

ANTHROPOLOGY

Modified human crania from Göbekli Tepe provide evidence for a new form of Neolithic skull cult

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Archaeological excavations at Göbekli Tepe, a transitional Neolithic site in southeast Turkey, have revealed the earliest megalithic ritual architecture with characteristic T-shaped pillars. Although human burials are still absent from the site, a number of fragmented human bones have been recovered from fill deposits of buildings and from adjacent areas. We focus on three partially preserved human skulls, all of which carry artificial modifications of a type so far unknown from contemporaneous sites and the ethnographic record. As such, modified skull fragments from Göbekli Tepe could indicate a new, previously undocumented variation of skull cult in the Early Neolithic of Anatolia and the Levant.

INTRODUCTION

Human skulls can be venerated for various reasons, ranging from ancestor worship to the belief in the transmission of protective or other properties from the deceased to the living (1). This focus on the human skull, including its special treatment, led to the establishment of the term skull cult in the anthropological literature [for example, Cauvin (2), Bienert (3), and Wahl (4)]. Skull cult can take on different forms, that is, with skull modifications frequently underlying very specific cultural codes. In the Pre-Pottery Neolithic (PPN; 9600–7000 calBC) of Southeast Anatolia and the Levant, there is an abundance of archaeological evidence for the special status assigned to the human skull: In addition to the deposition of skulls in special places, as attested by the “skull depot” at Tell Qaramel (5) or the “skull building” at Çayönü (6), human skulls are also known to have been decorated, for example, where the soft tissue and facial features have been remodeled in plaster [such as, Goren *et al.* (7) and Rollefson (8)] and/or color was applied to the bone (9, 10).

A hitherto unknown type of skull modification has recently been observed at Göbekli Tepe in Southeast Anatolia. Fragments of three human skulls have been recovered, all of which carry intentional deep incisions along their sagittal axes. In one of these cases, a drilled perforation is also attested. These findings are outstanding because they provide the very first osteological evidence for the treatment of the dead at Göbekli Tepe. The monumental stone buildings and rich symbolism encountered at this site have provided unprecedented insights into human belief systems and worldview at the Neolithic transition in one of its earliest geographical regions of genesis (11). Here, we present results from the analyses of these modifications according to several technical features. Results are compared with modified skulls from other Neolithic sites and examples from ethnographic research. Finally, we discuss whether the deep incisions (hereinafter also referred to as “carvings”) are congruous with activities associated with a variation of skull cult that is perhaps distinct to the site of Göbekli Tepe.

RESULTS

Although human burials are still absent from Göbekli Tepe, a considerable number of fragmented human bones ($n = 691$) have been

recovered. Notably, most of the human bone fragments ($n = 408$) stem from the skull, whereas postcranial fragments are less frequent ($n = 283$). Although these statistics could reflect taphonomic processes at work, a positive selection of skull material could be indicated. A total of 40 skull fragments (9.8%) carry cut marks from defleshing activities (12); additional signs of skeletal processing (decapitation) are represented by cut marks on two (of just seven) cervical vertebrae so far discovered at the site.

Skull fragments with specific modifications ($n = 7$) were discovered in three different excavation trenches: two located on the eastern side and one on the western side of the tell (Fig. 1). The seven skull fragments are assigned to three individuals on the basis of anatomical considerations, morphology (surface structure and robustness), as well as refits, and are referred to here as skulls 1 to 3 (Fig. 2; for more detailed descriptions, see the Supplementary Materials). The fragmentary nature of the skulls makes it difficult to determine the sex of the individuals; only skull 1 appears more female than male. All three skulls can be attributed to adults aged between 20 and 50 years. Investigations of taphonomic features revealed four different types of intentional modification (Figs. 2 and 3, and figs. S1 to S7): one drilled perforation, three cases of carvings, application of color (remnants of ochre on skull 1), and smaller cut marks (partly or not related to carvings).

Göbekli Tepe is the first site where carved skulls have been found. Carvings can be described as deep, mainly sagittally oriented grooves, resulting from multiple cutting activities (with minimal deviation, 0° to 6°) that run across the forehead (table S1 and Fig. 2), and in one case (skull 1) continuing onto the back of the skull and onto the mandible. In two cases (skulls 2 and 3), there are additional carvings oriented at an angle of 43° to 90° to sagittal. Carvings are the result of multiple cutting actions, which reached depths and widths of 0.2 to 4.0 mm. Minimal lengths of carvings on the three skulls vary between 6.0 and 45.5 mm, a range imposed by the fragmented and incomplete state of the skulls.

The following criteria attest to the prehistoric age of the carvings (and other cut marks) on the skulls: Marks are of the same color as the surrounding bone, and edges of incisions are smooth (in contrast to jagged edges typical of recent damage). In several cases, a layer of sinter adhering to the carvings is taken as additional evidence of their antiquity (13, 14).

Microscopic analyses have verified that carving and cutting activities were realized using lithic tools (table S2, Fig. 3, and figs. S1 to S3) (15–17). The criteria for the identification of lithic tool usage

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Fig. 1. The site of Göbekli Tepe. (A) Location of Göbekli Tepe in southeast Turkey (Upper Mesopotamia). (B) Overview of excavated areas, showing find locations of skull 1 (a), skull 2 (b), and skull 3 (c). Credit: Erhan Küçük, Göbekli Tepe Archive, German Archaeological Institute (DAI). (C) Impression of the monumental round-oval buildings with their characteristic T-shaped monolithic pillars. Credit: Nico Becker, Göbekli Tepe Archive, DAI.

include linear to slightly curved striations, also featuring parallel internal striations, V-shaped cross sections, and shoulder effect (15, 16).

Depths of carvings and the multiple cutting actions involved in their execution distinguish these modifications from superficial cut marks, which resulted from, for example, defleshing, intentional roughening of the surface, and/or (unintentional) trampling. Cut marks running adjacent and parallel to the deep incisions also fulfill the aforementioned criteria for ancient cut marks (table S2) and are interpreted as “errors,” which occurred when the flint blade slipped from the intended direction during carving. Further unrelated cut marks are interpreted as signs of defleshing and/or cleaning. In skulls 1 and 2 (figs. S1, S2, and S4 to S6), several sets of cut marks cluster in areas of muscle attachments, thus indicative of defleshing activities (18); cut marks recorded in other areas of skulls 1 to 3 could have resulted from the removal of periosteum/epicranium (figs. S4 to S7).

In summary, carvings are not connected with defleshing or scalping; although defleshing (and cleaning) is attested by other (minor) cut marks on the skulls, scalping can be ruled out on the basis of the absence of typical markers.

Because no signs of healing could be detected, modifications were probably performed shortly after death. Therefore, skulls were carved no earlier than the perimortem stage; this observation is confirmed by microscopic analyses: Cut marks are characterized by sharp edges, meaning that the bone was cut when still elastic, that is, at an early state of decay. Criteria for the identification of ancient cut marks also apply to the drilled perforation observed in the left parietal bone fragment of skull 1. Accordingly, surface characteristics point to an ancient origin, and the perforation was undertaken at an early state of decay. The perforation was performed from the outside of the skull inward, as indicated by its funnel-shaped cross section (external width, 6.7 mm; internal width, 5.00 mm). In addition, the wider opening of the perforation on the external surface of the skull features step-like remnants from drilling.

DISCUSSION

The modifications observed on the three skulls from Göbekli Tepe present a previously undocumented treatment of human skeletons

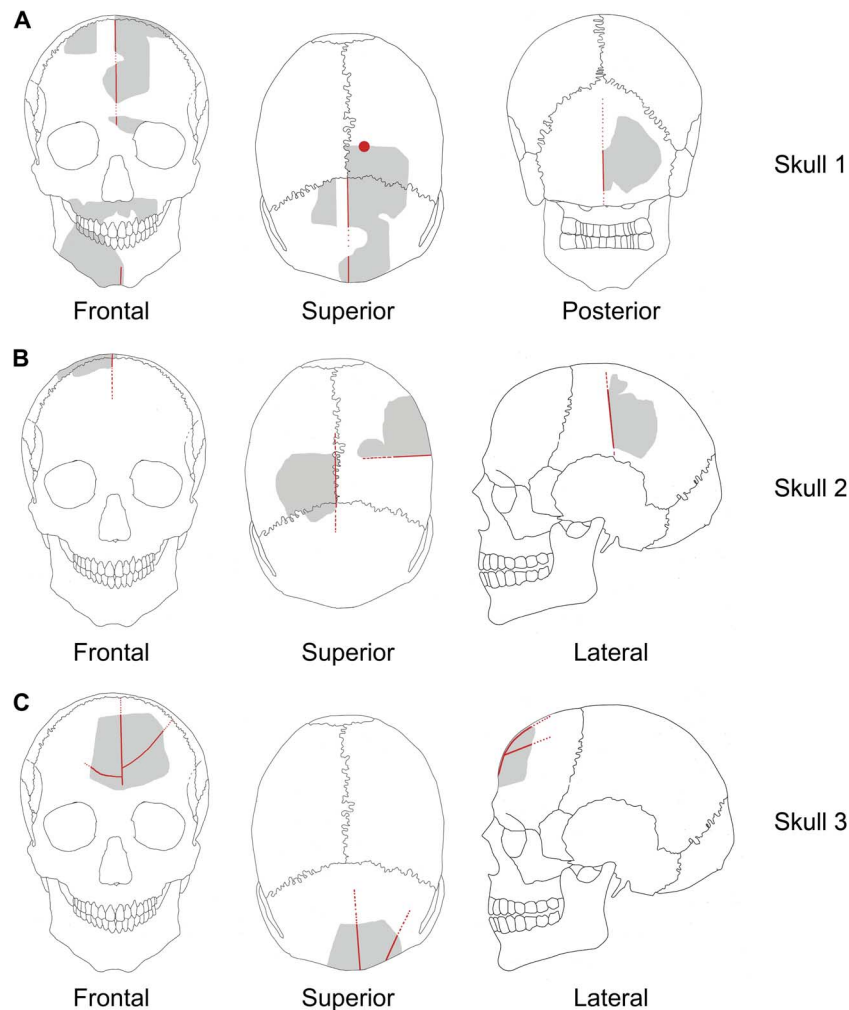


Fig. 2. Schematic drawings of Göbekli Tepe skulls. Gray, preserved elements; red, modifications. (A) Frontal, superior, and posterior view of skull 1. (B) Frontal, superior, and lateral view of skull 2. (C) Frontal, superior, and lateral view of skull 3.

in the PPN (table S3). Furthermore, convincing parallels cannot be identified through comparison with other archaeologically and ethnographically documented skull treatments, including trepanation, production of utilitarian and art objects, and modifications in connection with fertility rituals and ancestor veneration (Table 1 and the Supplementary Materials). One explanation is that this particular variation of skull modification was connected with activities specific to the Göbekli Tepe site. For this reason, in the following discussion, the term skull cult is further elaborated (see also the Supplementary Materials), additional evidence for skull cult at Göbekli Tepe is presented, and the modifications found on the three skulls are compared to secondary treatments attested at other Neolithic sites.

In archaeological discourse, the term skull cult is used relatively broadly, describing not only the intentional modification of human skulls but also their deposition in selected contexts. In Neolithic Anatolia and the Levant, postmortem skull modifications are a frequently observed phenomenon (table S4), so much so that it has been postulated they were a “regular” component of aceramic Neolithic burial customs (19, 20). Several criteria for the identification of skull cult in the

archaeological record have been proposed, albeit, because of an absence of inhumations at Göbekli Tepe, they are not applicable here (3, 19, 21). Therefore, we instead adhere to the definition put forward by Orschiedt (20), according to which skull cult must fulfill two distinct criteria: (i) It must take place in an existent “religious context,” and (ii) treatments must be found repeated on different/multiple skulls.

(i) Numerous lines of evidence point to a clear ritual component at Göbekli Tepe (22–24), including the monumental buildings, the monolithic T-shaped limestone pillars, an impressive repertoire of limestone sculptures, low and high reliefs (and their associated symbolism), and the location of the site at a most prominent position in the local landscape. In summary, this evidence has culminated in the interpretation of Göbekli Tepe as a ritual center of Early Holocene hunter-gatherer groups living within its catchment (11).

(ii) Although modifications are found on fragments belonging to just three skulls, this number must be seen in relation to the total number of skull fragments. Accordingly, the three skulls represent 15% of identified adult individuals (based on the minimum number of individuals) at Göbekli Tepe.



Fig. 3. Macroscopic details of artificial skull modifications. (A) Skull 1: Fragment of frontal bone with carvings. (B) Fragment of left parietal bone with drilled perforation. (C) Skull 2: Fragment of right parietal bone with carvings. (D) Skull 3: Fragment of frontal bone with carvings. Credit: Julia Gresky, DAI.

Table 1. Cases of human bone modification (from archaeological and ethnographic literature).

Period	Site	Artifacts	Bone element	Intention/interpretation	References
Upper Paleolithic	Gough's Cave, England	Cup	Cranium	Skull-cup production in combination with cannibalism	(47)
	Le Placard Cave, France	Cup	Cranium	Skull-cup production	(48, 49)
	Isturitz, France	Cup	Cranium	Skull-cup production	(50)
Mesolithic-Neolithic	Lepenski Vir, Serbia	Notation system	Long bone	Marking or counting a series of events	(51)
Neolithic	Heilbronn-Klingenberg, Germany	Sharpening of diaphysis	Long bone	Profane tool (paddle) for smoothing surfaces in clay vessel production	(4)
	Herxheim, Germany	Cup	Cranium	Skull-cup production	(52)
	Europe	Rondelles	Cranium	Amulet with magical or ritual function	(4, 53)
Bronze Age	Europe	Rondelles	Cranium	Amulet with magical or ritual function	(53)
	El Mirador Cave, Spain	Cup	Cranium	Skull-cup production in combination with cannibalism	(54)
Middle Ages	Tübingen, Germany	Flute	Long bone	Make music	(55)
Buddhist contexts	India and Tibet	Bowls and drums	Skull	Paraphernalia for religious ceremonies	(56)
Recent (20th century)	Dayak people, Borneo	Carved ornaments in skulls, attachment of objects with cord	Skull	Head-hunting as prestige	(57)
	Naga people, India, and Myanmar	Attached horns evoke hybrid-like appearance	Skull	Skulls as human trophies	(31)

Although primary burials are lacking at Göbekli Tepe, there are still strong indications for the special status of the human skull at this site. Osteological evidence includes a dominance of human skull bones in the assemblage, as well as the cut marks identified on some of these skull fragments (and on two cervical vertebrae) interpreted as signs of defleshing [and decapitation; (12)]. Archaeological evidence includes depictions carved into and from limestone, for example, the low relief of a headless ithyphallic figure on the broad side of a T-shaped monolith in building D, the comparatively frequent finds of carved human heads removed by force from larger statues, as well as sculptures of carnivores and raptors holding what could be severed human heads (Fig. 4) (25, 26). A remarkable find is a limestone statue, referred to as the “gift bearer,” a kneeling figure carrying a human head in its hands, the eyes and nose of which are discernible (25).

Although carvings on the three human skulls from Göbekli Tepe are so far unique, all other modification types have known parallels from Neolithic sites in Anatolia and the Levant (table S3). Cut marks connected with secondary burial customs are documented at numerous sites [for example, Tell Qaramel (5), Jericho (10), Körtik Tepe (27)], and ochre and other coloring substances have been found adhering to bones or as scattered layers covering skeletons [for example, Körtik Tepe (27), 'Ain Ghazal (9), and Jericho (10)]. The widespread use of ochre in burials throughout the PPN in Anatolia and the Levant has been associated with expressions of ritual and religious behavior, as a reflection of differential access to resources and as a marker of status (7). At Göbekli Tepe, ochre traces were detected on fragments of skull 1. The placement of this most complete skull, found in a concentration of ochre, indicates the special significance of this object. Another outstanding feature of skull 1 is the drilled perforation in the left parietal (Fig. 3 and figs. S1 and S4), the position of which was carefully chosen so that the skull might hang vertically and face

forward when suspended (Fig. 5). Alternatively, the perforation could have been a fixing point for a mask or other decorative elements. Drilled skulls are a very rare find in the Anatolian and Levantine PPN [Kfar HaHoresh (28)].

Interpretations

Against the background of available archaeological and ethnographic evidence, two interpretations of the carved skulls from Göbekli Tepe are presented. These interpretations are connected to ancestor veneration or the display of dispatched enemies through either active “branding” of individuals or functional modification of the skull for display.

Branding

The storage of human skulls connected to ancestor veneration rites and/or the display of dispatched enemies is one possible interpretation of the Göbekli Tepe skulls [for example, Özdoğan (29) and Santana *et al.* (30)]. At the Pre-Pottery Neolithic B (PPNB) site of Tell Qarassa North in Syria, deliberately mutilated facial skeletons have been interpreted as an expression of postmortal punishment, that is, an example of negative funerary rites (30). On the basis of this conclusion, carvings on the skulls from Göbekli Tepe might also suggest that these belonged to “branded” individuals, marking them as different from others, either in a positive or in a negative way.

Application of decorative elements and skull stabilization

Decorated skulls are well known from ethnographic contexts, for example, in the Pacific and South Asia [for example, Kunz (31); see the Supplementary Materials]. Foreign objects are attached to the skulls using a cord, which is also used to fix the mandible to the cranium. Remarkably, the positions of the cords in the ethnographic example of the Naga people from India (31) are practically identical to the positions of carvings observed on the Göbekli Tepe skulls, that is, on prominent

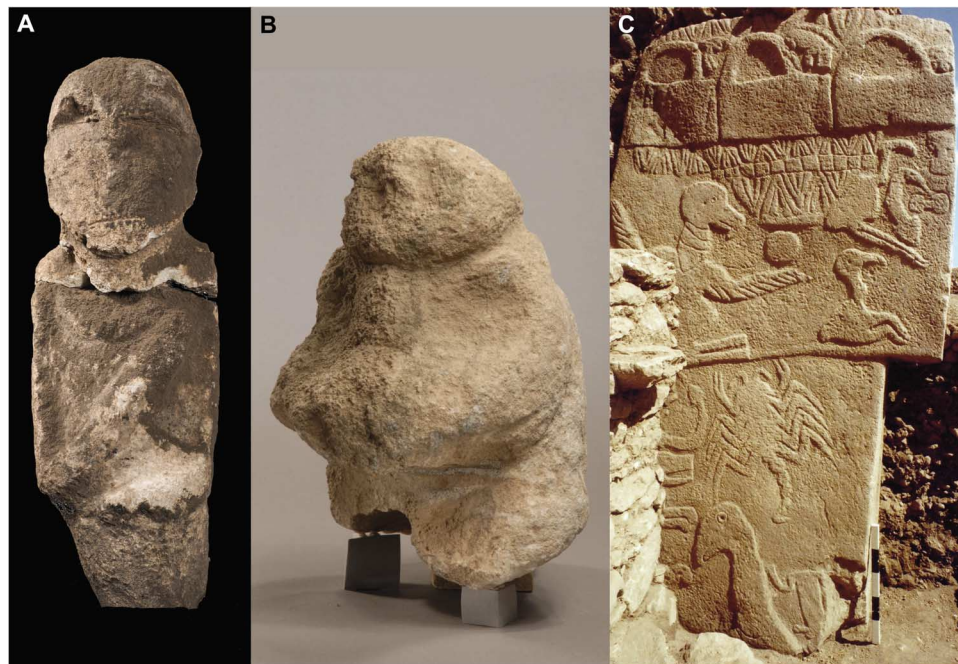


Fig. 4. Anthropomorphic depictions from Göbekli Tepe. (A) Intentionally decapitated human statue (height, 60 cm). Credit: Nico Becker, Göbekli Tepe Archive, DAL. (B) The gift bearer holds a human head in his hands (height, 26 cm). Credit: Dieter Johannes, Göbekli Tepe Archive, DAL. (C) Pillar 43 (building D) with low relief of an ithyphallic headless individual, one arm raised (bottom right). Credit: Klaus Schmidt, Göbekli Tepe Archive, DAL.

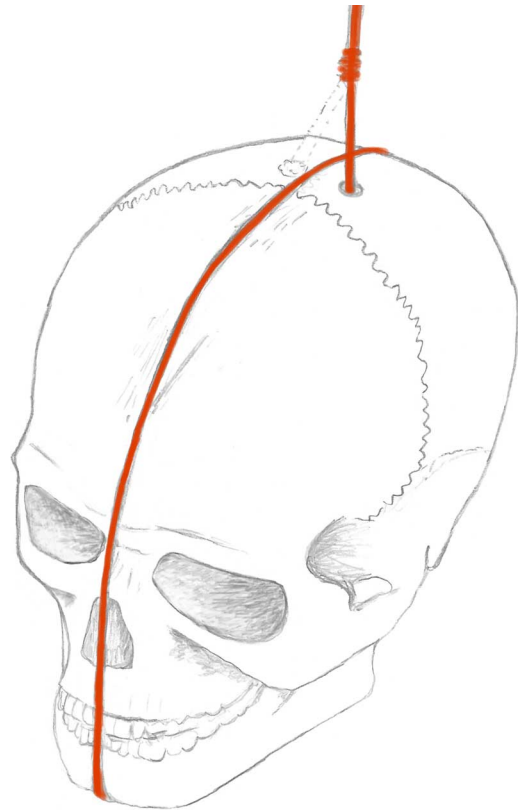


Fig. 5. Skull 1: Tentative reconstruction. Drilled perforation at the top of the cranium is used to suspend the skull with a cord (red). Carvings were used for stabilization purposes, preventing the cord from slipping. Credit: Juliane Haelm, DAL.

parts of the facial skeleton and on the back of the head. Carved grooves could have prevented the cord from slipping on the roundish bone surfaces. In addition, the drilled perforation at the left parietal of skull 1 suggests that this skull was suspended (Fig. 5).

Conclusion

The three modified skulls from Göbekli Tepe represent an entirely new category of find, which testifies to the interaction of the living with the dead at this important Early Neolithic ritual center. These skulls, most likely removed from the postcranium in the frame of secondary burial rites, attest to the special postmortem treatment of certain individuals at Göbekli Tepe. Special status of the individuals could have been emphasized through the application of decorative elements to the crania, which were then displayed (also suspended) at designated points around the site. At present, it is unknown whether these treatments were performed in the frame of ritual activities in the monumental buildings or were brought to the ritual center from settlement sites within its catchment.

MATERIALS AND METHODS

Archaeological background

The archaeological site of Göbekli Tepe is one of the most significant archaeological discoveries in recent decades. Its impressive monumental architecture, which features large monolithic T-shaped pillars carved from locally quarried limestone, numbers among the earliest known

examples of man-made megalithic buildings constructed specifically for the ritual requirements of their prehistoric builders. K. Schmidt, who conducted the first fieldwork at the site from 1995 until his death in 2014, described Göbekli Tepe as an important ritual hub for early PPN communities in a core area of Neolithization. This function is underlined by an ever-growing repertoire of carefully crafted images hewn in stone, all of which provide tantalizing glimpses into the beliefs of these hunter-gatherer groups between the mid 10th and late 9th millennia calBC (11, 25).

Göbekli Tepe lies some 15 km east of Şanlıurfa in the Germuş mountains (c. 770 m above sea level) from whence it has commanding views over the Harran plain to the south. It is a large artificial hill (*tell*) with higher-lying mounds interrupted by lower-lying hollows. The *tell* is composed of archaeological deposits (maximum of 15 m high), which accumulated on a natural limestone plateau over a period of circa 1600 years (c. 9600–8000 calBC) during the Pre-Pottery Neolithic A (PPNA; 9600–8700 calBC) and Early/Middle Pre-Pottery Neolithic B (8700–8000 calBC) (11, 25, 32, 33).

Currently, the remains of several multiphase monumental buildings have been excavated at Göbekli Tepe, labeled A to H in order of their discovery (Fig. 1). The earliest phases of some of these buildings, which were generally found in the lower-lying hollows of the mound, were probably erected in the PPNA, with the later phases attributed to the PPNB. In addition to these large monumental structures, there are remains of numerous smaller stone-built rectangular buildings. These were erected in the PPNB and were found on the higher-lying mounds and slopes, sometimes partially superimposing the larger monumental round-oval structures.

Two centrally positioned monolithic limestone pillars (up to 5.5 m high) are common to all monumental buildings at Göbekli Tepe. Three of the megalithic buildings (C to E) were erected directly upon the natural limestone plateau, which had been carefully smoothed, and, in the case of buildings C and D, the two central monolithic T-shaped pillars were found in situ, that is, slotted into platforms painstakingly carved from the natural plateau. The two central pillars are surrounded by one or multiple stone walls. The enclosing walls, which can be attributed to different phases of the buildings, were interrupted at regular intervals by inserted T-shaped limestone pillars, although these did not reach the same heights as the two central monoliths (34).

In addition, Göbekli Tepe is unique because of its rich and distinct repertoire of artistic representations, primarily images of animals. The T-shaped pillars themselves are anthropomorphic, as testified in some cases by carvings of low reliefs showing arms, hands, and clothing. The artistic repertoire also includes numerous stone statues and figurines of animals and humans, as well as small finds adorned with manifold depictions and symbols. This material provides insights into a deep-rooted hunter-gatherer worldview, probably including narratives and myths dating back to the Epipaleolithic, and at Göbekli Tepe for the first time immortalized in stone. As such they may be considered expressions of a common origin and identity that would have been so important for communities facing the challenges connected with Neolithization processes. It is this realization that makes Göbekli Tepe such a key site for our comprehension of this pivotal period in human history.

Site formation, relative and absolute chronology

In the course of excavations at Göbekli Tepe, a relative chronological system based on two main occupation phases was introduced. Whereas the lowermost level III was assigned to the PPNA, the overlying level II

was attributed to the PPNB; an uppermost plow horizon with finds from disturbed (levels III and II) contexts was referred to as level I. Meanwhile, it is recognized that this division is insufficient to express the intricate archaeological stratigraphy observed at the site. For example, building archaeology studies have revealed a much greater architectural complexity of the monumental round-oval buildings; formerly attributed to level III (PPNA), these structures are now known to have been considerably longer-lived, continuing into PPNB (level II) times (34). More recently, this conclusion could be verified by newly available (as yet largely unpublished) radiocarbon ages made on organic residues extracted from mud mortar and wall plaster samples (35). Human bones from different locations were submitted to two independent laboratories for radiocarbon (accelerator mass spectrometry) dating. These samples failed because of a lack of collagen, thus mirroring former attempts made to date animal bones from similar archaeological contexts at Göbekli Tepe (33). Meanwhile, it is recognized that bone collagen is very poorly preserved in the carbonate-rich sediments at Göbekli Tepe and is usually not suitable for absolute dating purposes.

Monumental buildings at Göbekli Tepe were “buried” with enormous amounts of detritus material in ancient times. This deposit, commonly referred to as backfill, is composed of extensive amounts of fist-sized limestone rubble interspersed with archaeological artifacts, primarily lithics and animal bone. An intentional (ritually charged) burial of buildings was previously posited (36–38); more recently, however, other explanations appear increasingly likely, including inundation from building collapse and eroded deposits from higher-lying and adjacent parts of the mound. These latter processes (collapse and erosion) would also account for the highly fragmented nature of human (and animal) bone contained in the backfill (11), thus providing first indications of a potential (formerly unknown) provenance for this material. For this reason, complex site formation processes at Göbekli Tepe mean that human skeletal remains can only be broadly dated to the PPNA/PPNB period.

Archeological context and taphonomic features of human bones from Göbekli Tepe

Osteological analyses of human bone began in 2009, and a total 691 fragments have so far been recorded. Human bone preservation at Göbekli Tepe can be described as “moderate,” especially because fragments can be covered by a thick cohesive layer of minerals (sinter) that is known to promote fragmentation. Some of the bones show signs of artificial modifications, including cut marks and burning; among these materials are cranial fragments from three individuals, which stand out because of the conspicuous nature of modifications, a repeated and substantial cutting on the outer skull vault (carvings) (Figs. 2 and 3, figs. S1 to S7, and table S1).

Skull 1

Fragments belonging to skull 1 were recovered from trench K 10-05 (loc. 18/24), a spatially isolated deep sounding situated at the north-west hollow of the site (Fig. 1). Skull fragments were discovered in the fill of an indeterminate architectural structure, adjacent to a stone wall. Remarkably, this area contained significant amounts of red ochre, traces of which were also found adhering to the skull fragments. Skull 1 is composed of cranial fragments from the frontal, the left parietal, the occipital, the maxilla, the right side of the mandible, and the right mastoid process (Figs. 2 and 3, and figs. S1, S4, and S5). Fragments of the left frontal and the left parietal could be refitted; all other fragments

were attributed to the same individual on the basis of bone appearance (thickness, surface texture, and color). Remnants of ochre were found adhering to all fragments; evidence of heat impact and animal gnawing was absent. Small patches of sinter were generally restricted to internal surfaces and broken edges.

Skull 2

Bone fragments belonging to skull 2 were discovered in excavation trench L 9-65 (loc. 113) located at the southeast hollow of the site (Fig. 1). This skull is composed of two fragments, which were discovered directly adjacent to one another: the right parietal (with part of the frontal bone) and the left parietal (Figs. 2 and 3, and figs. S2 and S6). These fragments were recovered from the fill of a rectangular-shaped building, situated westerly adjacent to (and stratigraphically younger than) monumental building A. Fragments belonging to skull 2 cannot be refitted; they were assigned to the same individual on the basis of appearance, that is, thickness, surface texture, and color. Evidence of heat impact and animal gnawing was absent; sinter was not observed.

Skull 3

Skull 3 is composed of one bone fragment from excavation trench L9-69 (loc. 65.1). This fragment was recovered from the fill of an architectural structure situated to the north of (and overlooking) building D (Fig. 1). Originally just one fragment of the frontal bone, it fell into three pieces shortly after excavation (Figs. 2 and 3, and figs. S3 and S7). Evidence of heat impact and animal gnawing was absent; sinter was not observed.

Age and sex determination

In the absence of other parts of the skeleton, age and sex determinations were based on available evidence from skull fragments according to criteria defined by Buikstra *et al.* (13). In the case of skull 1, a small part of the glabella, the mentum, the nuchal crest, and the mastoid process were present. Although the inclination of the frontal bone and the glabella suggested that the individual was male, this was contradicted by the mentum, the mastoid process, and the weak muscle relief of the occipital bone, all of which were more indicative of a female individual. An age range of 25 to 35 years was indicated on the basis of dental wear of mandibular teeth (13); maxillary teeth were indicative of an age range of 33 to 45 years. Parts of the coronal and anterior sagittal suture were not fused, thus implying an age younger than 40 to 50 years (13). In summary, evidence points to an individual, 25 to 40 years of age, who was more likely female than male.

Frontal and parietal skull fragments from skull 2 lacked essential markers for sex determination. For age estimation, only the closure of the sagittal and coronal sutures could be consulted (13), these being suggestive of an age range between 30 and 45 years.

For the frontal fragment of skull 3, no significant features for sex or age determination were present. Size and thickness of the fragment point to an adult individual of unknown sex.

Macroscopic and microscopic examination

All fragments were investigated macroscopically with low-power magnification. Number, length, and width of individual cut marks were measured, and their positions on the skull (and their relation to each other) were recorded. Investigations of the microstructure of surface modifications were studied using different microscopic techniques. Examinations using a stereomicroscope (Meiji Techno, DAI,

Berlin) with magnification between $\times 20$ and $\times 120$ were performed under an oblique light source. Bones were tilted and rotated, thus rendering surface alterations more visible. Images of significant structures were recorded using a digital camera (Nikon DS-5Mc). Digital imaging (Hirox digital microscope KH-870031, magnification from $\times 35$ to $\times 7000$; High Resolution $10\times$ Co-Axial Zoom Lens, DAI, Berlin) was used to measure a variety of features (for example, depth, width, angles). Three-dimensional imaging was realized using overlapping levels of focus. Finally, complete cut marks were studied and recorded using a compilation of several different sections. A scanning electron microscope (SEM) (LEO 430, DAI, Berlin; magnification, $\times 15$ to $\times 300,000$) was used to record the marks with a higher magnification and greater depth of focus. The investigations were conducted on surface replicas to avoid damage to original bone fragments. Replicas were produced using surface reprint masses (reprint 1000 and 2000) with a resolution up to $0.1\ \mu\text{m}$. The imprint was grouted with technical plastic (Technovit 4004), and the replicas were then sputtered with a thin layer of gold-palladium (Cressington 108 Sputter Coaters, DAI, Berlin).

Criteria for assessing ancient cut marks based on microstructure

Recent cut marks, for example, accidental trowel damage from excavation, were identified and excluded from the study. The prehistoric age of the carvings (and other cut marks) on the skulls was confirmed on the basis of two criteria: (i) marks are of the same color as the surrounding bone and (ii) edges of incisions are smooth (in contrast to jagged edges typical of recent damage). A layer of sinter adhering to carvings can also be taken as additional evidence of antiquity (13, 14).

According to Shipman (15) and Shipman and Rose (16), cut marks made by lithic tools can be distinguished from other taphonomic changes on the basis of clear criteria: (i) linear to slightly curved striations, (ii) parallel internal striations, (iii) V-shaped cross section, and (iv) shoulder effect. These criteria can be observed on all fragments belonging to the three Göbekli Tepe skulls and are summarized in table S2 and supplementary descriptions of the skulls.

Shipman (15) concluded that an intentional human modification of the bone can only be assumed if nonhuman taphonomic agents can be excluded. Therefore, a cut mark must testify to explicit and established characteristics, which can only be associated with modification by humans [for example, Shipman (15) and Binford (18)]. Notably, the appearance of intentional cut marks made by humans is often very similar to those made by nonhuman agents. Pseudo-cut marks can arise, for example, in the processes of trampling [for example, Olsen and Shipman (17), Andrews and Cook (39), and Milner and Smith (40)], animal bite marks [for example, Milner and Smith (40)], and weathering (41):

Trampling occurs when bones are exposed on the surface or just below the surface and are walked upon by animals. When the bone is embedded next to hard objects, such as stones or other bones, its surface can be scratched or polished by movement within this matrix and by pressure from above (14). A clear differentiation between trampling and cut marks cannot always be made, generally because microstructures appear very similar. Therefore, it is essential that other lines of evidence are considered, including the structure of the modification, its position on the bone, and its interaction with other positively identified cut marks (39). Although conditions at Göbekli Tepe favored damage of bone through trampling, that is, the stony matrix

of archaeological sediments in which human bone fragments were also found, this damage can be clearly distinguished from intentional cut marks.

Animal bite marks testify to access of animals to the skeleton. Carnivores are especially interested in meat and bone marrow. Their pointed tooth cusps leave rough puncture-shaped impressions with possible fracture cracks or scratches on the bone surface, which originate from holding, carrying, or chewing (15, 42). Rodents prefer the calcium and phosphate in bones, both of which are important for their diet, albeit gnawing restricts the growth of their incisors (43). Rodent tooth marks appear as parallel, square-bottomed, and shallow grooves and occur more frequently on bony prominences, especially on articulation facets of the diaphysis (13). Animal bite marks were not observed on the three skulls from Göbekli Tepe; this is apparent from comparisons with other human skeletal materials from the site, which feature a clear sign of carnivore and rodent gnawing.

Traces of weathering appear when bones are exposed on an unprotected ground surface. Evidence of weathering depends on a high number of different factors relating to the environment and physical impact of weather and climate. When the soft tissue has disappeared, bones lying on the ground surface are exposed to the sun, rain, changing temperatures, and humidity (14, 41). Exposure leads to cracking and peeling of the surface, fragmentation, and, finally, complete destruction of the bone. Hairline cracks, which develop on the surface, can resemble cut marks, although these can usually be identified following closer inspection of their microstructure. Although the three skulls from Göbekli Tepe showed signs of weathering, which included small cracks and fragmentation, this is usually linked to destructive processes of natural sinter development on the bone. Notably, these cracks differed considerably from cut marks, especially in section, course, and arrangement.

Processing the soft tissue: Defleshing and scalping

Cut marks are the relics of activities connected with the removal of soft tissue from bone. For this reason, archaeological-osteological studies typically focus on the processing (butchering) of wild and domestic animals; as such, cut marks are a frequent and well-researched topic in archeozoological literature (16–18).

Defleshing is a term that is used to describe the removal of soft tissue (and especially muscle) from the bone, particularly in the context of animal butchery. Removal of flesh is facilitated when cuts are made to the origin and insertion areas of the muscle. Therefore, butchery marks are usually visible in defined areas of the skeleton (18). In the case of skulls, cut marks associated with defleshing are usually found at the origin of the tongue and the masticatory musculature. Cut marks outside of these areas could indicate the removal of the periosteum (18). Although carvings on the three Göbekli Tepe skulls were too focused and deep to be connected with defleshing activities, other (minor) cut marks fulfilled these criteria.

Scalping is well attested in the anthropological literature, referring to the violent removal of scalp and hair (44). Scalping is often associated with warfare and trophy-taking; best-known examples are attested in prehistoric North America (45, 46). A special pattern of cut marks on the skull of the victim serves as evidence for scalping. Cut marks often occur in small clusters that form a rough circle around the skull (on the frontal, the parietal, and the occipital) (45). Despite the high fragmentation of the Göbekli Tepe skulls, the preserved fragments did not show the typical arrangement of cut marks associated with scalping.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at <http://advances.sciencemag.org/cgi/content/full/3/6/e1700564/DC1>

Supplementary Material
Supplementary Text

fig. S1. Skull 1: Details of carvings and drilling.

fig. S2. Skull 2: Details of carving.

fig. S3. Skull 3: Fragments of frontal bone with microscopic views of carvings.

fig. S4. Skull 1: Frontal, left parietal, and occipital bone fragments with carvings and cut marks.

fig. S5. Skull 1: Left mandible fragment with carvings and cut marks.

fig. S6. Skull 2: Right parietal bone fragment with adhering frontal bone fragment and left parietal bone fragment with carvings and cut marks.

fig. S7. Skull 3: Frontal bone fragment with carvings and cut marks.

table S1. Detailed description of the carvings on the three skulls.

table S2. Criteria for cut marks made using lithic tools (15–17) and associated images in figs. S1 to S3.

table S3. Modifications attested on human skulls from PPNA and PPNB sites in Anatolia and the Levant.

table S4. Compilation of Neolithic sites from Anatolia and Levant showing different burial customs [after Perschke tab. 1, p. 99, (19)].

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