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Investigating the function of Pre-Pottery Neolithic stone troughs from Göbekli Tepe – An integrated approach

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A B S T R A C T

An integrated approach using contextual, use-wear, scientific and experimental methods was used to analyze the role of stone troughs of up to 165 l capacity at the Early Neolithic site Göbekli Tepe in the context of other stone containers found there. Around 600 (mostly fragmentary) vessels from the site constitute the largest known assemblage from the Pre-Pottery Neolithic of the Near East. Besides the large limestone troughs, it encompasses middle-sized, coarsely made limestone vessels, finely executed platters and 'greenstone' vessels. All lines of evidence taken together indicate the use of limestone troughs for the cooking of cereals.

1. Introduction

Starting from the Epipalaeolithic (c. 12,000–9600 BCE), but especially during the Early Neolithic of the Near East (Pre-Pottery Neolithic, PPN, 9,600–6,500 BCE), a wide range of stone vessels appear in site inventories (Wright, 2000). This period is linked to the Neolithization process, which included a fundamental change of human diet through the adoption of cereals as staple food (Bar-Yosef and Meadow, 1995; Bar-Yosef and Belfer-Cohen, 1989; Colledge, 2002; Harris, 2002; Kujit and Goring-Morris, 2002; Nesbitt, 2002; Akkermaans, 2004; Byrd, 2005; Willcox, 2005; Willcox et al., 2008; Zeder, 2011; Fuller et al., 2012; Asouti and Fuller, 2013; Arranz-Otaegui et al., 2016; Vigne, 2015; Weide et al., 2018, all with further bibliography).

Recent research has emphasized the existence of diverse Neolithic foodways and regional traditions in food processing (Wright, 2000; Haaland, 2007; González Carretero et al., 2017; Fuller and González Carretero, 2018). Preserved food remains (Arranz-Otaegui et al., 2018), new methods for the classification of charred residues (González Carretero et al., 2017; Fuller and González Carretero, 2018), use-wear approaches combined with experimental programs (Eitam et al., 2015), and the identification of cooking installations (Fuller and González Carretero, 2018) have revealed the omnipresence of bread-like products in different regions of the Early Neolithic Near East. In addition, there is evidence for the presence of porridge-like products at some Neolithic sites (González Carretero et al., 2017) and ongoing discussion on early beer (Dietrich et al., 2012; Hayden et al., 2013; Rosenstock and Scheibner, 2018; Liu et al., 2018; Heiss et al., 2020). So far, this potential diversity of early cereal processing (boiling, baking, brewing) has not

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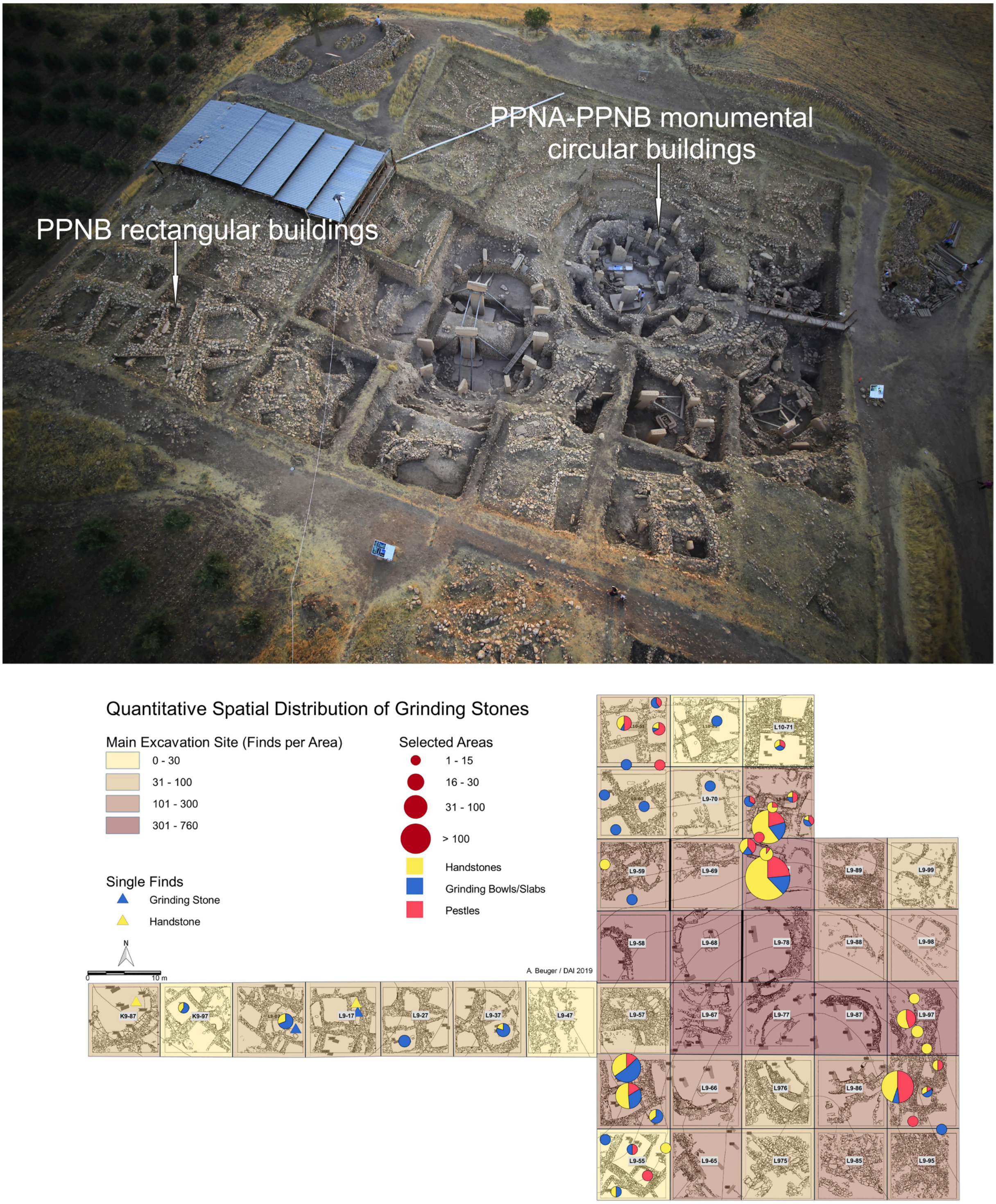

Fig. 1. The archaeological site of Göbekli Tepe. Above: Main excavation area (German Archaeological Institute, photo E. Kücük). Below: Distribution of the grinding stones (map L. Dietrich and A. Beuger).

been systematically linked to the diverse set of stone vessels known from this period. Rather, the appearance of dedicated cooking containers has been pinpointed to Late Neolithic pottery vessels that are directly heatable over a fire (Haaland, 2007).

While there are several supra-regional studies on ground stone assemblages and stone vessels for the Southern Levant (Wright, 1993; 2000; Rosenberg, 2008; Shea, 2013), few reports of sites with assemblages containing stone vessels have been published from Northern Mesopotamia (for example Jerf el Ahmar: Willcox and Stordeur, 2012; Nemrik: Mazurowski, 1997; Tell Abŕ3: Yartah, 2013; more generally Kozlowski and Aurenche, 2004; Sığın, 2008).

Both coarse and carefully finished vessels are attested since the PPNA in Northern Mesopotamia. Middle-sized, open limestone bowls approximately 20–30 cm in diameter, with heights of up to 15 cm, and different rim shapes as well as platters of up to 1 m in diameter occur frequently. Similarly sized thin-walled and often richly decorated containers made of a soft ‘greenstone’ have also been reported from early Neolithic sites in that area (Köksal-Schmidt and Schmidt, 2007; Özkaya and Coşkun, 2011; 2013;; Rosenberg, 2011; Benz et al., 2017; Gündem and Dağlı, 2018). Another object group are the large PPNA and PPNB limestone troughs, sometimes with volumes above 150 l (Dietrich et al., 2012; Hayden et al., 2013; Willcox and Stordeur, 2012; Yartah, 2013).

Platters and symmetrical bowls have been discussed as dishware for the orchestrated presentation and consumption of foodstuffs within households when nuclear families and the private realm became more important during the transition to a fully sedentary agricultural lifestyle (Rosenberg, 2008). For the Neolithic site of Çatalhöyük, it has been suggested that organic containers were used for boiling food (Atalay and Hastorf, 2006). Stone containers have only rarely been linked to the preparation of soaked or heated meals. Large containers in Neolithic houses have been proposed for the storage of water or foodstuffs including cereals (Bartl, 2004; Willcox and Stordeur, 2012; Yartah, 2013; Stordeur, 2015). In the case of the limestone troughs, an interpretation as tools used for the preparation of beer due to the presence of charred cereals in their fills and associations with burnt stones at some sites has been put forward (Haaland, 2007; Hayden et al., 2013). The presence of oxalate on the walls of such containers at Göbekli Tepe has been discussed as tentative evidence for beer (Dietrich et al., 2012), though oxalate can also be produced when grains regularly come into contact with water, or in certain plants (Zarnkow et al., 2006). For the fermentation process, modified starch particles in Late Natufian mortars have been used as evidence for beer (Liu et al., 2018; 2019; Eitam, 2019).

Here, we applied an integrated approach to investigate the functions of stone vessels in Neolithic foodways through contextual, use-wear, scientific and experimental analyses of the stone vessel assemblage from Göbekli Tepe. With about 600 pieces it is the largest known repertoire of Early Neolithic stone vessels. They are accompanied by more than 10,000 grinding stones, which previous analyses has connected to the large-scale processing of cereals (Dietrich et al., 2019). Experimental work and surface analysis of use-wear show that processing of both fine and coarse cereal flour was performed at Göbekli Tepe, although patterns for coarse flour prevail (Dietrich and Haibt, 2020; see below).

1.1. The stone vessel assemblage from Göbekli Tepe: Shapes, traces of production and use-wear

Göbekli Tepe (Fig. 1; Schmidt, 2012; Piesker, 2014; Kurapkat, 2015; Dietrich et al., 2019; S1.1) consists of monumental round to oval buildings, erected in an earlier phase (PPNA-Early PPNB), and smaller rectangular and apsidal buildings, built around them in a partially contemporaneous and later phase (Early to Middle PPNB). The monumental buildings are around 20 m in diameter and have stone pillars that are up to 5.5 m high and richly decorated with reliefs. At the end of their complex use-lives, at least the lower parts of the monumental buildings were intentionally re-filled. The rectangular buildings constructed on a slope around them are smaller and – in some cases – contain up to 2 m high pillars and terrazzo-floors. Many of these buildings can be linked to domestic activities, especially cereal processing, as has recently been shown (Dietrich et al., 2019), but in many cases a functional interpretation remains ambiguous as there are very few in situ finds from floor levels.

The vessel assemblage is made up of small and middle-sized limestone vessels, big limestone troughs, limestone platters and fragments of 'greenstone' vessels. The fragments of troughs and small/middle-sized limestone vessels are kept in the so-called 'stone garden' on site, six complete troughs are still *in situ* but (re-)filled with sediments for protection. Samples were taken and the troughs documented during excavations in 2010–2013. Most of the fragments are either sintered or covered with blackish deposits probably caused by post-depositional processes, as they are observed on all lithic finds from the site.

Highly fragmented limestone vessels dominate the vessel assemblage. 361 fragments belong to small to medium-sized open bowls of different depths with a wall thickness of up to 6 cm (S2.1). Four shapes were reconstructed: shapes 1, 3 and 4 belong to bowls with evenly thick walls, shape 2 is represented by a single piece with irregularly shaped walls (Table 1, Fig. 2). As most finds are small rim fragments, many cannot be attributed to a shape. The complete specimens of shapes 1 and 4 have 20–25 cm diameter and are up to 15 cm high. Their capacities do not exceed 5 l. The vessels show traces of pecking as well as scars, striking negatives and scratches associated with their production but no use-wear traces. The thickness of their walls is relatively even; however, their surface is not polished. Attention was focused on shape and properties, not on the general appearance. This is different for the 83 fragments of the so-called 'greenstone' vessels, which are thin-walled, polished, and often carefully decorated (Dietrich et al., in print; S2.2). Many were reworked into beads, pendants, and abraders when they broke, thus changing their original contexts of use (Fig. 3).

89 fragments belong to large troughs with walls up to 13 cm thick (Figs. 4-6, ST1-7; Table 2, S2.1). Six vessels were found completely preserved in situ (Fig. 6), one was in situ but fragmentary. They have diameters between 0.6 m and 1.12 m and capacities between 30 l and 165 l and were fixed parts of the furnishing of the rectangular and apsidal rooms. All preserved troughs are of different shapes, ranging from round-oval to rectangular in top view. Bottom and wall curvatures are diverse, too. Stone troughs were produced from big blocks of

Table 1
Small and medium-sized vessels from Göbekli Tepe: description of shapes.

Shape	Description
Shape 1	Globular bowl with regular concave base and wide opening
Shape 2	Bowl with unworked base and rough walls
Shape 3	Deep U-shaped bowl with regular worked base
Shape 4	Flat U-shaped bowl with regular worked base

Table 2
Limestone troughs in situ at Göbekli Tepe.

Trough	Shape and SizeLength/ Wide/Thickness/Volume	Description and context
ST1. L10-61, Locus 27	Oval shape with convex bottom; 0.60 m × 0.40 m × 0.40 m; 38 l.	Room 33 (only partially excavated); the size of the room is unknown.
ST2. L09-79, Locus 63.1, FNR: GT04-10072, Inv.: GT04-24	Oval-irregular shape with flat bottom; 0.35 m × 0.60 m × 0.20 m; 35 l.	Placed outside of the built area, from or near to the terrace wall north of Building D.
ST3. L09-70, Locus 4 (Fig. 5/1).	Almost round shape with flat bottom; 0.60 m × 0.55 m × 0.60 m; 70 l.	Room 50 (approximately 4 m × 4 m, walls not entirely excavated).
ST4. L09-69, Locus 31 (Fig. 5/2).	Oval shape with convex bottom; 0.73 m × 0.52 m × 0.60 m; 62 l.	Room 61 (approximately 4 m × 4 m, the walls are not good preserved).The vessel was surrounded by ash; it was placed on the terrazzo floor. Traces of fire are visible on its bottom.
ST5. L09-07, Locus 13 (Fig. 5/3; Fig. 6/2).	Oval shape with convex bottom; 0.70 m × 0.60 m × 0.42 m; 83 l.	Room 134 (at least 5 m × 4 m, walls end in profile).The vessel was placed on a small pedestal above the terrazzo-floor, in a niche made of stones. "Dark sediment" and small stones are mentioned near the vessel.
ST6. *K*10-79 Locus 29 (Fig. 5/4; 6/1).	Rectangular with flat bottom; 0.63 m × 1.12 m, ~0.60 m; 165 l.	Room 5 (6 m × 4 m). The room was not excavated up to the floor level. The vessel content was excavated. It contained sediment and lots of fist-sized stones, some with traces of fire. An onager scapula was found on the vessel bottom.
ST7. GT97, L0955, Loc7.3 + Loc34	Oval with thick flat bottom; 0.5 × 0.5 × 0.3 m	Room 7, Loc. 34 (only partially excavated). ST 7 was placed in a niche made of stones.

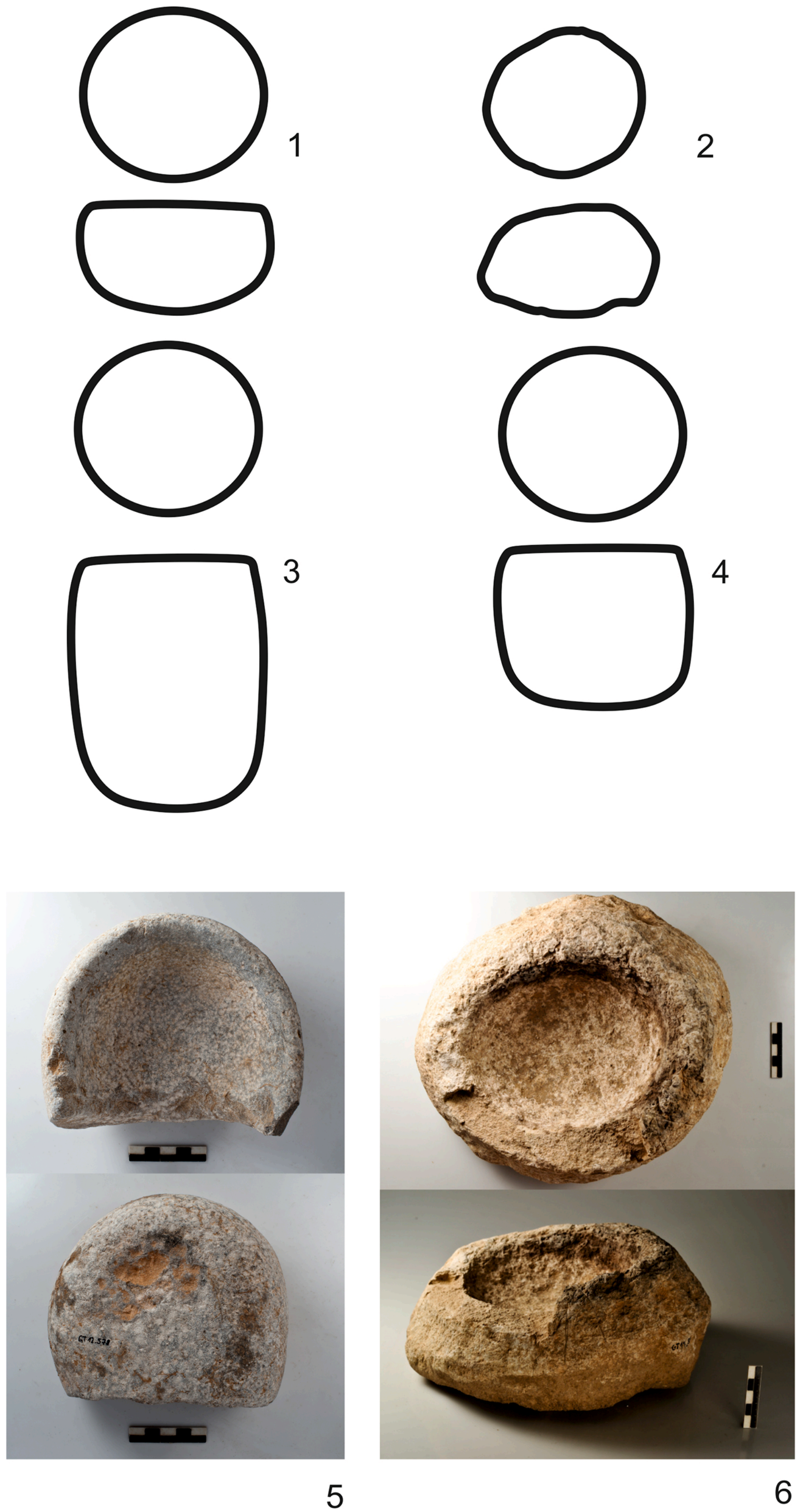

Fig. 2. Stone vessels from Göbekli Tepe: shapes (graphic L. Dietrich, photos German Archaeological Institute, N. Becker).

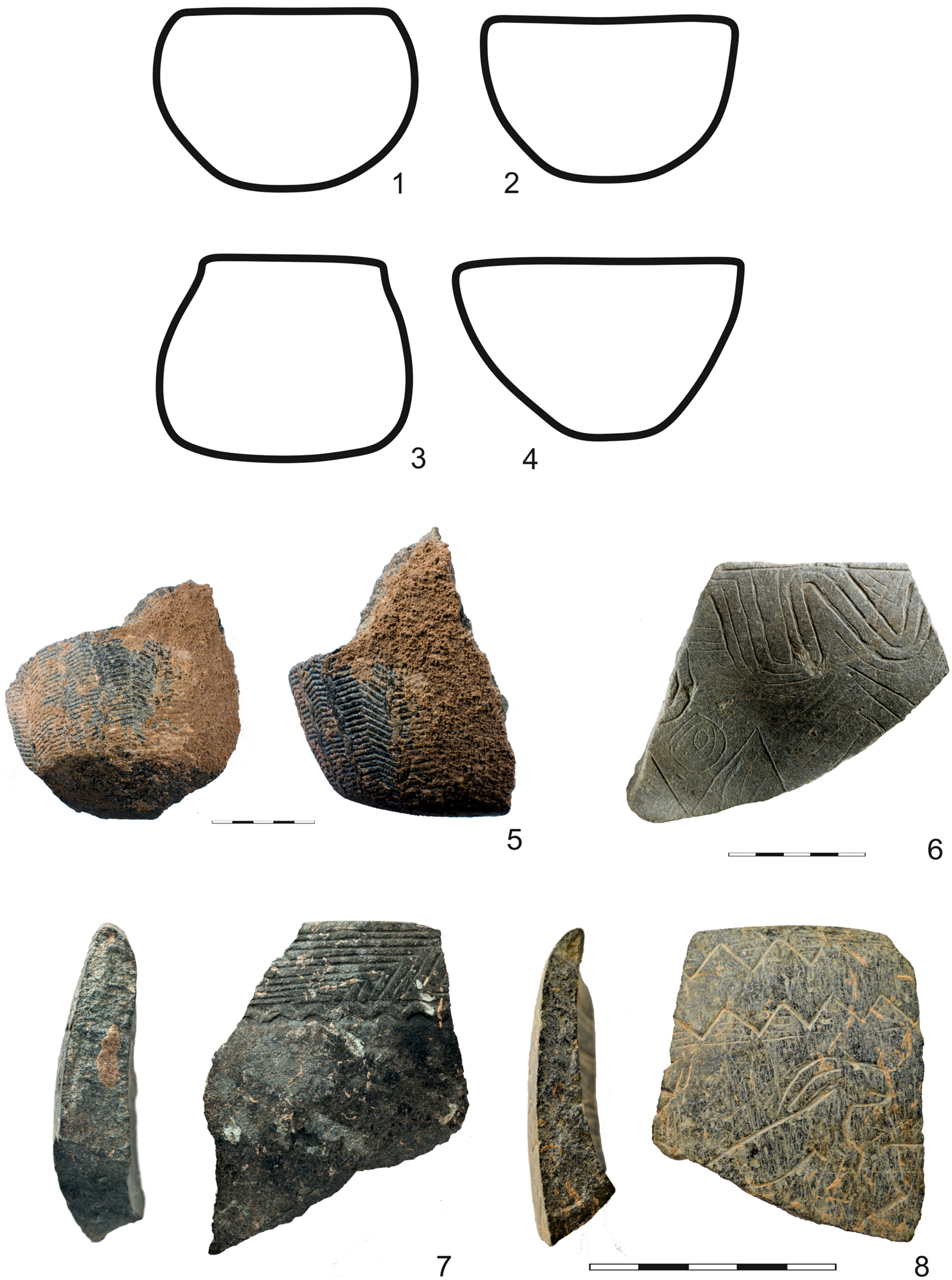

Fig. 3. 'Greenstone' vessels from Göbekli Tepe: shapes (graphics L. Dietrich; photos German Archaeological Institute, N. Becker, K. Schmidt).

limestone through flaking, carving and shaping, probably with hammers, axes, chisels, and hard cobbles. ST3 was carved and smoothed with circular motions up to its bottom while the bottom regions of ST3 and ST6 were flaked with hard tools with cutting edges, possibly axes, at angles of almost 90° to their walls. ST2 was carved irregularly with vertical strokes and circular motions. The interior was then smoothed while the exterior remained irregular with flaking traces and scar negatives. Only in one case (ST5) was the exterior smoothed like the

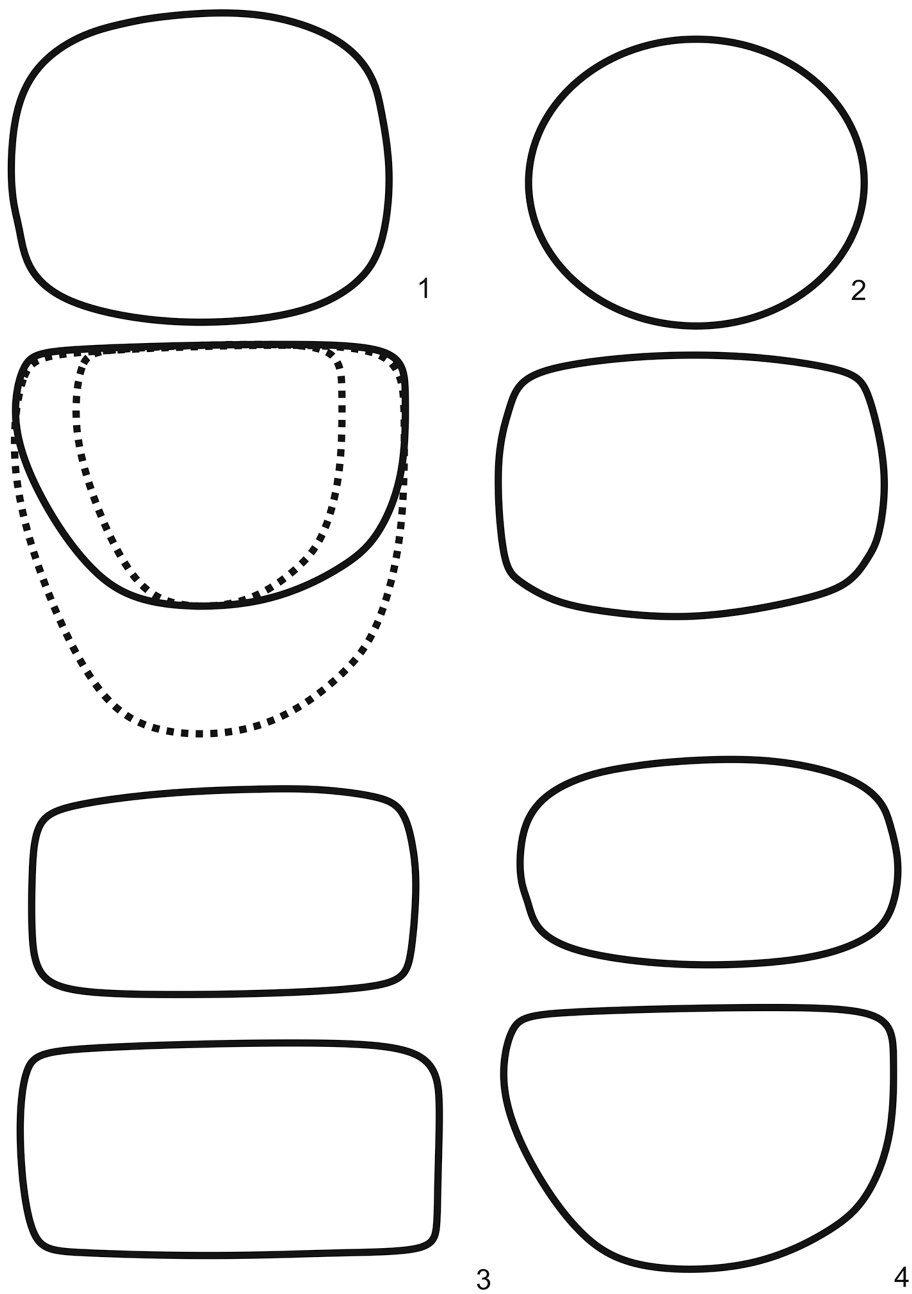

Fig. 4. Stone troughs from Göbekli Tepe: shapes (graphics L. Dietrich).

interior. In another case (ST2) the trough was deepened into a limestone boulder, the exterior surface showing no further treatment. A certain intention to produce symmetrical shapes is visible for most of the complete troughs; the walls have an almost consistent thickness and the rims are rounded.

Most of the trough fragments belong to shape 1 and show different wall curvatures. Their size cannot be reconstructed. 25% of the fragments have straight stable bottoms with walls rising at a sharp angle and belong to shapes 2 and 3. More effort was necessary to carve them, but their volume is larger. Troughs of shapes 1 and 4 would be unstable on plain floors. Beneath ST3 and ST5 stones were placed to ensure a stable position. The treatment of the interior was most probably related to their use: smoothing increased the impermeability of the walls.

111 round platters (S2.3) were found. They have diameters between 20 and 40 cm and a thickness of up to 10 cm with a median around 7 cm. Five shapes could be defined (Table 3, Fig. 7). All platters were shaped by flaking and then finely pecked, before either only the upper surface or the entire surface was smoothed and polished with a soft organic material, possibly animal skin.

Use-wear analyses (S1.2) were performed optically and through tactile analyses on the walls and bottoms of 12 stone vessels, troughs and platters and on the grinding gear. Data on the latter were already presented (Dietrich et al., 2019). A selection of ten fragments of troughs, and from small/medium-sized vessel walls as well as platters were examined macro- and microscopically (S1.2 Table 6). The vessels show no traces which can be interpreted beyond doubt as use-wear. Long scratches as well as scarring were observed, which may have occurred during production. Bottoms were only poorly preserved as fragments and show no particular use-wear. The troughs show similar traces which can be attributed to their production and not to their use. Erratic scratches were observed on the bottom of ST6. The absence of use-wear traces speaks against an active use as grinders or mortars, as some

Fig. 5. Stone troughs from Göbekli Tepe (Table 2 for contexts; photos German Archaeological Institute, N. Becker, O. Dietrich, I. Wagner).

ethnographic observations could suggest (Cappers et al., 2016). Only one exception was noticed: fragment ST7 has an unusually thick bottom covered with several moderately to highly reflective smooth zones with an irregular flat topography. They do not appear on the walls. This use-wear pattern has similarities with patterns observed on grinding stones. The preform for a vessel probably broke accidentally during fashioning and was then used as a grinding plate. The platters show markers related to pounding (Fig. 7/8–10) but these traces cannot be functionally determined at the moment.

1.2. Contextual analyses

There is a clear contextual connection between the rectangular and apsidal buildings and the assemblage of grinding stones and stone vessels, suggesting also a functional connection. The distribution of grinding stones indicates dynamic deposition processes and frequent relocation in and out of the buildings (Dietrich et al., 2019). Most were originally placed on the flat roofs of the buildings, occasionally falling inwards with the collapse of the roof into the middle and upper fills of rooms. Later they were dislocated through erosion towards the lower slope and became part of the middle and upper fills of the monumental buildings. The distribution of the stone vessel fragments follows the same patterns (Table 4).

The large troughs still standing in situ were – with one exception (ST2 found on a terrace next to grinding gear) – placed on floors in large rectangular and apsidal buildings, either directly next to a wall or in one of the corners. For most buildings, only the last use-phase is known, as the excavations usually stopped at the first floor level. However, one larger profile has revealed a dense succession of terrazzo floors in room 61, which contains ST4 (S1.1, Fig. 8). The vessel was already in place in the earliest use-phase of the building and remained in use over a long period of time. The large troughs are fixed containers within the rooms. They were only removed when they broke, as the distribution of fragments suggests. The fragments of troughs were found either on the terraces (34 fragments) or in the upper part of the fills of the monumental buildings (46 fragments), eroded from the terraces above. This disposal behavior is different from grinding stones or smaller vessels, which were occasionally left at the places where they broke or where they fell from above. The bulkiness of the troughs in comparison to smaller objects is surely part of the reason, but concepts of cleanliness would also have to be analyzed for Göbekli Tepe (Dietrich, 2016 for the methodology).

Complete platters were found both on the floors of the monumental buildings and on those of the rectangular and apsidal rooms (Fig. 9, Table 5). Their position in the monumental buildings in some cases suggests intentional depositions and a role with a likely cultic background. Most remarkable is a cache discovered in Building C, which contained a boar sculpture and several vessels (Schmidt, 2008). One platter was intentionally perforated and put over a vessel of shape 2, presumably destined to capture its contents.

Troughs, smaller vessels, platters and grinding stones were used in the same contexts, all belonging predominantly to the inventories of the (partially) later rectangular and apsidal buildings surrounding the monumental ones. Architectural analysis proposes a contemporaneity of most rectangular buildings, or better their excavated last floor levels (Kurapkat, 2015), but this has yet to be confirmed through radiocarbon dating. The rhythm of production, use and discard of vessels related to specific stratigraphical layers of these buildings cannot be calculated at the moment. Judging from the large number of relocated fragments we can assume that more buildings were initially equipped with troughs, vessels and grinding stones. No trough was found in situ in the monumental buildings. Platters are present only in possible ritual arrangements as described above, and the grinding stones from these buildings predominantly show use-wear traces and residues connected to the processing of ochre (Dietrich et al., 2019). The large and richly decorated 'special buildings' were not the loci for food processing.

The best evidence for understanding possible vessel functions from find contexts comes from the six large stone troughs standing still *in situ*. The availability of data on similar finds from other sites strengthens this line of argument. Several troughs were linked to the use of fire. Burnt stones were noticed in the filling of T6; T4 was surrounded by ashes and had fire traces on its bottom. In other sites large troughs were also associated both with traces of fire and burnt stones. At Jerf el Ahmar (Fig. 10), three large troughs were placed in a corner of a room together with platters, grinding stones and a vessel as well as charred emmer remains and seed cakes (Willcox and Stordeur, 2012). A cluster of burnt stones was found on the floor. At Tell Abr' 3, five troughs were found in an approximately 8 m wide circular building with central pillars

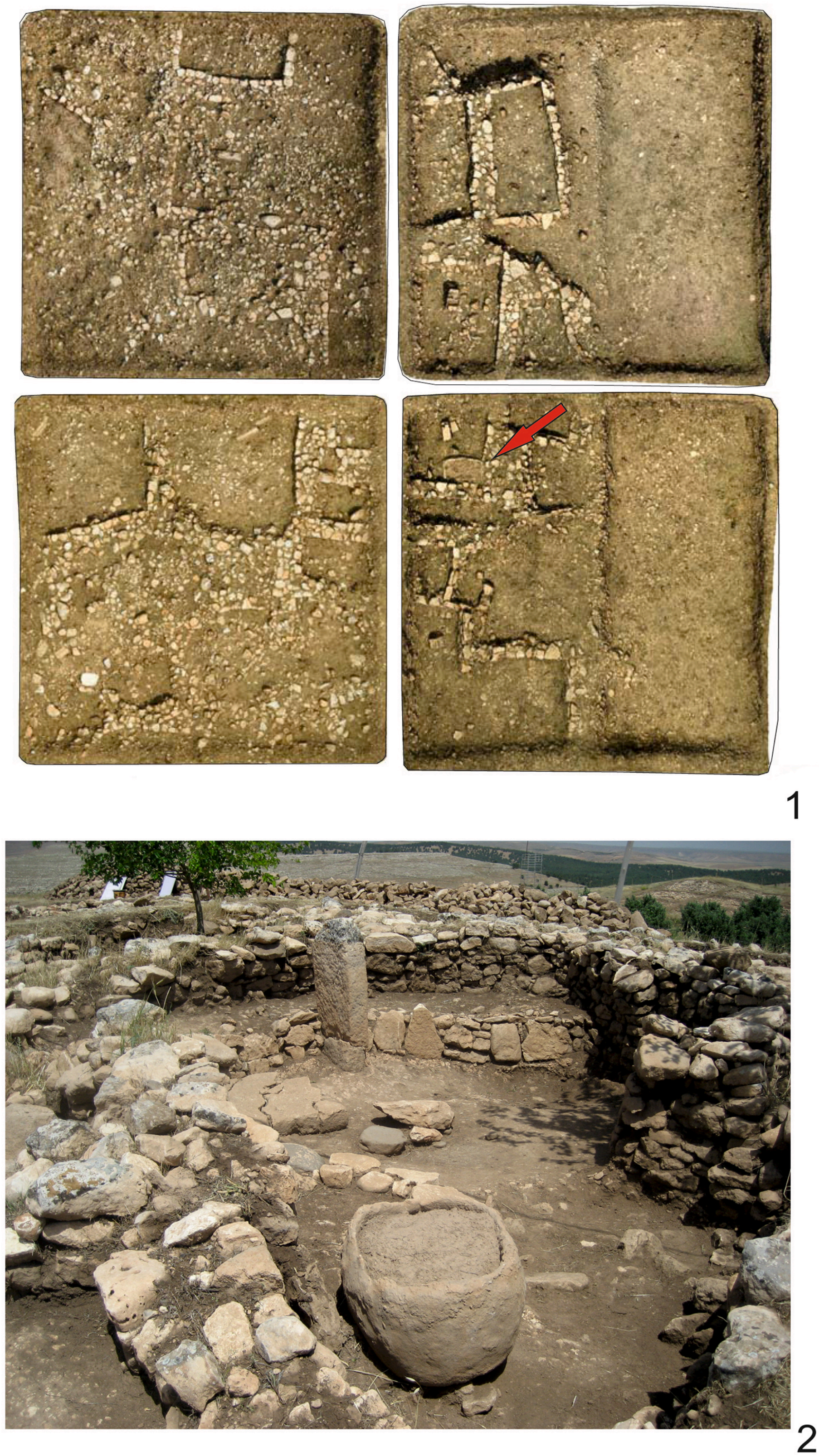

Fig. 6. Stone troughs *in situ* at Göbekli Tepe (Images German Archaeological Institute, T. Urban, O. Dietrich).

(Yartah, 2013). Charred cereals were found in several troughs and on the building floor. One of the troughs held an onager scapula (Yartah, 2013); a situation also encountered in ST6 from Göbekli Tepe (Dietrich et al., 2012). Burned stone balls were found in the vicinity of the Tell Abr‘ 3 troughs (Yartah, 2013). As proposed for Çatalhöyük (Atalay and Hastorf, 2006) and Jerf Ahmar, they could have served as heating stones. Stone balls were not discovered at Göbekli Tepe, but a re-evaluation of finds from the troughs revealed the presence of several burnt basalt stones. Two of them were handstone fragments, probably reused as heating stones as their uniform black coloration implies.

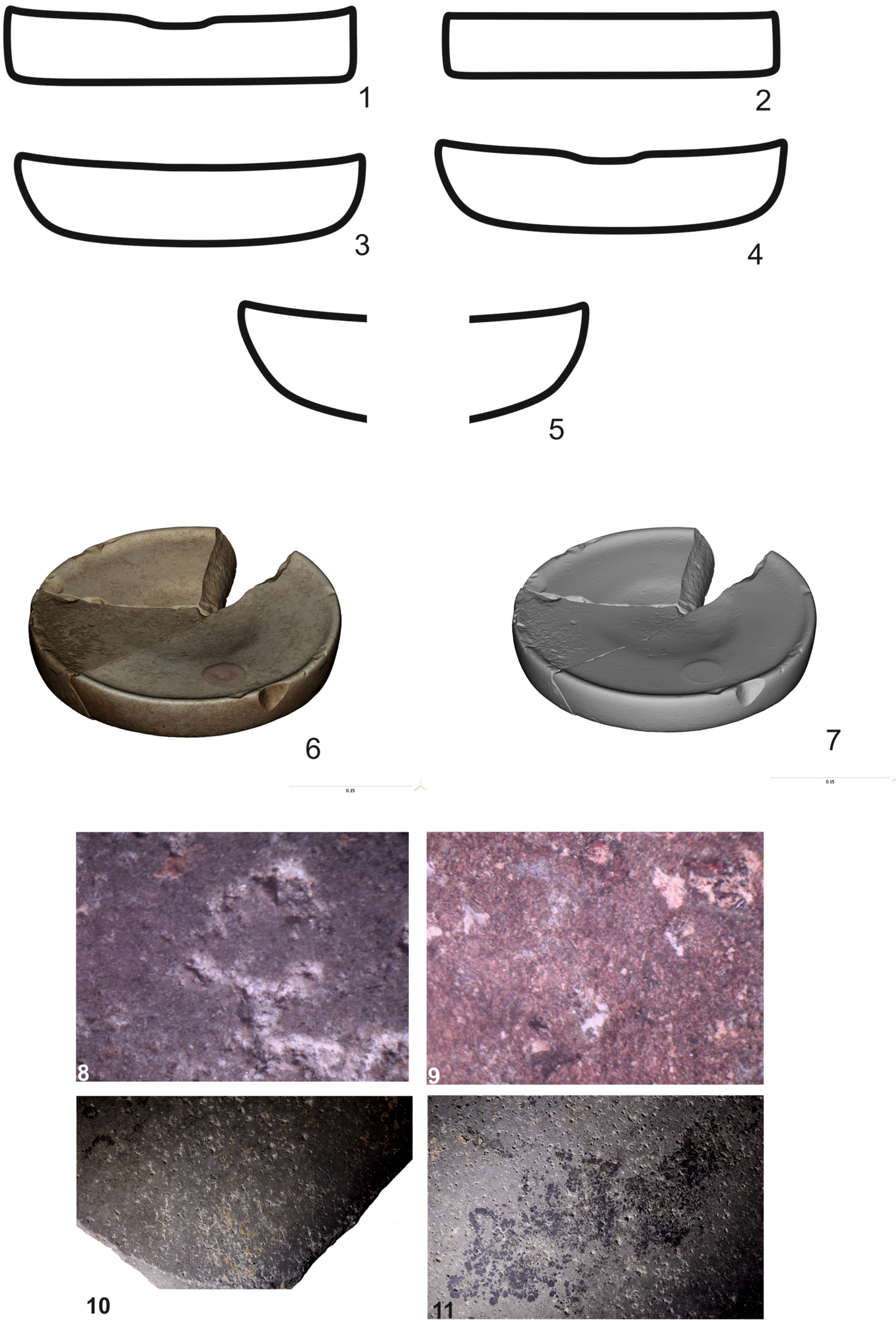

Fig. 7. Platters from Göbekli Tepe: shapes and microwear (graphics L. Dietrich, photos H. Höhler-Brockmann).

Ongoing experiments (Ullmann, in preparation and see below) have revealed the uniformity of burning/coloring as one of the characteristics of intentional multiple heating. The experiments also highlight the difficulties of recognizing intentional fire traces on basalt. A rough find screening during excavations may lead to false negative results, only microscopic analysis allows clear identification. It is possible that burnt basalt stones were removed as debris during excavations at Göbekli Tepe. The contexts and analogies hint at a cooking function for the troughs.

2. Residue analyses

Charred plant remains are nearly absent from the monumental and rectangular buildings (Neef, 2003) and none are associated with vessels.

Table 3
Platters from Göbekli Tepe: shape description.

Shape	Description
Shape 1	Platters with a defined rim and a deepened center. Walls and the bottom are straight.
Shape 2	Platters of shape 2 have walls and bottoms similar to shape 1 but the surface is straight and the rims are not defined.
Shape 3	Platters of shape 3 have curved walls and a straight center.
Shape 4	Platters of shape 4 have curved walls and a deepened center.
Shape 5	Perforated platter with a massive base.

Table 4
Find contexts of the stone vessels and troughs from Göbekli Tepe.

Find contexts of the stone vessels and troughs	Quantity
Rectangular and apsidal buildings, upper part of the fills.	56
Rectangular and apsidal buildings, lower part of the fills.	13
Rectangular and apsidal buildings, floors.	10
Monumental buildings, upper part of the fills.	153
Monumental buildings, lower part of the fills.	1
Monumental buildings, floors.	1
Terraces.	15
Uncertain.	64
Surface finds.	105

However, previous analyses of phytoliths from sediments have shown large concentrations of cereals (Dietrich et al., 2019; possibly *T. monococcum* in samples M11-269, M11-270, possibly *H. spontaneum* and *H. vulgare* in sample M11-133) in different contexts including rectangular rooms with stone vessels. The phytolith samples included one taken from a middle-sized limestone vessel found in a rectangular room (Dietrich et al., 2019, S4, S7, sample M11-133); it yielded evidence for *H. spontaneum* and *H. vulgare*. However, considering the impact of post-depositional processes, no clear association can be assumed between phytoliths and the fragment. Also, analysis of use-wear shows that processing of both fine and coarse flour of cereals was performed at Göbekli Tepe (Dietrich and Haibt, 2020; Fig. 11, S 1.2).

Starch analyses (S1.3) were performed optically and chemically to determine the presence of starch granules and polymers on three samples from the most promising trough, ST6 with its in situ contents that included burned stones and the onager scapula. Two samples were scratched from the bottom of ST6 and one sample taken from its content (samples M10-18, M10-114 and M10-116). Both the optical and chemical examination show that starch is not preserved in these samples. Several previous studies have shown that grinding and other types of processing like boiling combined with post-depositional processes may affect the preservation of starch negatively (Samuel, 2006; Henry et al., 2009; Dai et al., 2013). Even in charred fragments of cereal food, starch was badly preserved (Arranz-Otaegui et al., 2018). The absence of starch in samples from Göbekli Tepe may be a consequence of the previous processing of cereals.

Putative biomarker analyses (S1.4) were performed through Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (ESI(−) FT-ICR MS) on content samples from ST3, ST4, ST5, ST6 and ST7. Every sample analyzed yielded a similar arrangement with between 1410 and 1778 elementary compositions corresponding to mainly oxygen- (CHO) and oxygen–nitrogen-containing (CHON) species, respectively representing close to 61% and 37% of the contributions (Table 7). The sample ST6 has more CHO species with 71% of the assignments and 27% of CHON compounds. The observed highly saturated chemical signature with

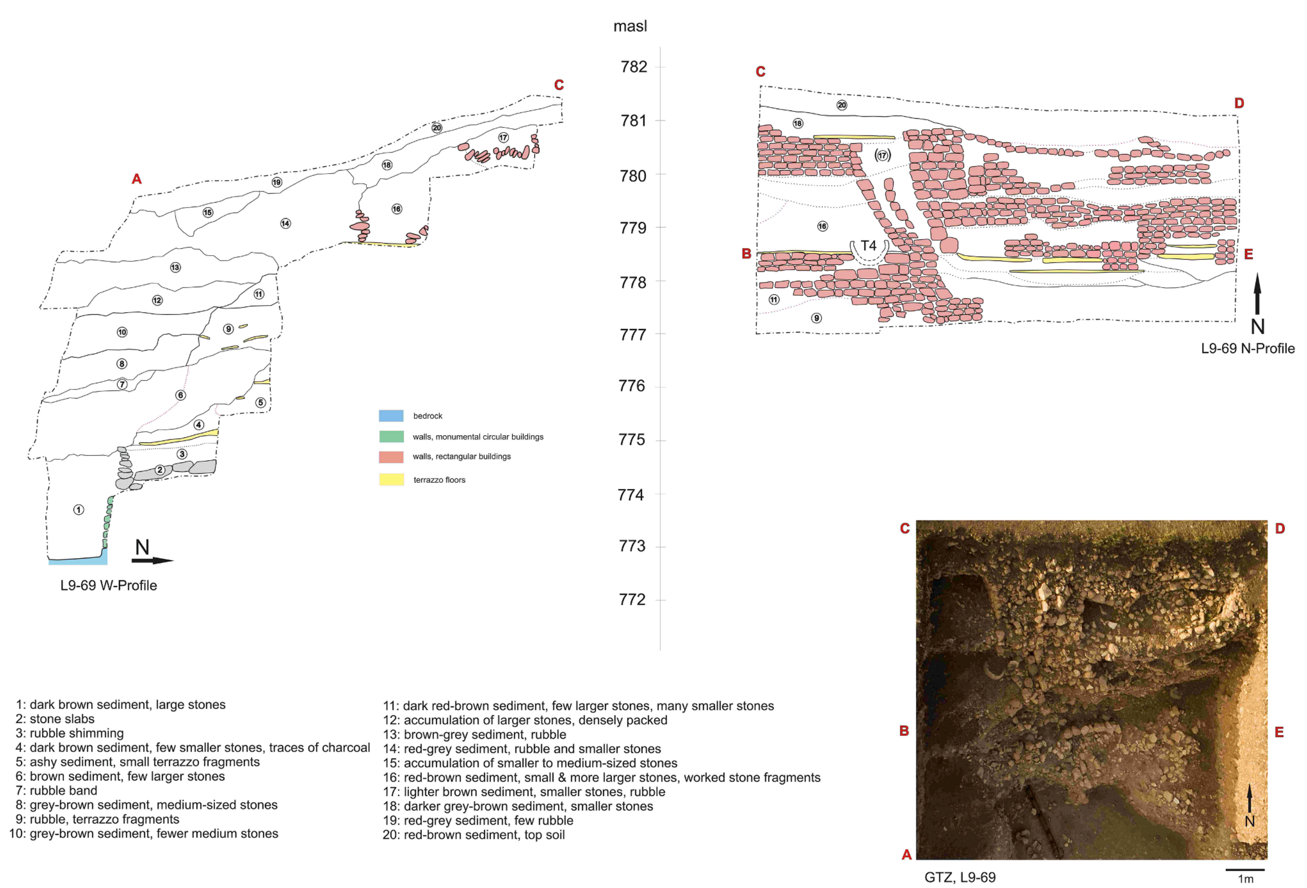

Fig. 8. Profile of the excavation area L9-69 at Göbekli Tepe (German Archaeological Institute, photo K. Schmidt, graphics J. Notroff).

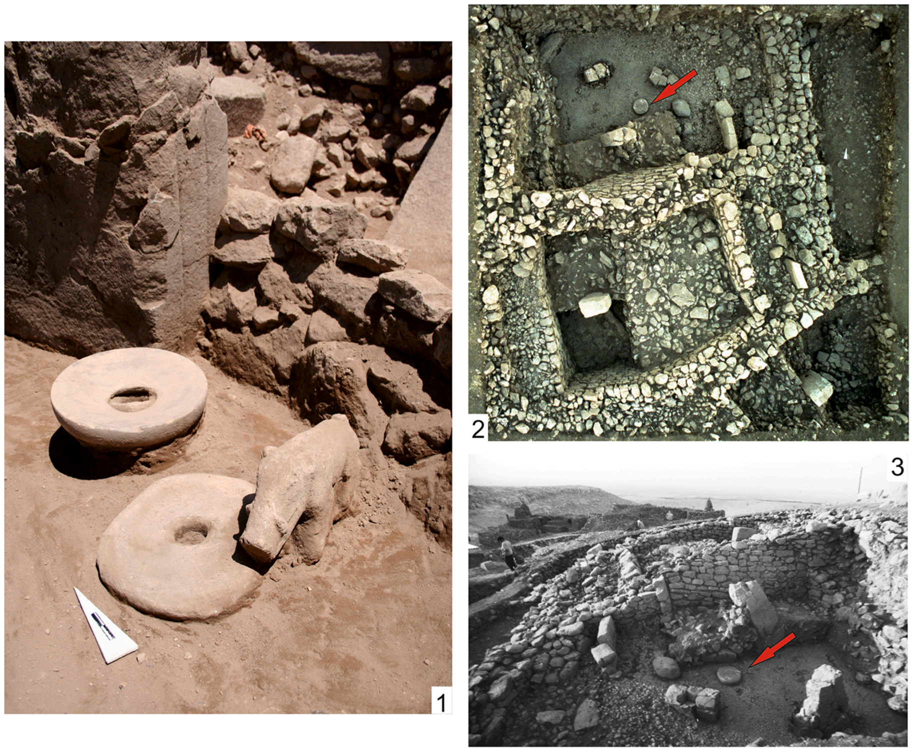

Fig. 9. Platters from Göbekli Tepe in situ (photos German Archaeological Institute, Klaus Schmidt).

Table 5
Find contexts of the platters from Göbekli Tepe.

Find contexts of platters	Quantity
Rectangular and apsidal buildings, upper part of the fills.	7
Rectangular and apsidal buildings, lower part of the fills.	5
Rectangular and apsidal buildings, floors.	4
Monumental buildings, fills.	33
Monumental buildings, floors.	7
Terraces.	1
Uncertain/Early contexts.	45
Surface finds.	5

homologous chemical series (in CH_2) is not corresponding to any compositional profile of soil organic matter such as humic material that has typically a strong aromaticity and oxygen contents (Schulze-Makuch et al., 2018). Signals putatively attributed to fatty acids were found in different intensities (Table 8). They most probably originate from plant biomolecules, as they could be determined as long chain fatty acids. Interestingly, hydroxyl and dicarboxylic acids are both oxidation products of unsaturated fatty acids caused by ageing but also by burning processes resulting for example from cooking. Regarding cereal biomarkers, some hints with formulae of alkylresorcinol (AR) species were found. AR C17:0 and AR C19:0 were found either in two or in all samples, respectively, but with a very low intensity. This last result suggests the former presence of cereals in the containers. Very few carbohydrate species (monosaccharides) are observed (Fig. 12), which may originate from the cereal starch. The most striking fact in these samples is the high amount of CHON species localized in the fatty acid area of the van Krevelen diagram (Fig. 12) showing a close chemical information. Most of these species contain one nitrogen atom and are saturated or contain one double bond, due to the high hydrogen-to-carbon ratio (H/C) values. A possible explanation is that these components are fatty amides stemming from the reaction between a fatty acid and ammonia during heating. Cereals contain a certain amount of fatty acids and protein; therefore, ammonia could possibly stem from protein decomposition due to heat. No signs of cholesterol compounds, typical of animal fat, were found. However, the presence of such fatty amides may also be due to modern contamination from plasticizer slip reagents.

Gas chromatography-mass spectrometry (GC–MS) analyses of the same five trough samples (S1.5) yielded similar chemical evidence as those obtained by FT-ICR MS, viz., the prevalence of fatty acids, the lack of cholesterol and other zoosterols, and the presence of nitrogenous compounds (S1.5, Fig. 13). Additionally, the GC–MS results showed a higher ratio of palmitic to stearic acid, as well as lignin phenols that are attested in ‘paleovegetation’, which may be due to ancient plant materials.

Fatty acids dominated all the samples, as was also documented by FT-ICR MS (S1.4). The high palmitic to stearic acid ratio is more typical of plant products (McGovern et al., 2013). Other saturated fatty acids that were present, including pelargonic (C_9), capric (C_{10}), lauric (C_{12}) and myristic (C_{14}), might have either plant or animal sources. The two monounsaturated fatty acids - palmitoleic (C_{16}) and oleic (C_{18}) - are also found in both plants and animals. The absence of cholesterol or any other zoosterol, based on both the GC–MS and FT-ICR MS results, provides an additional argument that the fatty acids are not animal derived. Nevertheless, if a trough or sample were handled post-excavation, modern steroids and fatty acids found on human skin, including palmitic, stearic and other fatty acids, might be secondarily introduced.

In short, the two chemical techniques generally used in combination as their results overlap, reinforce the interpretation that any ancient organics in the samples are probably derived from plants. Moreover, the lignin phenols have been argued to provide molecular traces of “paleovegetation“ (Kovaleva and Kovalev, 2015). However, no specific biomarkers for cereals, herbs or other plants were detected by either technique.

Modern contaminants are also present in the samples, as seen on the GC–MS chromatogram (Fig. 13). Polychlorinated biphenyl is a universally observed modern contaminant in GC–MS analyses. Oleamides, erucamides, phthalates, and triphenylphosphate are common plasticizer slip reagents. Oleonitrile and eruconitrile are amide reaction products resulting from the high temperature (325 °C) at the injection port. Erucic

Table 6
Macroscopical and microscopical analyses on troughs, vessels, and platters from Göbekli Tepe.

Vessels	Topography/Levelling	Linear traces	Polish	Burning traces	Fractures	Tactile	Markers
ST3. L09-70, Locus 4. Trough in situ	Flat irregular. Levelling connected, covering.	Striations,circular and erratic.	No	No	Scar negatives on the rims.	Smooth.	Unspecific.
ST4. L09-69, Locus 31. Trough in situ	Flat irregular, Levelling connected, covering.	Striations, circular and erratic.	No	On the bottom	Scar negatives on the rims.	Smooth.	Unspecific.
ST6. K10-79 Locus 29. Trough in situ	Rugged and flat irregular.	Striations, erratic and concentrated on the bottom.	No	No	Scar negatives on the rims.	Rough.	Unspecific.
Nr. 20_001 (8359?) Vessel	Rugged and flat irregular on the walls. Flat irregular and sinuous irregular on the bottom. Levelling concentrated on the HT, covering the HT.	Striations on the walls, circular and erratic. Striation on the bottom on the HT, erratic.	Dull and slightlyreflective on the bottom	No	Scar negatives on the rims.	Smooth on the bottom, rough on the walls.	Of coarse flour.
Nr. 20_002 Vessel	Rugged and sinuous irregular.	Striations, circular and erratic.	No	No	Scar negatives on the rims.	Smooth and rough mixed.	Unspecific.
GT10, K10-58, Loc23 Vessel	Rugged and sinuous irregular.	Striations,circular and erratic.	No	No	Scar negatives.		
Nr. 19_000008 Platter	Flat regular, leveling covering the surface.	Striations long, parallel and short, erratic.	Slightly reflective surface, high reflective bands	No, but Bitumen traces	Scar negatives in the center of the plate.	Very smooth.	Unspecific.
GT08-67 Platter	Flat regular, leveling covering the surface.	Striations long, parallel and short, erratic.	Slightly reflective surface,high reflective bands		Scar negatives in the center of the plate.	Very smooth.	Unspecific.
SGN 1872 Platter	Flat and sinuous irregular.	Striations,circularand erratic	No	No	Scar negatives on the rims.	Smooth.	Unspecific.
SGN 2921 Platter	Flat and sinuous irregular.	Striations, circular and erratic.	No	No	Scar negatives on the rims.	Smooth.	Unspecific.
Experimental trough before use	Rough irregular.	Traces of sawing and scars from the manufacture with modern tools.	No	No	Scars from the manufacture with modern tools.	Rough.	Unspecific.
Experimental trough after use	Rough irregular.	Traces of sawing and scars from the manufacture with modern tools.	No	No	Scars from the manufacture with modern tools.	Rough.	Unspecific, identical with the preceding.

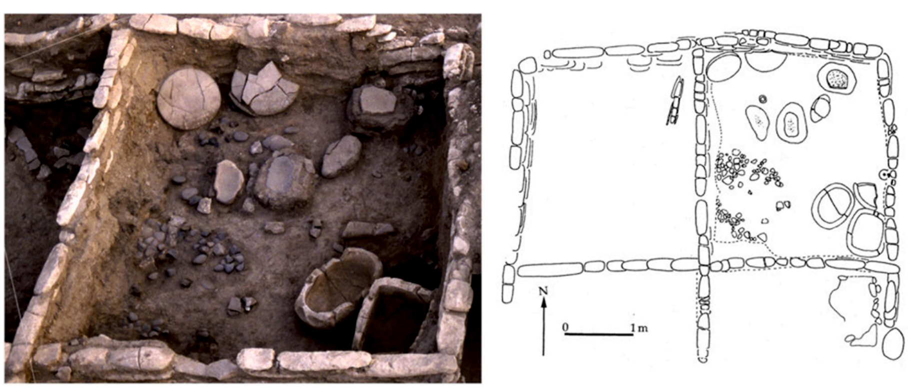

Fig. 10. The 'Kitchen' in Jerf el Ahmar with stone troughs and grinding gear (after Stordeur, 2015).

acid might have been similarly formed, but it could also be an ancient compound from a plant with a high concentration of the acid, particularly rapeseed or a mustard. Mustard seeds are attested in the 'kitchen' of Jerf el Ahmar (Willcox and Stordeur, 2012). The diterpenoid compound (abietic acid) and triterpenoid compound (moronic acid) could be derived from tree resins. Arachidonic acid is contained in high concentrations in Artemisia (wormwood and mugwort), which are important as medicinal (especially antimalarial) additives to fermented beverages e.g. in China (McGovern et al., 2010). Margaric (C-17) acid occurs in milk fat but also in some species of Vicia (Çaçan et al., 2016); given site context and date both would be possible, but the latter is more likely. There are no indications for incipient domestication and there is no evidence for herd management from Göbekli Tepe so far (Peters et al., 2019).

The various nitrogenous modern contaminants, which were detected by GC–MS, might also explain some of the CHON compounds reported for the FT-ICR MS analyses, which are argued to have possibly resulted from an ancient heating process (S1.4).

Taking the two sets of chemical data together, the combined evidence suggests that a cereal product was prepared in the troughs. This conclusion gains added credence in light of the well-attested cereal remains inside troughs and on the floor, together with grinding implements, fire-cracked stones, etc. at the contemporaneous sites of Jerf el Ahmar and Tell Abŕ3 in northern Syria (see above). Although the macro- and micro-archaeobotanical, and organic residue evidence is more minimal and equivocal at Göbekli Tepe, signs of burning on the exterior

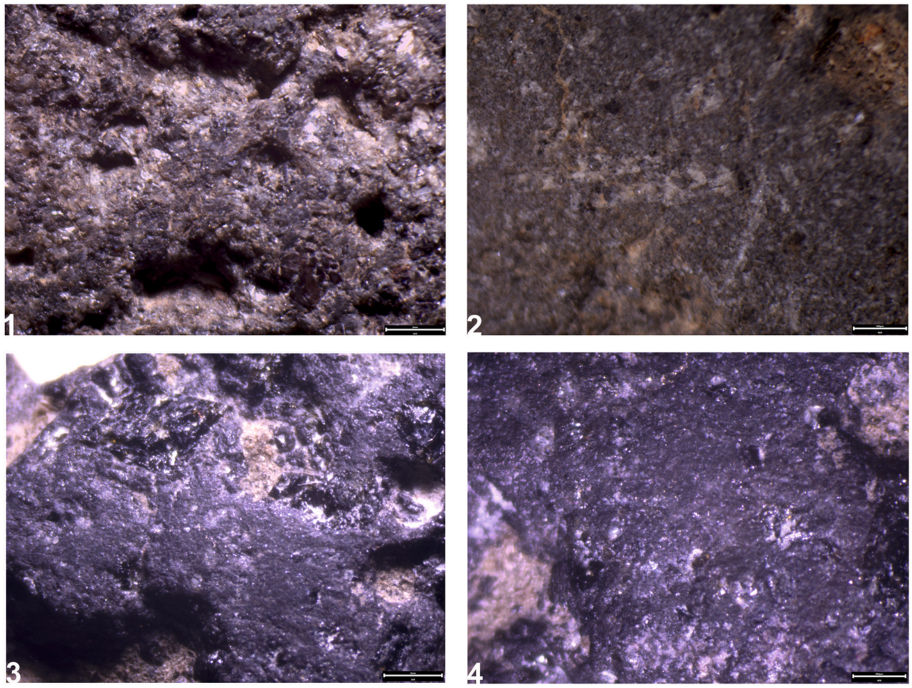

Fig. 11. Microwear on handstones (L. Dietrich).

Table 7
Composition description of the residue collected from five samples, from Gobeliki Tepe, and analysed by ESI(−) FT-ICR MS with number of features per molecular series and corresponding percentages.

	St3 - Probe 2	St4 - Probe 4	St5 - Probe 8	St6 - Probe 11	St7 - Probe 6
CH/CHO	1035 (61%)	902 (60%)	887 (63%)	1269 (71%)	985 (62%)
CHOS	20 (1%)	18 (1%)	17 (1%)	35 (2%)	4 (0%)
CHON	633 (38%)	586 (39%)	506 (36%)	474 (27%)	606 (38%)
TOTAL	*1688*	*1506*	*1410*	*1778*	*1595*

of two troughs, fragments of fire-cracked basalt, etc. point in the same direction. Fire-cracked stones, in particular, suggest that a more liquid product - perhaps a porridge, gruel or beer - was prepared in the troughs (for further discussion and references, see McGovern, 2009; McGovern and Hall, 2016, and McGovern, 2017). The current results and conclusions need to be double-checked using more refined chemical analyses, viz., liquid chromatography-mass spectrometry-mass spectrometry (LC-MS-MS).

As much of the evidence hints at a use of the large stone troughs as cooking vessels, a series of experiments was designed to determine their suitability for cooking.

3. Experiments: grinding, cooking, brewing

An additional approach to functional studies on artefacts is to experimentally measure their functional capacity. We tested the possibility of using large troughs as tools for cooking porridge and brewing beer with heating stones as both possibilities were indicated by the evidence. Two experiments were performed with a replica trough following the shape of ST6 (S1.6, S1.7, Fig. 14). The replica vessel was made from a limestone block using modern tools in 8 h. In comparison to the original the replica was smaller, with a capacity of 30 l. This is the lowest limit of the capacities of the preserved stone troughs from Göbekli Tepe.

For practical reasons we combined the experiments by using malted Einkorn to boil porridge in a first step; this was then separated into grains and liquid and subsequently fermented to beer. No other ingredients were added, and the Einkorn malt was not previously soaked but only coarsely ground. Malting includes wet treatment, which possibly weakens resistance during thermal processing and shortens the cooking time. As previous soaking with similar effects can be presumed for prehistoric operational chains, we did not consider this difference to essentially affect our experiment and results. Beer can be made in various ways and with various ingredients (Narziß et al., 2017). Hayden et al. (2013) as well as Rosenstock and Scheibner (2018) have described the processes in detail based on prehistoric and ethnographic evidence. We chose the simplest procedure, which includes (previous) malting of Einkorn, its coarse crushing, heating in water, mashing, lautering and fermenting without added yeast and hops. The ratio of 1:5 of malt and water was chosen in accordance with modern standards of beer brewing. Of course, in the case of porridge, the quantity of water is variable; however, it could be observed that by using this method of cooking, more water in relation to grains would avoid loss due to adhesion to the cooking stones.

It takes one work day (8 h) to coarsely grind 4 kg of malt and to boil it to porridge in 20 l of water, and another 5 days until the leftover liquid (11 l) will ferment to a beer-like beverage with a low concentration of alcohol of 2%. The whole process of cooking to porridge/beer was perceived as easy to perform and practicable with a small team of 2–4 people even with inexperienced participants. The heating stones of limestone or basalt were transferred with wooden spoons; other tools like the aforementioned onager scapulae would have also worked. A total of 33 basalt and 96 limestone heating units were used experimentally, but around 10 constantly reheated stones would have sufficed. Extrapolating the data, it would need 78 heating units for a container of 70 l and 182 heating units for the largest container of 165 l in the same period of time; much less during higher outdoor temperatures. 9.4 kg of Einkorn malt or cereals could have been cooked in a 70 l trough or 22 kg in the 165 l trough. As the experiments showed, cooking at higher temperatures (up to 90 °C) can be easily achieved by introducing more heating units.

All cooking stones were heavily burnt. The heating leaves obvious traces on limestone, which immediately becomes uniformly black. Traces on basalt are much less visible. The latter can thus be easily

Table 8
Candidate compounds attributed to *m/z* peaks observed in the ESI(−) FT-ICR mass spectra of the five samples from Göbekli Tepe. Baseline of the mass spectra is at 1.5×10^6.

Cat.	Candidate compound	*m/z*	Formula	St3	St4	St5	St6	St7
Fatty acids	Octanoic acid - C8:0	143.1077540	C8H16O2	5.75E + 07	9.03E + 07	8.32E + 07	6.69E + 08	2.41E + 08
	Nonanoic acid - C9:0	157.1234040	C9H18O2	1.36E + 08	1.58E + 08	1.44E + 08	7.40E + 08	3.76E + 08
	Decanoic acid - C10:0	171.1390540	C10H20O2	1.22E + 08	1.49E + 08	1.50E + 08	5.83E + 08	3.14E + 08
	Undecanoic acid - C11:0	185.1547040	C11H22O2	4.25E + 07	5.39E + 07	4.80E + 07	1.46E + 08	8.65E + 07
	Dodecanoic acid - C12:0	199.1703540	C12H24O2	3.52E + 08	2.90E + 08	2.03E + 08	2.59E + 09	2.49E + 08
	Tridecanoic acid - C13:0	213.1860040	C13H26O2	6.11E + 07	6.91E + 07	4.92E + 07	1.88E + 08	9.59E + 07
	Myristic acid - C14:0	227.2016540	C14H28O2	1.43E + 08	1.80E + 08	9.66E + 07	6.45E + 08	1.53E + 08
	Pentadecanoic acid - C15:0	241.2173040	C15H30O2	8.90E + 07	1.64E + 08	6.77E + 07	6.31E + 08	1.27E + 08
	Palmitic acid - C16:0	255.2329540	C16H32O2	8.02E + 08	1.45E + 09	5.38E + 08	3.86E + 09	7.11E + 08
	Margaric acid - C17:0	269.2486040	C17H34O2	5.04E + 07	8.94E + 07	3.71E + 07	3.25E + 08	6.41E + 07
	Stearic acid - C18:0	283.2642540	C18H36O2	3.89E + 08	8.65E + 08	3.22E + 08	1.76E + 09	3.08E + 08
	Nonadecylic acid - C19:0	297.2799040	C19H38O2	1.02E + 07	1.64E + 07	6.46E + 06	5.04E + 07	1.24E + 07
	Arachidic acid - C20:0	311.2955540	C20H40O2	1.69E + 07	3.58E + 07	1.17E + 07	1.21E + 08	1.45E + 07
	Behenic acid - C22:0	339.3268540	C22H44O2	1.48E + 07	3.59E + 07	1.06E + 07	1.40E + 08	1.29E + 07
	Tricosylic acid - C23:0	353.3425040	C23H46O2	1.24E + 07	3.04E + 07	8.03E + 06	1.05E + 08	1.16E + 07
	Tetracosanoic lignoceric acid - C24	367.3581540	C24H48O2	3.51E + 07	9.82E + 07	2.57E + 07	4.14E + 08	2.92E + 07
	Hexacosanoic acid - C26:0	395.3894540	C26H52O2	1.93E + 07	5.87E + 07	1.53E + 07	2.20E + 08	1.56E + 07
	Octacosanoic acid - C28:0	423.4207540	C28H56O2	6.64E + 06	2.02E + 07	5.50E + 06	6.05E + 07	5.16E + 06
	Triacontanoic acid - C30:0	451.4520540	C30H60O2	–	7.81E + 06	2.96E + 06	2.13E + 07	–
	Dotriacontanoic acid - C32:0	479.4833540	C32H64O2	–	3.48E + 06	–	6.42E + 06	–
	Tetratriacontanoic acid - C34:0	507.5146540	C34H68O2	–	–	–	2.95E + 06	–
	Palmitoleic acid - C16:1	253.2173040	C16H30O2	1.02E + 08	1.71E + 08	6.95E + 07	8.03E + 08	1.32E + 08
	Oleic acid - C18:1	281.2486040	C18H34O2	2.16E + 08	3.34E + 08	1.39E + 08	1.47E + 09	1.83E + 08
	Linoleic acid - C18:2	279.2329540	C18H32O2	1.87E + 07	5.25E + 07	1.32E + 07	2.15E + 08	2.78E + 07
	Eicosadienoic acid - C20:2	307.2642540	C20H36O2	2.73E + 06	9.19E + 06	–	5.41E + 07	4.90E + 06
	Linolenic acid - C18:3	277.2173040	C18H30O2	2.27E + 06	6.47E + 06	2.79E + 06	1.61E + 07	5.25E + 06
	Stearidonic acid - C18:4	275.2016540	C18H28O2	–	2.67E + 06	–	4.40E + 06	–
	Arachidonic acid -C20:4	303.2329540	C20H32O2	–	5.07E + 06	2.56E + 06	9.29E + 06	5.16E + 06
	Eicosapentaenoic aicd - C20:5	301.2173040	C20H30O2	1.62E + 07	4.02E + 07	6.52E + 06	1.92E + 07	3.84E + 07
	Gondoic acid	309.2799040	C20H38O2	2.08E + 07	3.04E + 07	1.30E + 07	8.53E + 07	1.56E + 07
	Eruric acid	337.3112040	C22H42O2	2.40E + 08	2.42E + 08	1.66E + 08	2.93E + 08	1.31E + 08
	Tetracosenoic acid	365.3425040	C24H46O2	5.56E + 06	8.45E + 06	5.05E + 06	3.08E + 07	4.55E + 06
Diacids and hydroxyfatty acids	Adipic acid C6	145.0506340	C6H10O4	–	–	–	9.34E + 06	–
	Pimelic acid C7	159.0662840	C7H12O4	–	–	–	3.83E + 06	–
	Octanedioic acid/Suberic acid	173.0819340	C8H14O4	4.70E + 06	4.80E + 06	3.62E + 06	2.02E + 07	4.81E + 06
	Nonanedioic acid/Azelaic acid	187.0975840	C9H16O4	2.30E + 07	2.20E + 07	1.88E + 07	5.18E + 07	2.43E + 07
	Sebacic acid C10	201.1132340	C10H18O4					

(continued on next page)

Table 8 (*continued*)

Cat.	Candidate compound	*m/z*	Formula	St3	St4	St5	St6	St7
				3.40E + 07	2.28E + 07	2.55E + 07	5.81E + 07	2.97E + 07
	Diacid C14	257.1758340	C14H26O4	1.11E + 07	9.80E + 06	7.11E + 06	1.82E + 07	1.18E + 07
	Ferulic acid	193.0506340	C10H10O4	1.05E + 07	1.67E + 07	1.42E + 07	3.05E + 07	5.35E + 07
	Hexadecanedioic acid	285.2071340	C16H30O4	1.03E + 07	1.27E + 07	1.05E + 07	3.45E + 07	1.91E + 07
	Octadecenedioic acid	311.2227840	C18H32O4	1.00E + 07	1.26E + 07	7.31E + 06	1.65E + 07	1.17E + 07
	Octadecanedioic acid	313.2384340	C18H34O4	2.03E + 07	2.04E + 07	1.63E + 07	3.76E + 07	2.48E + 07
	Eicosanedioic acid	341.2697340	C20H38O4	9.56E + 06	1.76E + 07	1.09E + 07	5.28E + 07	1.75E + 07
	Docosanedioic acid	369.3010340	C22H42O4	5.86E + 07	5.56E + 07	5.43E + 07	1.44E + 08	7.45E + 07
	Hydroxynonanedioic acid	203.0924990	C9H16O5	3.83E + 06	3.04E + 06	3.26E + 06	–	3.37E + 06
	Dihydroferulic acid	195.0662840	C10H12O4	–	–	–	3.34E + 06	–
	Hydroxydecanoic acid	187.1339690	C10H20O3	2.08E + 07	1.85E + 07	1.94E + 07	3.90E + 07	2.96E + 07
	Hydroxyhexadecanoic acid	271.2278690	C16H32O3	1.49E + 07	1.92E + 07	7.56E + 06	2.86E + 07	1.68E + 07
	Hydroxyoctadecanoic acid	299.2591690	C18H36O3	7.00E + 06	1.02E + 07	4.70E + 06	2.56E + 07	7.99E + 06
	Hydroxyoctadecenoic acid/Ricinoleic acid	297.2435190	C18H34O3	6.08E + 07	4.73E + 07	4.96E + 07	7.60E + 07	5.79E + 07
	Hydroxyeicosanoic acid	327.2904690	C20H40O3	2.50E + 06	–	–	1.20E + 07	–
	Hydroxydocosanoic acid	355.3217690	C22H44O3	3.60E + 06	4.00E + 06	–	1.26E + 07	–
	Dihydroxyoctadecanoic acid	315.2540840	C18H36O4	3.02E + 07	2.33E + 07	2.37E + 07	3.55E + 07	4.06E + 07
	Dihydroxyeicosanoic acid	343.2853840	C20H40O4	1.42E + 07	6.67E + 06	9.18E + 06	2.79E + 07	1.48E + 07
	Dihydroxydocosanoic acid	371.3166840	C22H44O4	2.93E + 07	1.27E + 07	1.76E + 07	3.28E + 07	2.40E + 07
	Dihydroxytetracosanoic acid	399.3479840	C24H48O4	3.11E + 07	1.78E + 07	2.06E + 07	5.18E + 07	3.05E + 07
MAG / DAG / TAG	MAG - C14:0	301.2384340	C17H34O4	5.45E + 07	5.58E + 07	4.23E + 07	6.20E + 07	3.79E + 07
	MAG - C16:0	329.2697340	C19H38O4	3.42E + 07	3.97E + 07	3.08E + 07	3.02E + 07	2.77E + 07
	MAG - C16:1	327.2540840	C19H36O4	1.47E + 07	1.74E + 07	1.28E + 07	4.06E + 07	1.62E + 07
	MAG - C18:0	357.3010340	C21H42O4	2.73E + 07	1.07E + 07	1.56E + 07	3.16E + 07	2.10E + 07
	MAG - C18:1	355.2853840	C21H40O4	9.94E + 06	1.51E + 07	8.48E + 06	3.67E + 07	1.34E + 07
	DAG - C14:0 C14:0	511.4367990	C31H60O5	–	–	–	2.91E + 06	–
Alkyl-resorcinol	Heptadecylresorcinol (C17:0)	347.2955540	C23H40O2	–	–	2.31E + 06	4.21E + 06	–
	Nonadecylresorcinol (C19:0)	375.3268540	C25H44O2	3.08E + 06	9.78E + 06	3.80E + 06	5.68E + 06	8.03E + 06

overlooked during excavations, especially when other fire traces or fire installations are largely absent in the archaeological record, as is the case at Göbekli Tepe. However, a solid crust of burned Einkorn immediately formed on the stone surface (Fig. 15; see Heiss et al., 2020) and remained stuck even after further immersion in water. The surface of the stone trough showed no deformation after three heating events with a duration of 2:30 h each. However, some of the factors impacting the vessels from archaeological contexts could not be simulated in the experiments: constant heating and cooling events over a long period of time, heating in wet weather conditions, and post-depositional effects like dislocation as part of erosion processes.

The temperature was maintained by adding or removing heating units and constantly checking with a thermometer; traditional brewers would have either used the reflective properties of the water (Hayden et al., 2013), counted the heating units or tested with a finger. Lautering resulted in 11 l of wort. Thus, through the cooking process with heating stones and liquid absorption approximately one third of the liquid was lost. Extrapolating for larger troughs, quantities of 25 l respectively 60 l of beer could be calculated.

4. Discussion and results

Our integrated contextual, functional, residue analytical, and experimental approach indicates that parts of the stone vessel assemblage at Göbekli Tepe can be linked to practices of cooking and consumption of cereal meals like porridge, gruel, and possibly beer.

Use-wear analysis on handstones has produced evidence for large-scale processing of cereals, whose presence at the site is substantiated by phytolith data in the absence of charred plant remains (Dietrich et al., 2019; Dietrich and Haibt, 2020). The current paper presents evidence

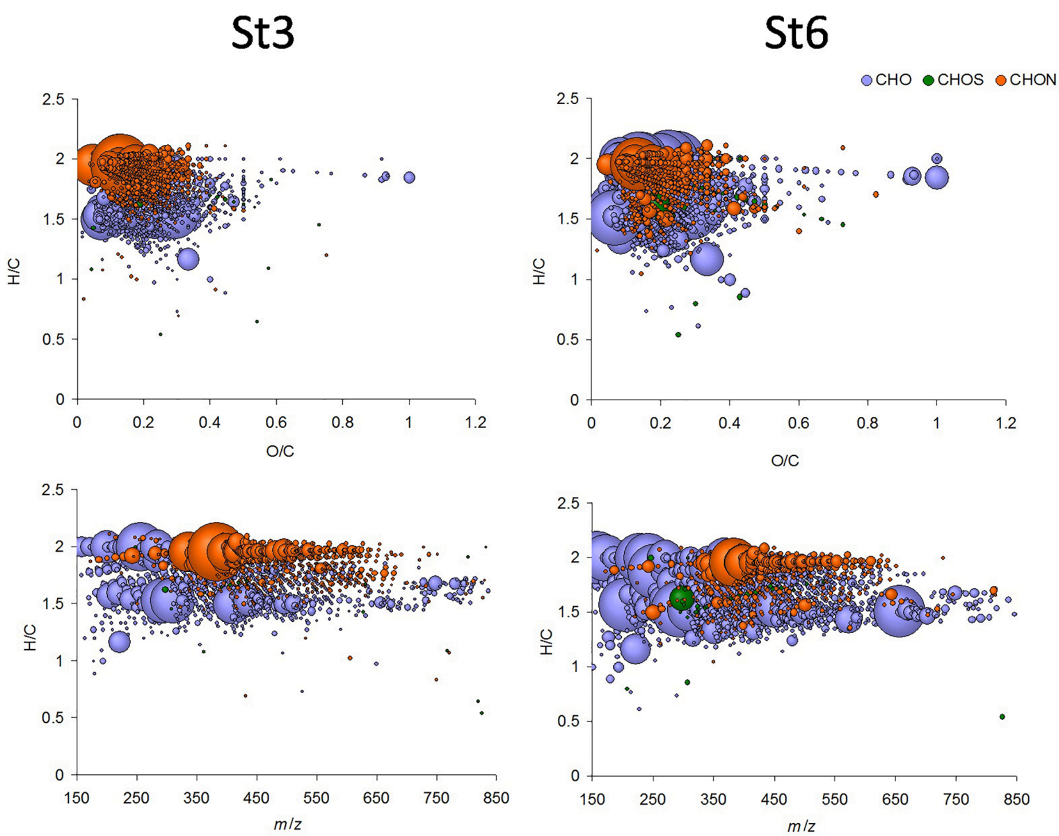

Fig. 12. van Krevelen (top) and H/C vs. *m/z* (bottom) diagrams achieved for organic residues from St3 and St6, analysed in ESI(−) FT-ICR MS. Bubble size of the van Krevelen diagram refers to peak intensity in the mass spectrum (graphics J. Hertzog).

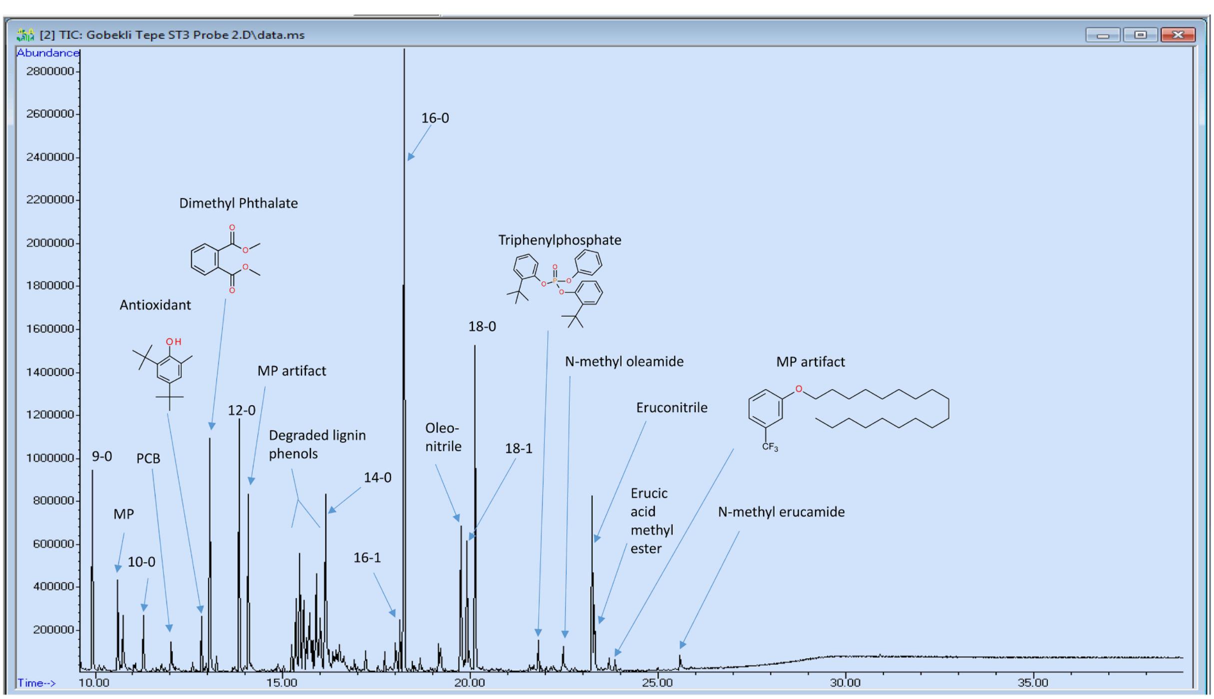

Fig. 13. GC–MS chromatogram of sample ST3/probe 2 (graphics P.E. McGovern).

for the next steps in this *chaîne opératoire*. Signs of burning on the exterior of / around large limestone troughs and fire-cracked basalt cooking stones hint at their role as cooking vessels. The combined results of GC–MS and FT-ICR MS further substantiate their use for the preparation of a porridge-/gruel-like cereal product, while experiments help to reconstruct the concrete process of cooking cereals in these vessels using fire-heated stones. Although experiments also show that fermentation is possible in the stone troughs, there is no unambiguous

Fig. 14. Experimental production of porridge and beer (1 photo German Archaeological Institute, O. Dietrich; 2–8: O. Dietrich).

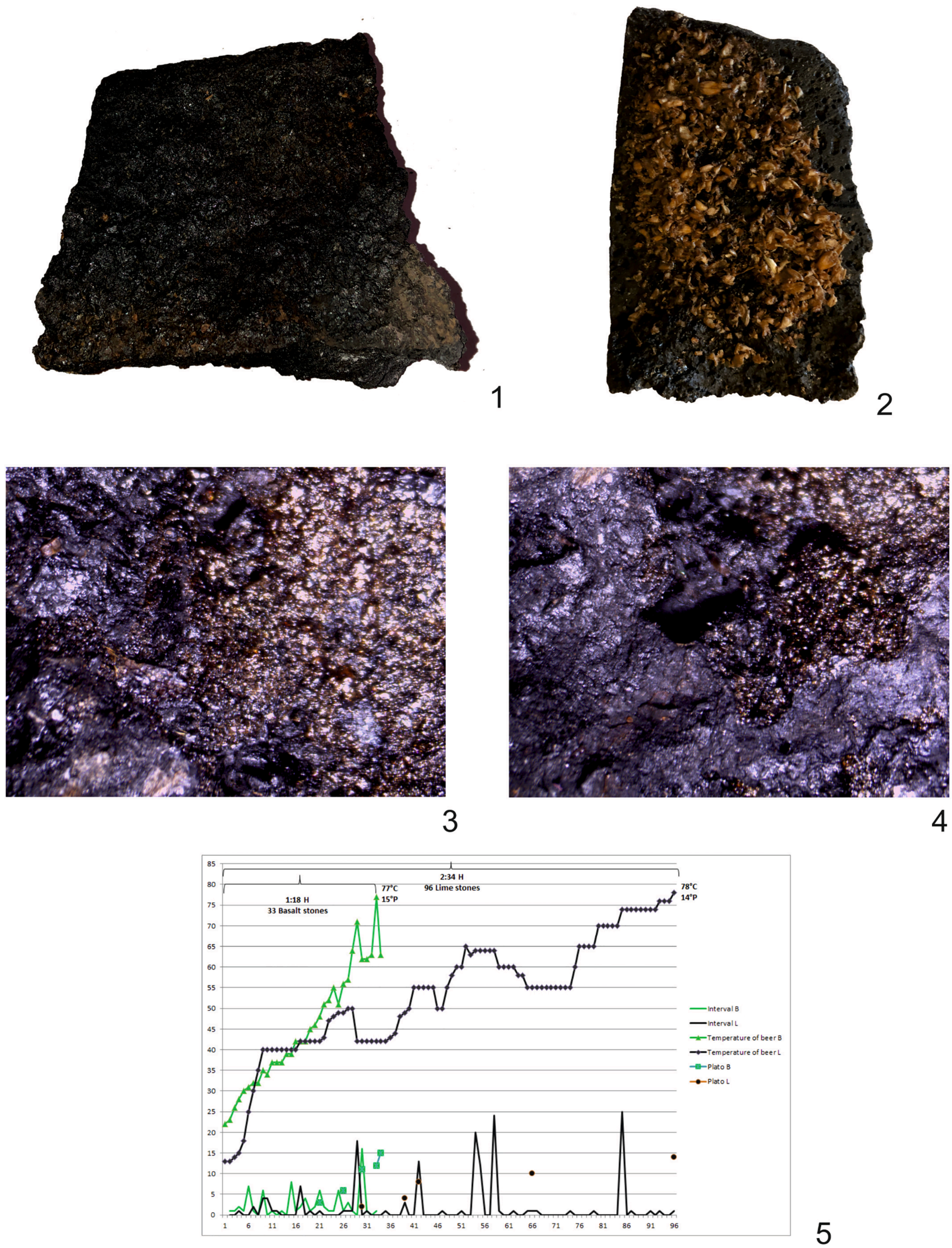

Fig. 15. Burnt heating stones with cereal ‘crust’; time relation between basalt and lime heating stones for the heating of the porridge (images L. Dietrich).

evidence for this practice.

The large cooking vessels appear together with a multitude of other more or less movable stone containers of different capacities and shapes, which could have had different functions in the process of serving and consumption of meals, as already suggested for stone containers from other sites (Wright, 2000; Rosenberg, 2008). The unusual size of the troughs (up to 165 l) and of the vessel assemblage has to be interpreted within the context of a special site like Göbekli Tepe. There is an evolution in the use of the stone containers from the older (monumental round buildings) to the partially younger (rectangular and apsidal building) structures. The assemblage of stone containers associated with the monumental buildings was composed of finely made limestone platters, middle-sized stone vessels and thin-walled, decorated ‘greenstone vessels’. A lot of work was invested in their production. Although some of these vessels might also be linked to food, some contexts clearly indicate a displaying or offering role within cultic acts (Schmidt, 2008). Evidence from the grinding stones and the phytolith samples attest the processing of cereals too (Dietrich et al., 2019); however, the grinding stones found together with the platters in the monumental buildings bear traces of processing ochre. Some of the objects, including grinding stones, pestles and platters were deposited either directly at the pillars or in the sockets holding them in an ochre layer.

The assemblage in the rectangular and apsidal buildings is different. Stone troughs appear as fixed furniture in rooms and the middle-sized vessels become frequent and have more diverse shapes. The workload implied in their production was high, even more so in the case of the large stone troughs. However, most of them were no longer finished (smoothed and polished). Diversity and quantity replace quality and display. Platters are still attested but their role in cooking is not clear; use-wear suggests pounding. The fine, decorated 'greenstone' vessels are only attested as secondary 'raw material' to produce beads and abraders in these contexts.

There is thus good evidence for different activities in different, partly contemporary areas of the site. The rectangular buildings can be identified as the loci for extensive cereal food production far beyond the needs of a small group of people, while there is no evidence for food processing at all in the monumental buildings. No storage facilities could be identified so far. The reason for specialized devices for cooking large quantities of cereals in the absence of storage has to be sought in the social dimensions of food at Göbekli Tepe. The construction of the monumental architecture would have necessitated a workforce of hundreds of people even by conservative estimates (Notroff et al., 2014). One model to explain cooperation in small-scale communities, which we may suspect for Early Neolithic semi-sedentary hunter-gatherers, involves ritualized work feasts (for Göbekli Tepe: Dietrich et al., 2012, Dietrich et al., 2019 with bibliography). The evidence for large cooking devices presented here fits this model.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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