocked back and forth against a flat surface until the entire rim rests firmly and evenly. It will "lock" into place in its correct original orientation.

26 Diameter: The rim sherd is now kept in this inclination and moved on a radius table until the curve of the rim matches the curve of one of the concentric circles. This measurement, radius or diameter, as well as the outer contour of the rim sherd in the correct inclination are then transferred to the sheet. This includes a horizontal line with the diameter, which thus indicates the extent of the vessel opening and provides a vertical central axis, and the outer contours to the left and right of it at the corresponding points of the measured radius.

27 Profile, exterior and interior view: In the profile view, the vessel is cut by drawing, indicating the shape and thickness of the wall. The interior view shows the appearance of the inside of the vessel, while the exterior view shows surface, volume and decoration and thus the characteristics of the vessel, which again is important for typology (Fig. 11). Within these general conventions for the representation of ceramics there are variations, different schools or standards. There is for example a difference between Europe and America/Latin America/Asia concerning the position of the exterior and profile view. American convention has the exterior view on the left, whereas European publications require it on the right side of the central axis. Putting the exterior view on the right side has the advantage that the object shadow, which is on the right side of the object, is giving it volume and extension. In consequence, the shaded part increases the effect of plasticity. The exterior view being placed on the left side, however, shows only the illuminated surface, without the possibility to support three-dimensionality with the help of the shadow.

28 Decoration: Decorated sherds are placed in the center in order to minimize the perspective distortion of the motifs. Decoration, such as incisions, grooves, painting, etc. or appliques, such as handles and knobs, are also drawn three-dimensionally so that concave or convex elements are clearly intelligible.

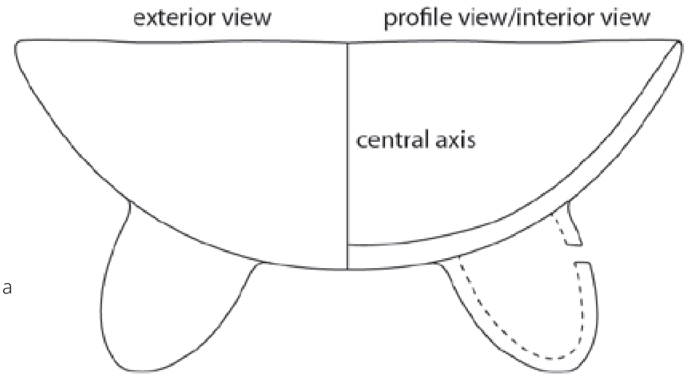

Fig. 11: Schematic drawing of a vessel

29 Cross sections: Cross sections are given as additional information at selected, significant places.

30 Completion: Missing parts, which can be determined with certainty, or hypothetical parts, which add to the comprehension of the object, are drawn so that they are graphically clearly distinguishable from the existing archaeological find.

31 The following material and instruments are useful for measurement and the technical process of drawing: radius table for determination of the vessel diameter, a sliding caliper for the exact measurement of objects and wall thickness, a profile comb for duplicating shapes of pots, mm-paper as a measuring aid and a grid for orthogonal drawing, triangles as a measuring aid and for supporting the principle of the right angle, and a glass plate in order to transfer an object at right angles to the drawing surface.

32 The ceramic finds of Guadalupe have been drawn with the exterior view on the left and the profile view on the right. Since these vessels have generally been made using the coiling technique, each of them an individual vessel, the volume, surface structure and decoration are drawn with tonal value on the preliminary pencil drawing (Fig. 12). This drawing, completed with all necessary information about the object, will be the basis for the final rendering. For that matter it is important to know in which scale the drawings will be published. For space reasons, the drawings are reduced, ceramics often at a scale of 1:3. While realizing the final rendering, the illustrator therefore consciously has to reduce and abstract so that the main characteristics of the objects can quickly be captured (Fig. 13).

33 Due to printing technology, most drawings of ceramics are rendered in black and white with the stippling technique. This way of rendering has proven itself in archaeological publications and is still used today. By using more or less dense, regular or irregular dots, detailed tonal values can be obtained, which in turn describe the objects in detail. These final drawings can be executed traditionally with ink or digitally in a graphic program. Ink drawings are then scanned and digitally processed until ready for printing.

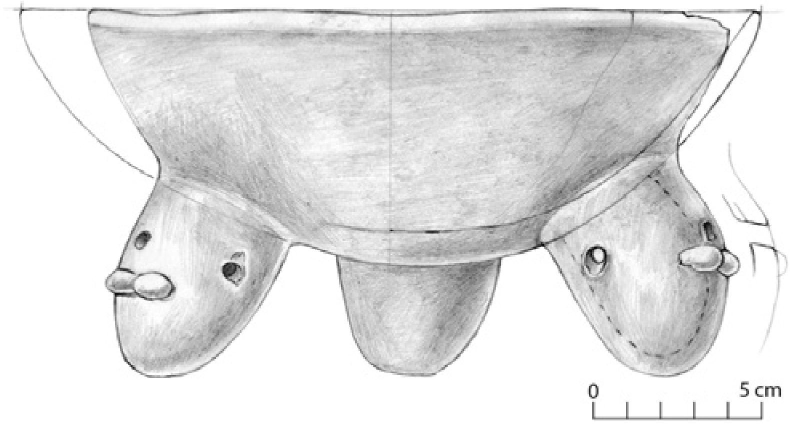

Fig. 12: Pencil drawing of a vessel (PAG-29-100), scale 1:3

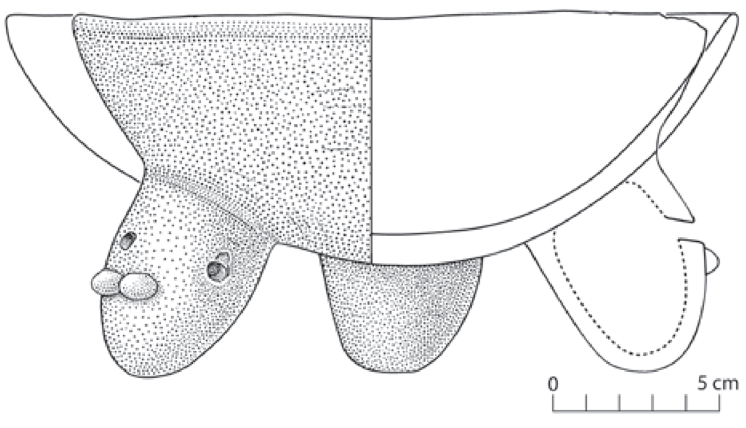

Fig. 13: Ink drawing of a vessel (PAG-29-100), scale 1:3

34 The creation of an archaeological find drawing is not a snapshot, but a process in which the object is touched, rotated and examined. By thoroughly observing shape, surface and details, such as traces of processing, relevant knowledge is gained, which is incorporated in the drawing as well as into the find description. Drawing therefore is also a method of research, or a research instrument. The illustrator's interpretation is decisive: they can accentuate what is important or omit what is not relevant. Good, sharpened illustrations eliminate confusing elements and on the other hand highlight diagnostic features. This way they fulfil the task of scientific documentation, i.e., to consciously and conceptually clarify all the characteristics and pertinent information of the find.

35 Archaeological drawings are adapted for a reduced print by the sum of the abstraction steps. On a table of finds, each single find is clearly discernible due to its individual peculiarities – even in a reduced form – and can be quickly compared with the others. The preliminary pencil drawing as a basis requires only a few technical accessories. Computers, scanners and drawing programs are only used for the processing of the ready-to-print template. However, several work steps are necessary from the preliminary pencil drawing to the final rendering to the digital processing. This is very time-consuming. The more complex the finds, the more difficult for the illustrator. To be able to realize a high-quality drawing of a complex find, the illustrator must have significant experience.

3.2 Digital documentation techniques

36 The vast amount of pottery found during the excavations in Guadalupe and the overwhelming task of its manual documentation led to the decision to find more effective digital means for documentation in light of the recent advances in computational archaeology. Therefore 3D acquisition techniques and software packages for processing 3D data were tested during the field campaign. To capture objects in situ, the relevant techniques are Structure from Motion (SfM) and Structured Light Scanning (SLS). SfM was briefly tested and found not to be suitable for mass-acquisition for several reasons: 1) the time required from taking the images to having a 3D-model is far too long, which means that acquisition errors are only able to be detected with a tremendous amount of time – in the worst case, after the end of the excavation when the objects are no longer accessible – and 2) image acquisition requires significant skill and experience, which strongly influence the quality of the 3D data. In contrast, SLS immediately provides a partial 3D model after a single scan. So any arising problem, e.g., unintentional changes to the setup, overlooked components of the surface and any other handling error of the 3D scanner, can be fixed on the fly. Additionally, representations of 3D models in the catalog are linked to the corresponding 3D model in the object database iDAI.objects / Arachne (https://arachne.dainst.org/) and may be viewed by clicking the link (see below).

37 There are a vast number of SLScanners on the market, which range in price from a few hundred to several tens of thousands of Euros. We were fortunate to have two devices – each well-known in archaeology – at hand at both the low-cost and high-end price tag. In 2017, we compared the DAVID-SLS-2 (now Hewlett-Packard) against the Hexagon smartSCAN-3D-HE (formerly known as AICON or Breuckmann). Both include proprietary software packages for the Windows operating system, however, the DAVID software is faster and easier to learn, while the Hexagon OPTOCAT has more functions and options to fine-tune the results. An essential element of our methodology is the use of a turntable, which is available for each system. It is very useful and saves time when working with excavation finds. However, the DAVID system's turntable prevails as it is small, light and easy to use. The turntables offered by Hexagon are too heavy and bulky for transportation to an excavation, thus they are only usable at nearby locations,

such as museums. In terms of accuracy, the expensive industrial grade system clearly prevails as it is able to capture the smallest details, such as preliminary engravings for ceramic decorations or the subtle features of objects like cuneiform tablets (Mara et al. 2010; Mara – Krömker 2013). For the given task of documenting Cocal-period ceramics, the low-cost system has a sufficient resolution and we were able to effectively use two of these 3D scanners for the following campaigns in 2018 and 2019. By the end of the third campaign, 402 objects, mainly pottery, but also bone, shell, metal and stone objects were acquired as 3D models (Fig. 14, Fig. 15).

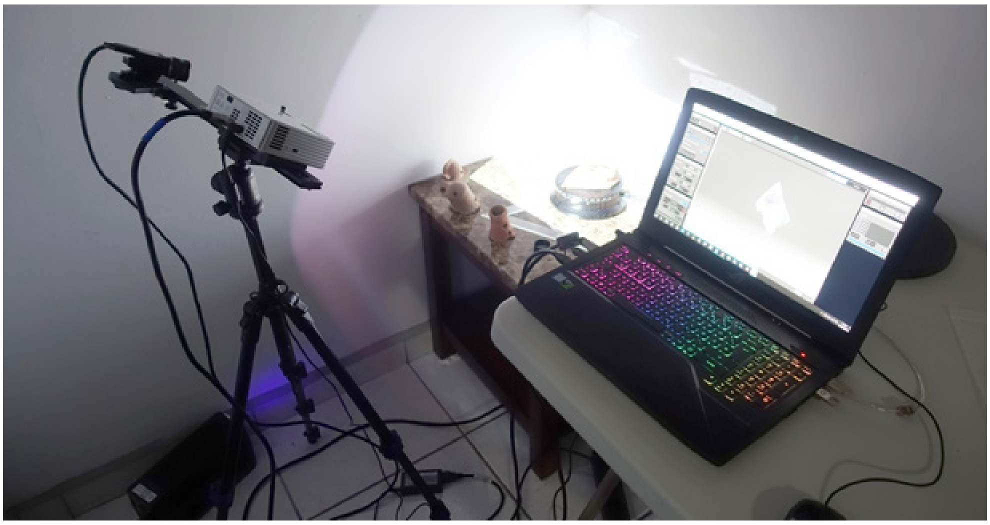

Fig. 14: Setup of the 3D-Scanner

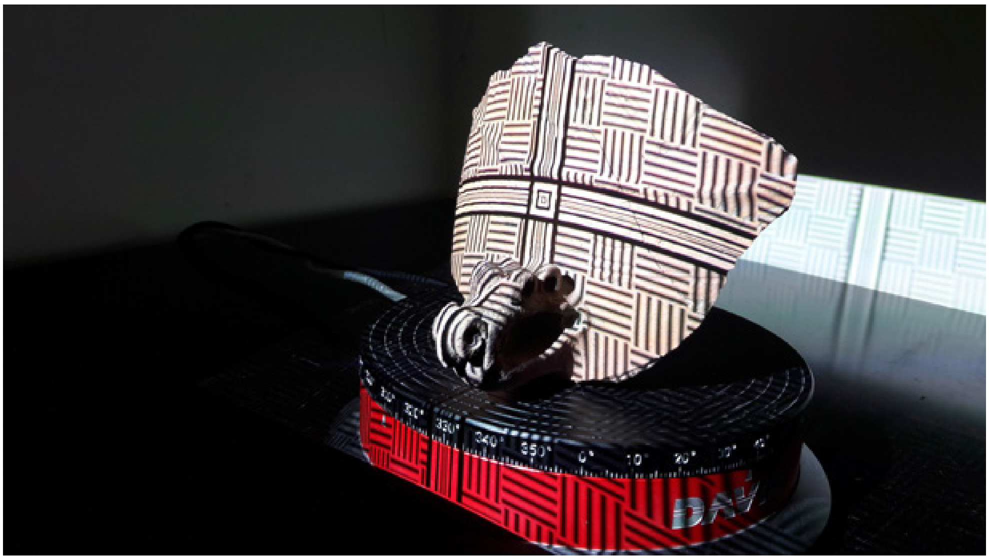

Fig. 15: Sherd on the turntable with structured-light pattern

38 Color capture and representation of SLScanners is not sufficiently applicable for use in archaeological research because surface properties like shininess, specularity, etc. are not captured. This is also true for SfM, which generally results in texture maps with colors that bear a closer resemblance to those of the real object. This led to the decision to use a supplementary photograph for color representation and to skip recording texture with the 3D scanners. At the end of the acquisition process, each 3D model was stored in the Stanford Polygon (PLY) file format, which has an open definition and is a de-facto standard. On an average working day, about 12 objects were acquired with each 3D scanner depending on their complexity and the corresponding number of necessary scans. The acquisition rate can be increased for simple sherds, e.g., using a frame to acquire multiple sherds at once. The partial scans of each model were aligned and fused directly after scanning to ensure and check the model's completeness and quality (Mara – Sablatnig 2005).

39 The pottery profiles were computed using the Open Source GigaMesh Software (https://gigamesh.eu) in a similar way to how hand drawings are conducted (Bayer 2018): First, the 3D model of the sherd has to be orientated correctly according to its position in the former vessel. This step is necessary to obtain the correct diameter of the rim and/or base and to achieve the proper position of the exported profile drawing. Despite a number of automated and semi-automated methods for fragment orientation, this step is typically performed manually within a few seconds using GigaMesh's highly optimized keyboard layout for precise mesh orientation. A virtual radius table is then used to fit the sherd to the best corresponding circle representing the diameter of the vessel. From this (top) view, the rotational axis is set and is followed by a selection of one or more positions on the sherd. Together, the axis and points define intersecting planes to compute the profile cuts. More than one position/plane is required when several profile cuts from different positions need to be combined in order to cover the entire preserved height of the vessel (Fig. 16).

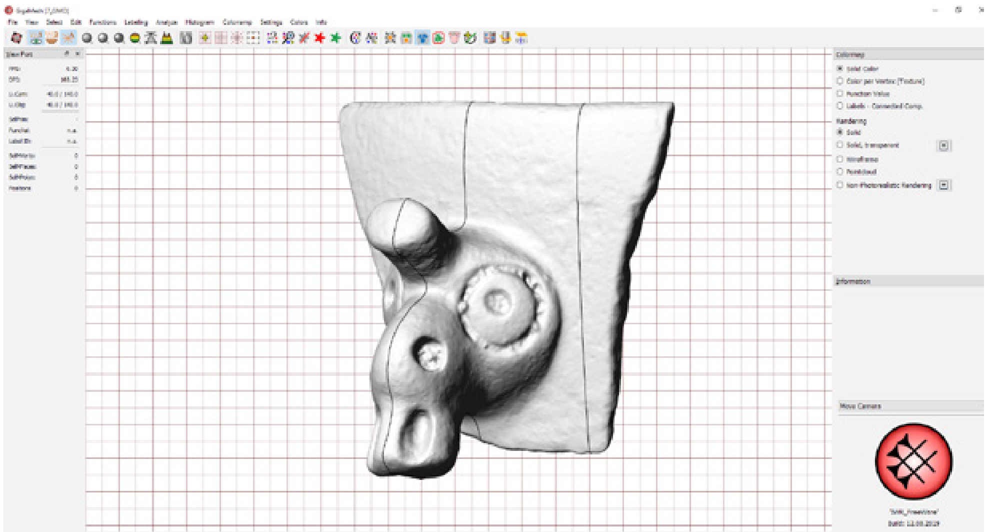

Fig. 16: Extracting profile lines in GigaMesh

40 The profile cuts are exported from GigaMesh as Scalable Vector Graphics (SVGs). These are true-to-scale as 3D data from SLScanners is generally calibrated. Relevant measurements such as height and upper and lower diameter are saved as text elements in the SVG file. Further measurements can easily be conducted within software, such as the open source SVG editor Inkscape. The highly automated computer-generated drawings require a minimum of manual post-processing, such as removing the profile lines obtained from broken surface parts. As the 3D data has a high resolution and accuracy – even for the low-cost system – the expected deviation of profile lines is far less than 1 mm. No errors were quantifiable within the typical representation of pottery drawings at a scale of 1:3. Additional orthogonal grayscale renderings of the sherds were placed in the drawing to provide information about specific features, such as decorations or manufacturing traces. To finalize object documentation, experience has shown that many features have to be verified on the physical object by the archaeologist in person (Karl et al. 2019) because some features cannot be recorded sufficiently with any 3D scanner, such as a faded painting. Another task requiring manual intervention is highlighting the vessel's decoration without showing potentially distracting damage. The digital 3D workflow limits the attention each object gets during the drawing process. Therefore, the written description of the pottery and the corresponding analysis has to be conducted in addition, which can be separated from the 3D data-acquisition and subsequent digital drawing.

41 The documentation process was clearly improved in terms of time needed per object as well as precision and objectivity. The traditional pen-and-paper style hand

drawings that need to be scanned and later digitally redrawn was no longer required, which resulted in a completely digital workflow. The object is handled less than during the manual drawing process, protecting the fragile sherds from damage.

3.3 Comparison of analog and digital methods

42 The explanations in the previous sections have shown that the various methods have advantages and disadvantages. They concern the areas of project organization and infrastructure, workflow, as well as scientific knowledge and the publication of results. These are summarized and compared here.

43 As mentioned in the introduction, projects that take place far away from the workplace face certain challenges and limitations. One of these limitations concerns the financial circumstances of the project. A large part of the budget is used for travel expenses and accommodation. In this respect, analog documentation methods have the clear advantage in that the required materials are inexpensive and are often widely available abroad. If this is not the case, as in Honduras, the transport of the required materials to the country does not present a significant problem. A 3D scanner, on the other hand, is expensive to purchase. The technical equipment costs a few thousand Euros, but this investment can be quite sustainable when it is used over several years or in several projects. The transport of the equipment is indeed more complex, but still manageable, especially considering the DAVID/HP system with its small and lightweight turntable, as the scanner can fit in suitcases or hand luggage.

44 On site, one is free to choose a workplace when it comes to drawing. A table and good lighting conditions are all that is needed. The work can take place either indoors or outside. In addition, you are independent of a power supply. When scanning, a darkened room is recommended as a workplace. A stable source of electricity is also necessary, which can be difficult in countries like Honduras, where there are many small and sometimes long power outages on any given day. However, an additional uninterruptible power supply (UPS) can help or even bridge at least minor power outages.

45 As far as know-how is concerned, prior knowledge is required for both analog and digital documentation techniques. In both cases, the fundamental requirements can be learned in one to two days. While the scanning process is quite standardized after learning the workflow and the same steps are repeatedly carried out, manual drawing requires more training, especially for the documentation of complex objects. The two-dimensional representation of three-dimensional objects requires practice and each object brings with it individual challenges. In order to draw an object, it must be examined and experienced by the illustrator. It is usually useful to touch the object and move it to different positions. While for archaeological objects in general, the less they are moved the better; there is a particular problem with fragile objects that can be damaged by such movements or even touch. In such cases, processing with a 3D scanner represents a significant advantage, as it even allows the digital refitting of fragments, as was the case for a fragile bone figurine (Fig. 17).

46 Scanning also has an advantage when it comes to speed. Since workflows are highly standardized, many objects can be documented in a short time. This is also true of hand drawing in consideration of simple rim sherds, but when it comes to more complex objects, as in our case, vessels with elaborate appliqués, the scanner clearly excels due to its speed. Moreover, only a few work steps are necessary for scanning. After the object has been scanned, these steps can all be done digitally on the computer, while analog drawing consists of several work steps, namely drawing, scanning and inking or post-processing on the computer. Because these work steps in manual drawing are often carried out at a later date back in one's home country, errors are often only noticed at this point. Checking the original object is no longer possible. However,

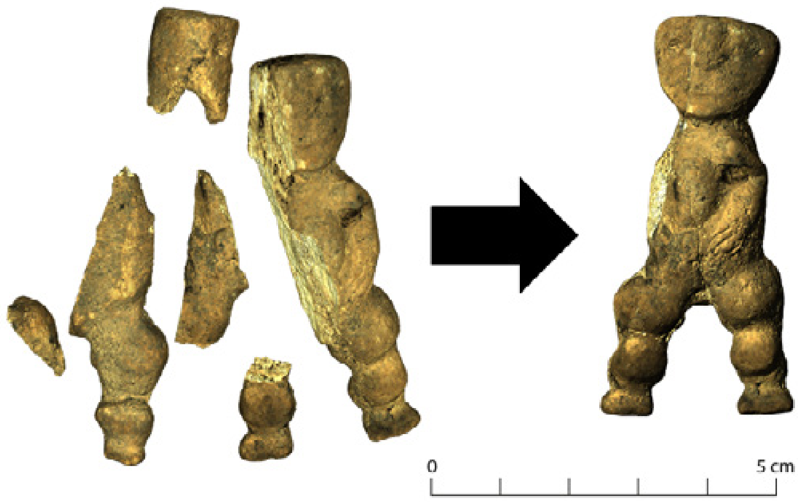

Fig. 17: Bone figurine. The fragile figurine was assembled digitally

an advantage of drawing by hand is that several people can work at the same time. Only space and drawing implements, which can be shared, limit the process. When scanning, it is clear that only one person can work per scanner.

47 A central point of the documentation of finds is the scientific gain of knowledge. Drawing requires precise observation and intensive examination of the object. The illustrator will notice specific features during this process and at the same time they will have the opportunity to highlight these special features in the drawing and to neglect unimportant details. The drawing is thus more than a pure illustration; it also contains a scientific interpretation of the object and represents the first step towards analysis. In this sense, the standardized process of 3D scanning lacks interpretation. In the 3D scanning workflow, the object is dealt with less. In addition, there is hardly any possibility to emphasize relevant characteristics. The step of scientific interpretation has to be done later. Nevertheless, the 3D scan is a very precise technique and all available information is recorded reliably. The 3D view generated by the scan allows the object to be viewed in its entirety – even if digitally – at a later time. It thus provides the closest possible analogy currently available to actually having a specimen in hand. This also has advantages for the later publication. It can be freely decided in which scale the models are to be reproduced and changes are easy to make. This is only possible to a limited extent with hand drawings. The illustrator must decide on a scale at the latest when creating the final illustration. Finally, although this depends on personal taste, it should be noted that our team agreed that hand drawings present a higher degree of aesthetics.

4 Results and conclusions

48 The aim of the Guadalupe Archaeological Project is to investigate and analyze a previously little-known ceramic complex from northeast Honduras and to revise the systematics of the existing ceramic typology. In order to create a representative catalog of ceramic types, a selection from the 20,000 excavated diagnostic ceramic fragments had to be made. Approximately 900 objects were selected for documentation. Based on the experience we had gained in testing the various documentation processes, a workflow was developed that combines the advantages of the analog and digital documentation methods respectively. At the same time, this workflow was adapted to the specific conditions of our workplace in Guadalupe.

49 To create the profile drawings, the objects were first divided into various categories. “Simple” rim sherds, i.e., sherds that are easy to handle and do not have a complex profile, such as those with simple appliqués or entirely without, were documented by hand drawing. Since this type of documentation can be learned quickly and does not

require much practice, it could be performed by all project members. If the sherd had exterior appliqués, they were only displayed linearly. This decision represents a compromise between time expenditure and information gain. In order to keep the error rate as low as possible and to minimize later complications during post-processing on the computer, the drawings were each checked by a second person. Scans of the drawings were made on site – also functioning as a backup – but post-processing on the PC took place back in Europe.

50 Objects classified as complex were scanned with a structured light scanner. These included: 1) unwieldy objects due to their size or those that would have had to be glued in several places for drawing, 2) objects with complex profiles, i.e., if they had several or elaborate appliqués, 3) single appliqués and 4) vessels with a profile that could be considered complete, since experience has shown that untrained illustrators are more likely to make mistakes with such vessels. Some objects with incised ornaments were also scanned, as these are particularly visible on a 3D model when the color is omitted, whereas they may not be clearly visible in a photo. The objects were scanned and their 3D models generated on site. The drawings from these models were then generated in Germany.

51 In addition to the profile and exterior view, the sherd itself is also displayed. This method of illustrating provides important information about the degree of preservation of the vessel and provides a better feeling for the actual appearance of the ceramic fragments. Since the color representation of the scans are limited and a graphic representation does not provide any color information – and would also be very time-consuming – we have decided to insert a photograph into the drawing (see catalog). Thus, in addition to the production of the drawing by hand or 3D scan, all fragments were photographed in position. With some practice and depending on the nature of the objects, up to fifty pieces can be photographed per day. At this point, software that can provide a degree of control over the accuracy and position of an object is helpful, such as the freeware DigiCamControl. Back in the office, the background of the photos can be removed and each can be fitted into the respective drawings.

52 In summary, the Guadalupe Archaeological Project developed a workflow for the documentation of an extensive, little-known pottery complex. The combination of hand drawings and 3D scans allows for fast and efficient documentation and combines the advantages of each respective method. The new methods of digital 3D modelling represent a time-saving and precise tool, which is particularly helpful when it comes to the documentation of large quantities of archaeological objects. Nevertheless, we do not believe that it can completely replace traditional hand drawing. Specifically, a person tasked with creating a ceramic typology should take the time to draw some of the objects, as drawing can serve as more than just a documentation method, but also an important analytical tool for the study of archaeological ceramic objects.

53 Furthermore, the digital recording of archaeological artifacts opens up the possibility of a wide variety of new forms of publications, including the publication of 3D objects and open access publication using digital object identifiers (DOIs) as it was done recently for 2,000 cuneiform tablets (Mara – Bogacz 2019). As a result of the Guadalupe project, the publication of the complete catalog of the documented objects in an open access format is planned for the near future. Meanwhile, as an appendix to this article, a catalog is provided of a representative sample of objects with different 2D views that illustrate the 3D models. Additionally, representations of 3D models in the catalog are linked to the corresponding 3D model in the object database iDAI.objects / Arachne and may be viewed by clicking the link.

(Note: to activate 3D models of ceramic objects, click the respective hyperlink)

Comparisons of hand drawing to 3D models

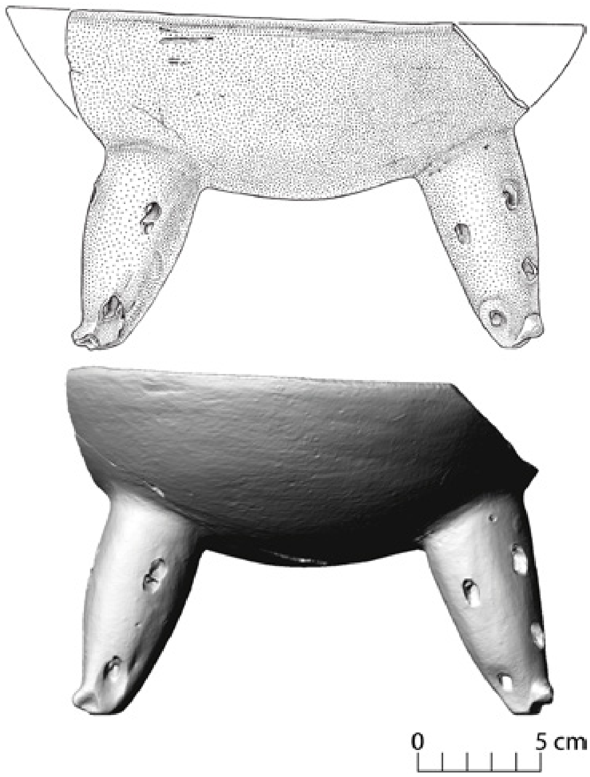

Fig. 18: PAG-15-682 (Vessel fragment).

Fig. 19: PAG-26-407 (Vessel handle in the form of a bat).

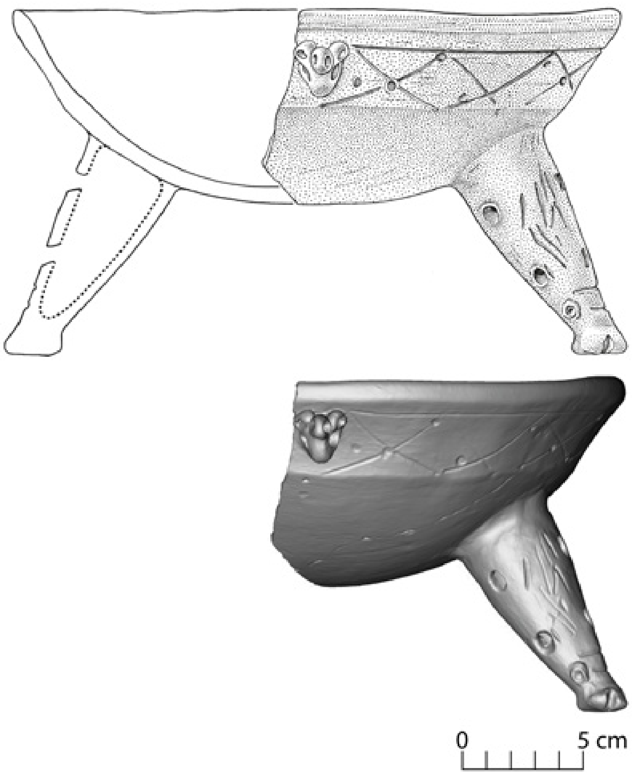

Fig. 20: PAG-15-683 (Vessel fragment).

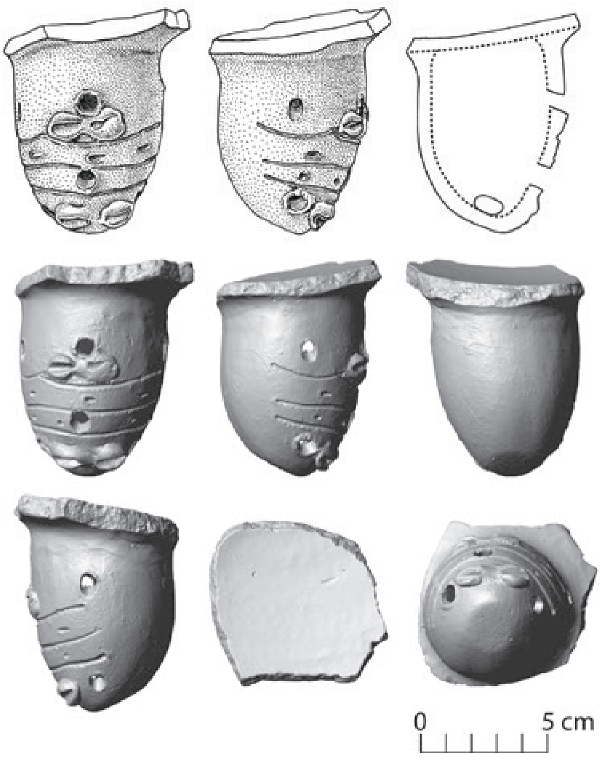

Fig. 21: PAG-10-35 (Vessel appliqué).

Fig. 22: PAG-29-452 (Handle of a ladle censer).

Profile drawings with photos inserted

Fig. 23: PAG-8-2

Fig. 24: PAG-8-210

Fig. 25: PAG-10-151

Fig. 26: PAG-15-87

Fig. 27: PAG-46-60

Fig. 28: PAG-53-66

Profile drawings generated in GigaMesh with 3D models inserted

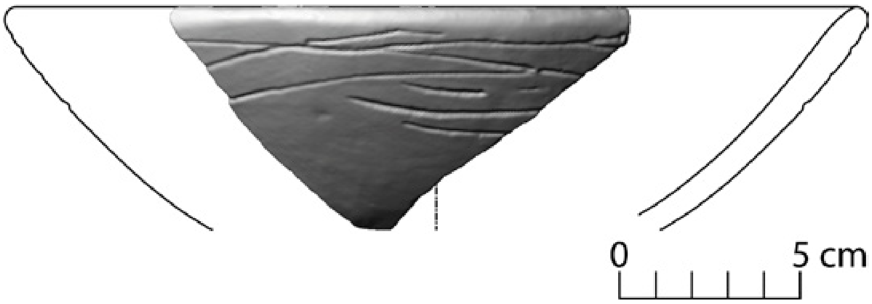

Fig. 29: PAG-6-63

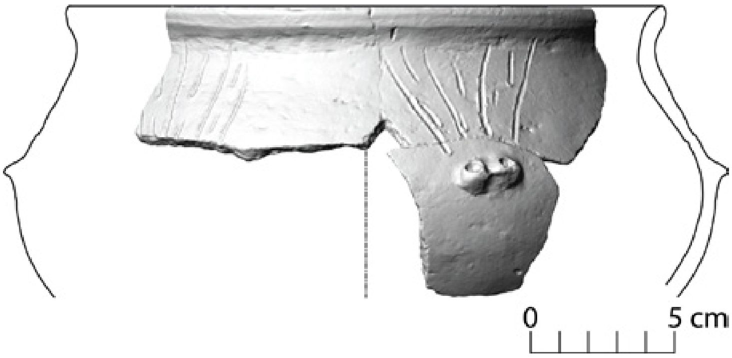

Fig. 30: PAG-15-16

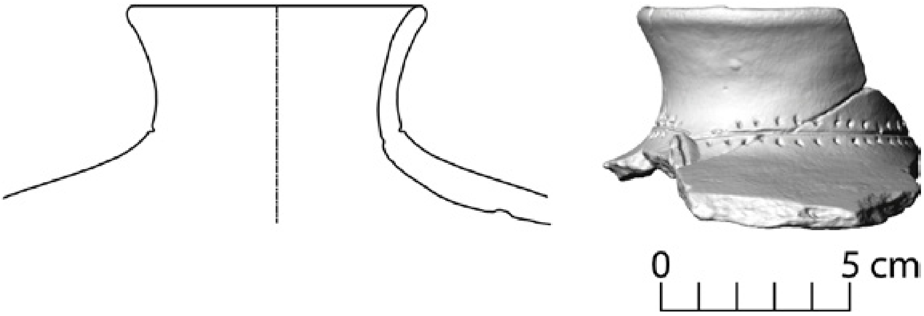

Fig. 31: PAG-17-24

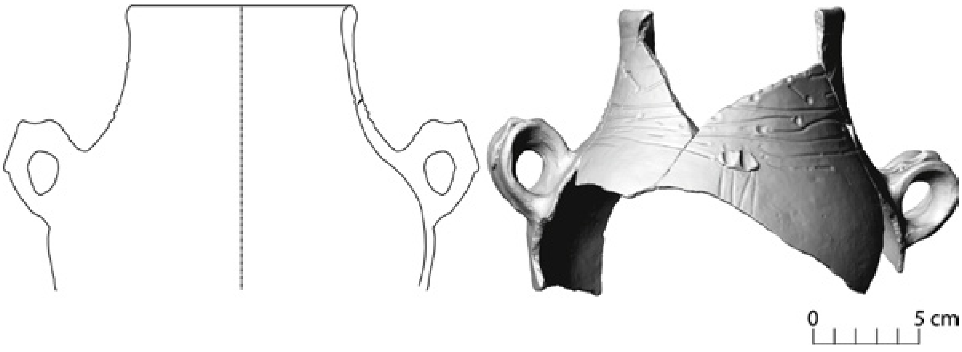

Fig. 32: PAG-44-55

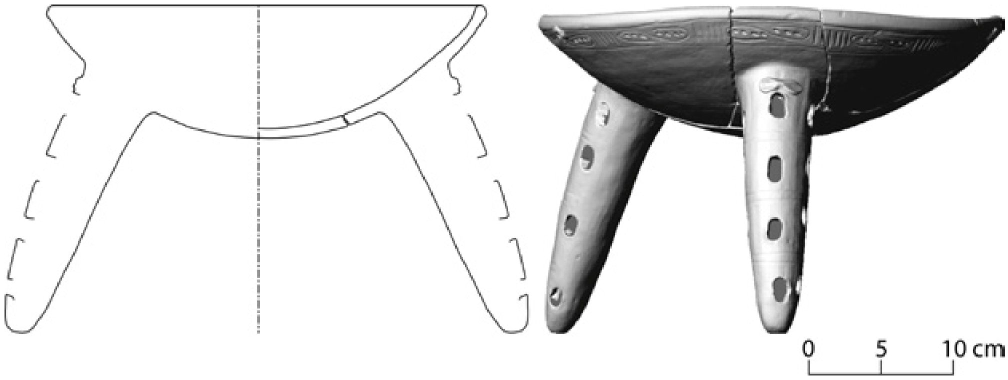

Fig. 33: PAG-46-57

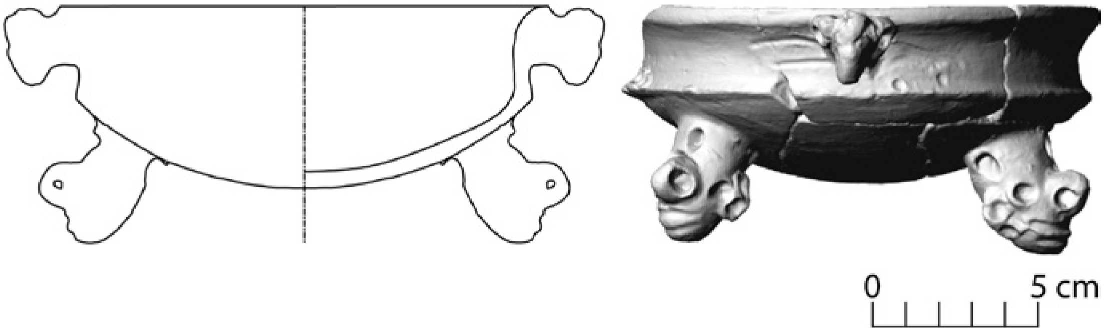

Fig. 34: PAG-53-29

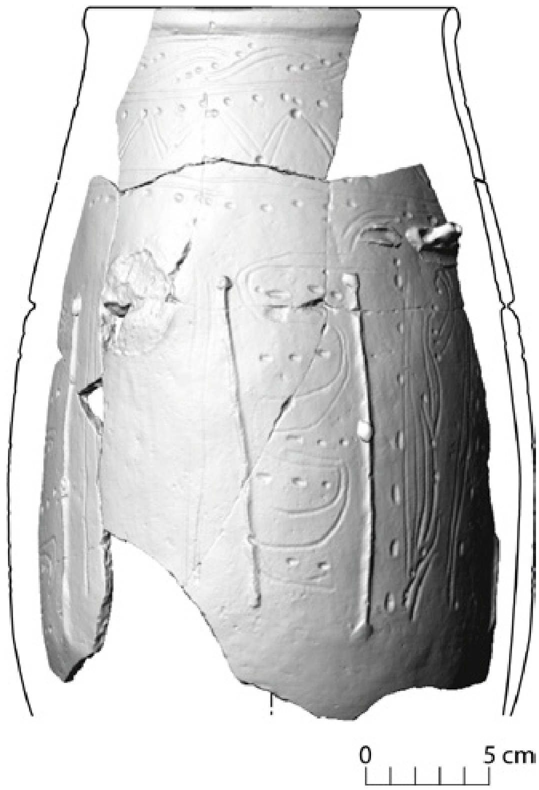

Fig. 35: PAG-53-110

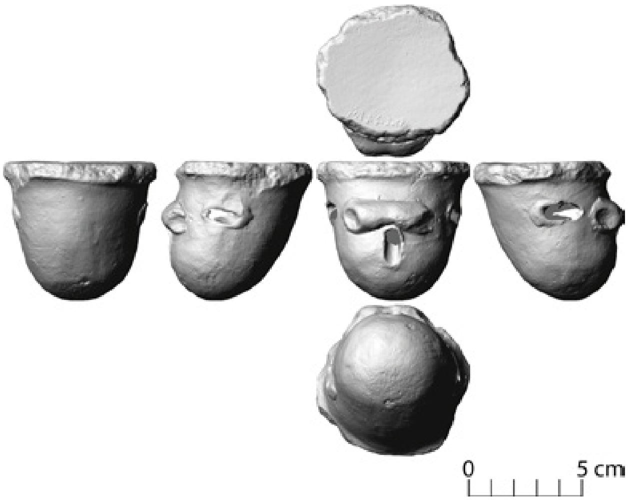

Fig. 36: PAG-6-527 (Vessel appliqué).

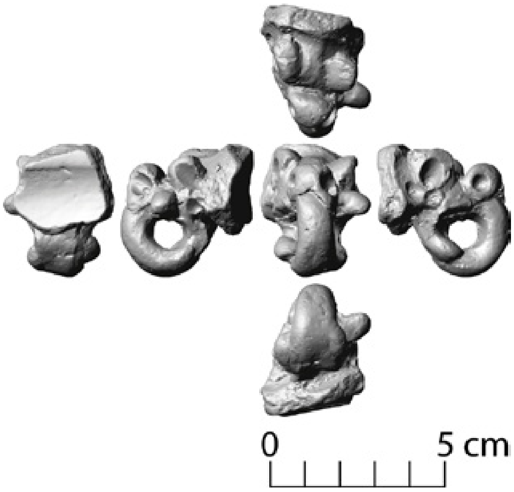

Fig. 37: PAG-7-353 (Vessel handle).

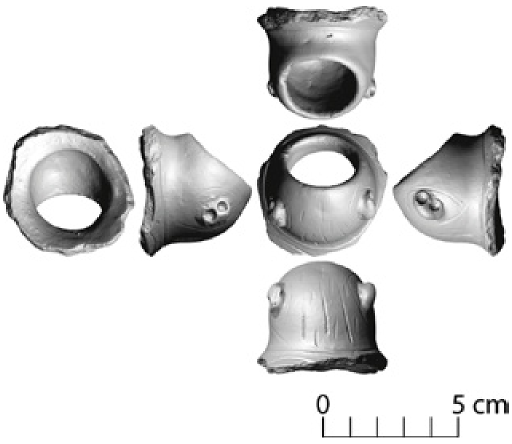

Fig. 38: PAG-8-366 (Vessel appliqué).

Fig. 39: PAG-12-384 (Vessel appliqué).

Fig. 40: PAG-14-36 (Vessel support).

Fig. 41: PAG-17-37 (Vessel appliqué).

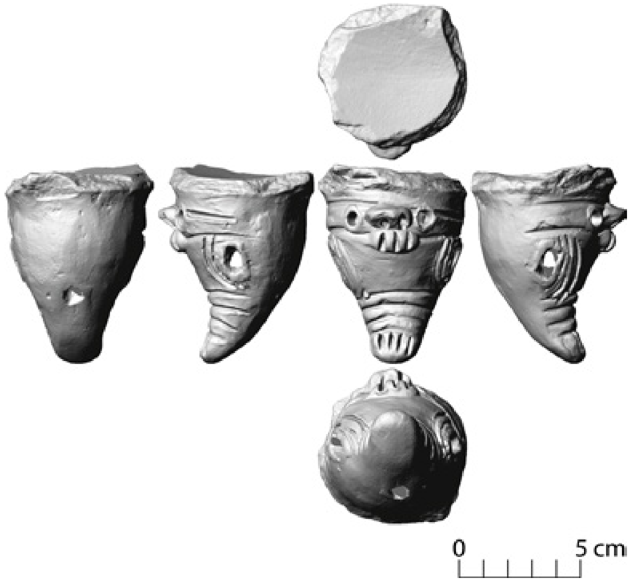

Fig. 42: PAG-17-38 (Vessel appliqué).

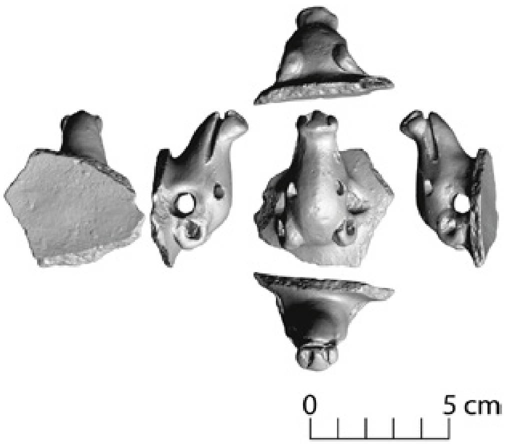

Fig. 43: PAG-31-180 (Vessel handle).

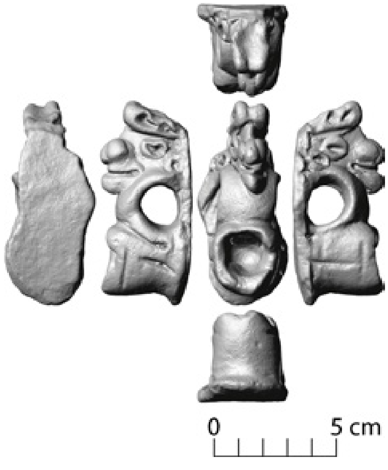

Fig. 44: PAG-32-30 (Vessel handle).

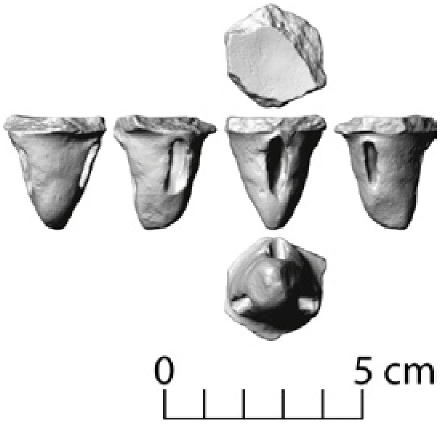

Fig. 45: PAG-46-48 (Vessel appliqué).

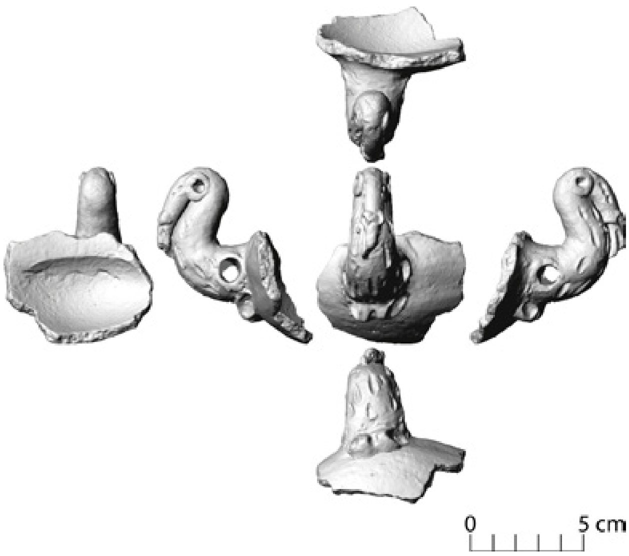

Fig. 46: PAG-53-40 (Vessel appliqué).

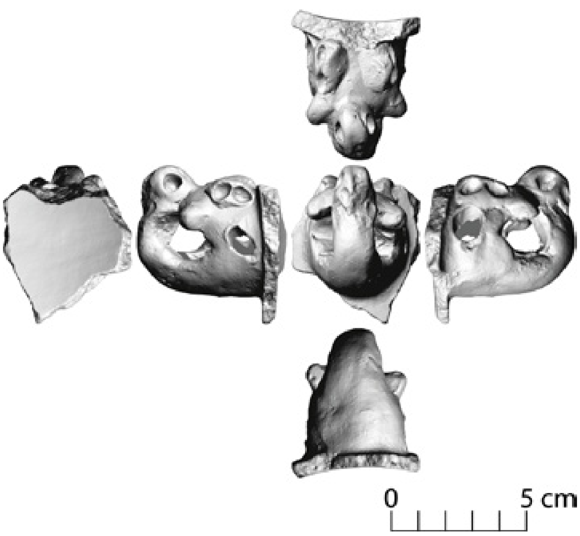

Fig. 47: PAG-71-24 (Vessel appliqué).

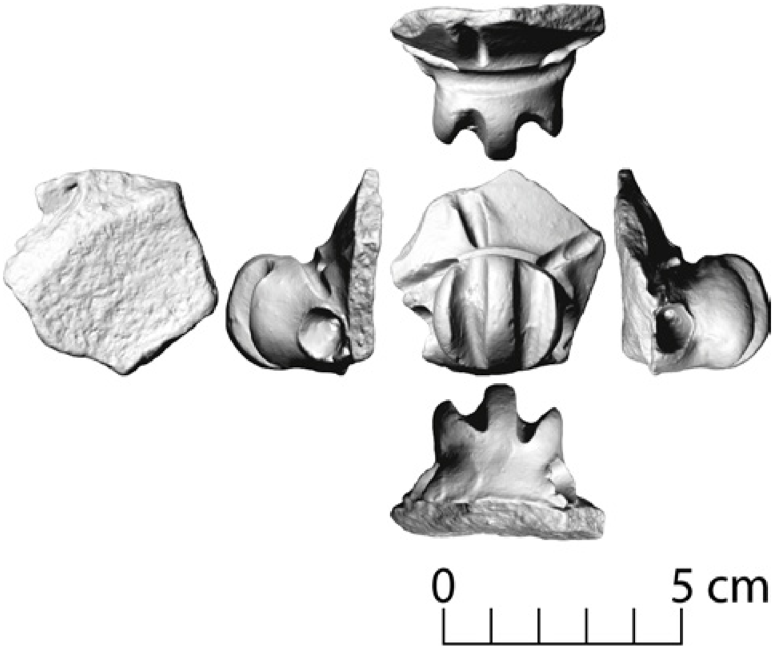

Fig. 48: PAG-71-33 (Vessel appliqué).

Fig. 49: PAG-71-35 (Vessel support).

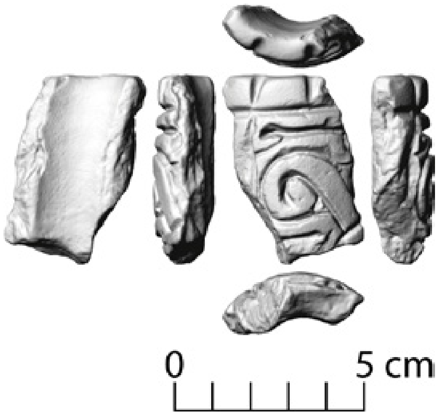

Fig. 50: PAG-10-195 (Fragment of a roller stamp).

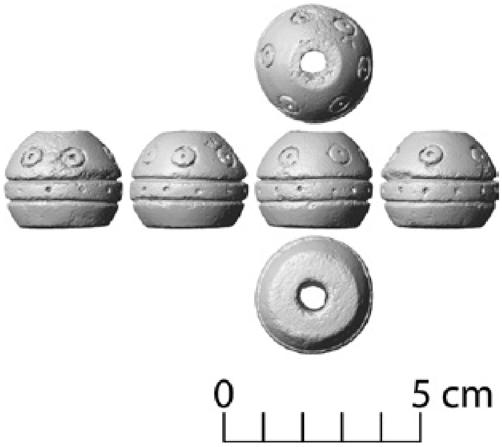

Fig. 51: PAG-23-320 (Spindle whorl).

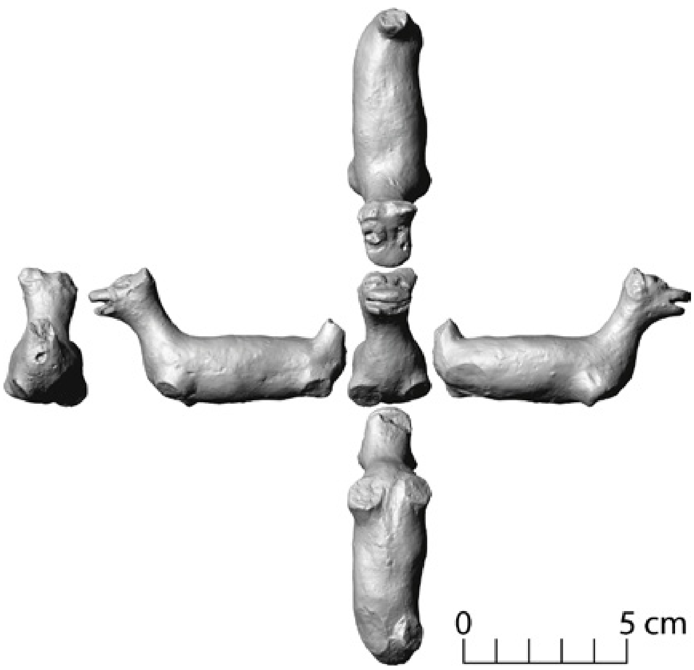

Fig. 52: PAG-32-325 (Figurine).

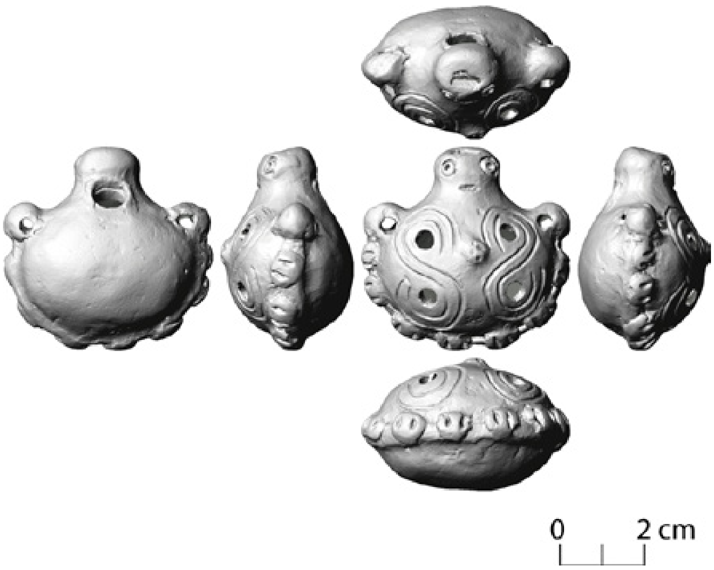

Fig. 53: PAG-43-1 (Ocarina in the form of a turtle).

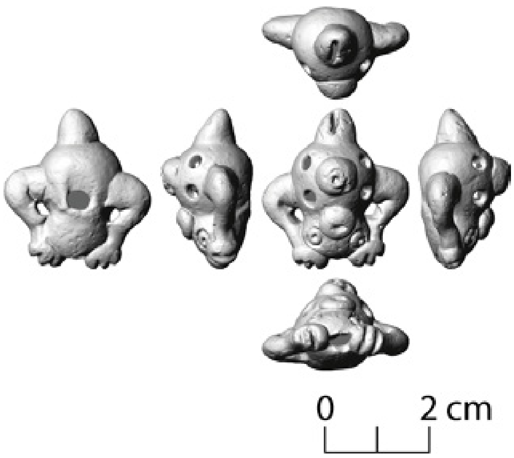

Fig. 54: PAG-57-1 (Zoomorph ocarina).

Fig. 55: PAG-195-1 (Ocarina).

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ZUSAMMENFASSUNG

The ceramic finds from Guadalupe, Honduras

Optimizing archaeological documentation with a combination of digital and analog techniques

Franziska Fecher, Markus Reindel, Peter Fux, Brigitte Gubler, Hubert Mara, Paul Bayer, Mike Lyons

Archäologische Projekte sind am Ausgrabungsort oft mit der Verarbeitung von extrem großen Mengen von keramischem Material konfrontiert. Üblicherweise ist das Handzeichnen von diagnostischen Scherben und Gefäßen essenzieller Bestandteil von Dokumentation und Analyse des Fundgutes. Dies ist insbesondere bei komplexen Gefäßformen sehr zeitaufwendig. Das Archäologische Projekt Guadalupe arbeitet im Nordosten von Honduras mit dem Ziel, die lokale Kultur der Cocal-Periode (1000-1525 n. Chr.) zu charakterisieren. Während der Untersuchungen verglich das Projekt systematisch die Vorteile traditioneller Handzeichnungstechniken mit moderneren Ansätzen, wie z.B. der 3D-Modellierung und 3D-Datenverarbeitung, um einen effektiven Arbeitsablauf für die Dokumentation vor Ort zu entwickeln. Durch eine Kombination aus Scannen mit strukturiertem Licht, traditioneller Handzeichnung und der automatischen Erzeugung von Profilzeichnungen mit der 3D-Software GigaMesh konnten wir unsere Arbeit mit unterschiedlich gearteten Objekten durch die Anwendung der jeweils geeignetsten Technik optimieren.

SCHLAGWORTE

Zentralamerika, Honduras, Postklassik, Keramikzeichnung, Streifenlichtscanner, 3D-Modellierung, Archäoinformatik

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