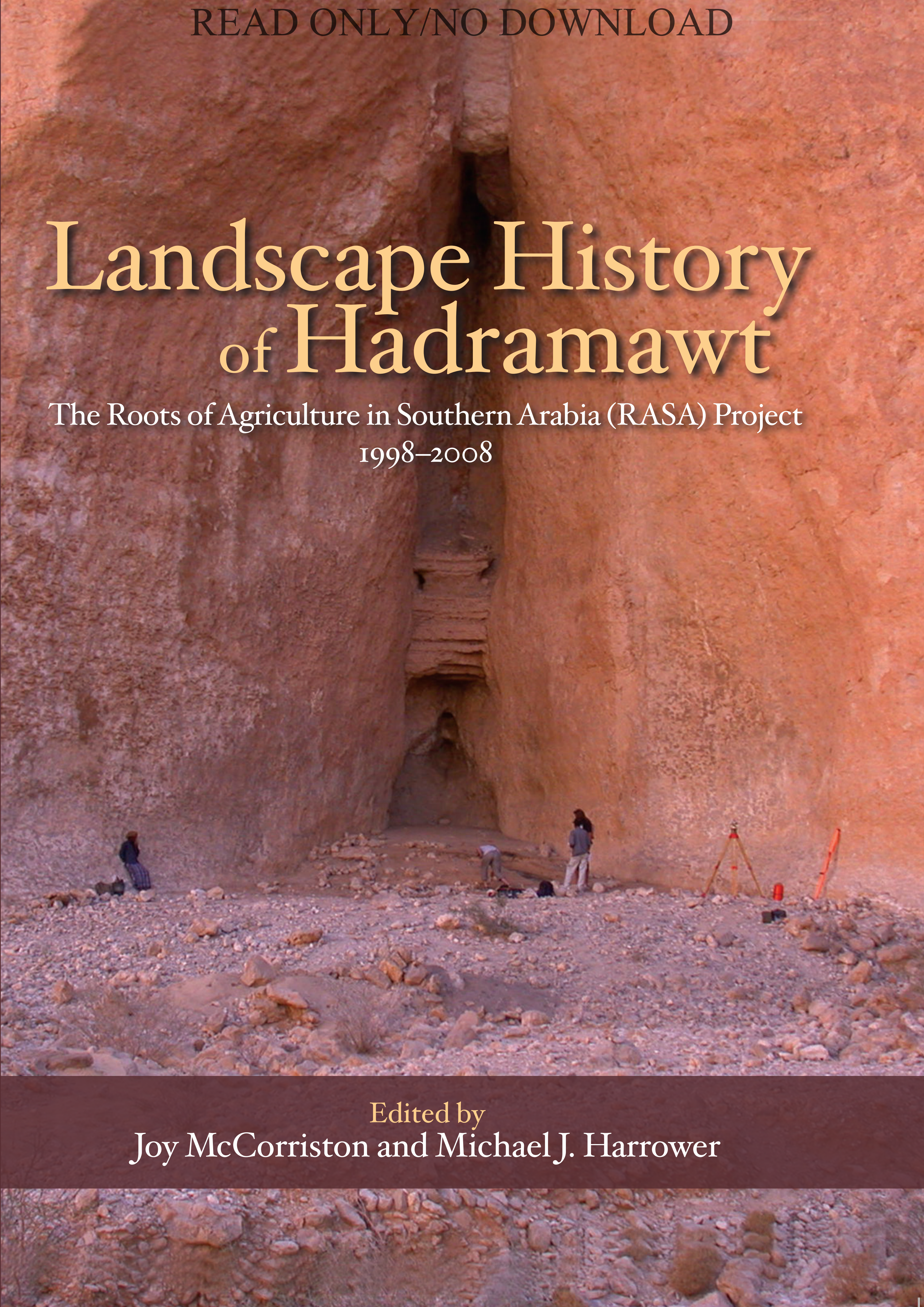
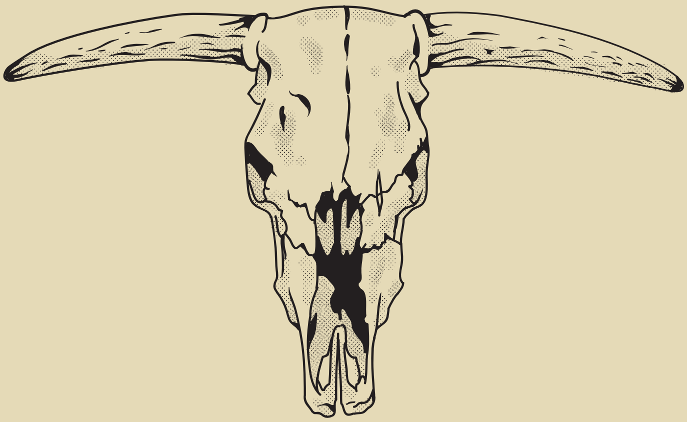


Landscape History of Hadramawt

The Roots of Agriculture in Southern Arabia (RASA) Project 1998–2008

Edited by
Joy McCorriston and Michael J. Harrower



Landscape History of Hadramawt

The Jo Anne Stolaroff Cotsen Prize Imprint honors outstanding studies in archaeology to commemorate a special person whose appreciation for scholarship was recognized by all whose lives she touched.

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To the people of Yemen,
with gratitude

Contents

Page 272–273: Imaginative reconstruction of the Kheshiya cattle skull ring by Judith Dobie, based on archaeological, zooarchaeological, and geoarchaeological evidence. This scene imagines the phase between 6526 and 6123 cal. yr. BP (see Figure 10.20).

Chapter 11

The Kheshiya Cattle Skull Ring

Zooarchaeological Analyses

Louise Martin with a contribution by Joe Roe

On December 31, 2005, Louise Martin, Lisa Usman, and Joy McCorriston settled on a hard floor in a sparse hotel in Mukalla to watch Pakistan ring in the New Year a few hours to the east. Toddler Jojo slept a cherubic sleep propped up by all the available pillows, having exhausted all episodes of *Balamory*. During the day, Louise and Lisa unwrapped 6,000-year-old cattle skulls and cleaned them for photographs, measurements, and curation. To say the conservation lab was improvised would overly gloss a battered room with rigged lighting and peeling floors. But the onshore breeze fills the Mukalla Museum, there's a five-star overlook of the brilliant sea, and you could get a rock lobster dinner for two dollars in those days. ʿAbdalʿazīz Bin ʿAqīl left us only for the morning of Eid al-Fitr, working through his holiday and the final Ramadan vigil. He and Joy kept Jojo busy so that his mother, Louise, could measure the frontal bones and wear patterns on cattle molars. This chapter is the outcome of her analysis, supported by Lisa's clever conservation solutions and Joe Roe's statistical skills in the comparison with East African cattle.

Domestic Cattle in Arabia and the Nature of Herding

The 2004 discovery of the site of Kheshiya SU151-1 in the highland Southern Jol region of Yemen was a gift not only to prehistorians and historians of the Arabian Peninsula and beyond but also to those interested in human–animal relations in the Neolithic. The oval installation constructed of at least 40 partially buried cattle skulls, adjacent to a similar-shaped stone "platform" structure, was unique at the time of discovery and remains so at the time of writing. It is immediately clear that the cattle skulls are no normal faunal assemblage made up of discard from everyday food consumption. Indeed, the site is a monument rather than an occupation location (McCorriston 2011; chapter 10 this volume), with the cattle skulls forming a central part of monument construction. The sample of cattle skulls retrieved from the site provides an as-yet-unchallenged insight into the nature of cattle, and human–cattle relations, in the Neolithic of Southern Arabia. This chapter focuses on analysis of the skulls themselves and the zooarchaeological information they yield, both at a site and local level, and also at a broader regional level, where they contribute to discussion on the appearance of early domestic cattle in Arabia and their role in subsistence and ritual.

Zooarchaeological analyses of the cattle skulls contribute to three main research spheres. First, despite their fragmented state, the skulls allow assessment of cattle cranial morphology, which has implications for species assignation of the cattle from which they derived. Morphometrics also inform on the domestic/wild status of the animals. Second, assessment of the animals' ages at death and their sex distributions within the sample allow discussion of the selection of animals for the cull and subsequent skull monument construction. Third, bone surface modification data and skull breakage patterns contribute toward our understanding of how skulls were prepared and installed as part of the construction of the Kheshiya monument.

The discovery, excavation, stratigraphy, and associated finds of the site—known also as the Kheshiya cattle skull ring—are detailed in chapter 10. To recap briefly, in 2004 the RASA survey team found several large mammal skulls eroding out of a gully in the Shiʿb Kheshiya. The team returned in 2005 to excavate the site to which these skulls belonged. By this time the skulls had been identified as cattle. The team first excavated the small (2 x 2.5 m) semisubterranean stone structure to reveal details of its construction and use. Intriguingly, the structure did not emerge as either occupational or a tomb but was classified as a "platform" of slabs with deliberate infill. Chapter 10 details how the occupational deposit cut by the platform extends externally, containing burned rock and flakes of chipped stone. It was into this deposit that the 40 or so cattle skulls were placed. Their placement formed an oval similar in size to the adjacent platform. The skulls faced frontals inward, maxillary teeth outward. Horns and horncores, which did not survive, would have risen aboveground, pointing upward and inward toward the center of the oval. Considering the close placement of some skulls, many horns would have interlocked. Mandibles had been removed before burial. There is good evidence (chapter 10) that the skulls were pushed into soft marshy sediment (seemingly in winter) all at one time, without a sequence of deposition. Only after the cattle skull ring was installed was the stone platform constructed. The skull ring sits approximately 1.5 m southeast of the stone structure.

Several publications have discussed preliminary zooarchaeological results of the cattle skulls from the ring (e.g., Henton et al. 2014; McCorriston 2011; McCorriston and Martin 2009; McCorriston et al. 2012); some zooarchaeological details have been refined as a result of the analyses presented in this chapter.

It is widely accepted that Arabia did not witness indigenous domestication of local plants and animals; instead, the area received domesticates from elsewhere (see chapter 1 this volume; Boivin and Fuller 2009). By the time of the Kheshiya cattle ring construction in the mid-seventh millennium cal BP, we have the following picture of domestic cattle in the peninsula.

Domestic cattle are seen in the Persian Gulf area from the seventh millennium cal BP, where they appear alongside a much larger assemblage of domestic sheep and goats at the site of Jabal al-Buhais 18 in Sharjah, UAE. Excavators interpreted the site as a station within a mobile herding system rather than a location of year-round habitation (Uerpmann and Uerpmann 2008:127–31). Late-seventh-millennium cal BP Ras al-Hamra 6 in northern Oman yielded a faunal assemblage that also included small numbers of domestic cattle and caprines, and by the sixth millennium cal BP, Ras al-Hamra 5 provides substantial samples of the same package of domesticates, interpreted as being for meat production rather than secondary products (Uerpmann and Uerpmann 2003). Domestic sheep, goats, and cattle are mentioned from the site of H3 in Kuwait (Beech and Glover 2005:99), which may indicate an earlier regional appearance of animal domesticates than previous evidence has suggested, considering the eighth-millennium cal BP dating of the main occupation of the site (Carter and Crawford 2003). It is clear that by the seventh millennium cal BP at the latest, the three major animal domesticates (cattle, sheep, and goats) formed a dominant part of subsistence systems in the Gulf region, with caprine herding the dominant activity.

A slightly different picture has emerged from the southwest of the Arabian Peninsula. The rockshelter site of Manayzah in the Southern Jol mountains of Yemen provides the earliest evidence of domestic cattle, sheep, and possibly goats in Southern Arabia, dated to the early eighth millennium cal BP (Martin et al. 2009; McCorriston and Martin 2009; chapter 8 this volume). The small sample hints at a mixed herding economy, alongside equally important gazelle hunting. Domestic cattle and caprines were also found at highland Wādī ath-Thayyilah 3, dating to the seventh millennium cal BP (along with Jibal Qutrān and Najd al-Abyad) (Fedele 2008). The slight dominance of cattle at Wādī ath-Thayyilah 3, together with architectural evidence, has led to interpretations of a Neolithic village-based cattle-herding economy (alongside caprines), which by 5,000 years ago gives way to caprine-dominant subsistence.

The north of the Arabian Peninsula is less well researched, but small samples of very likely domestic cattle have been found at Jebel Oraf 2 in the Nefud region in late seventh millennium cal BP, among a series of open-air hearths, strongly suggestive of mobile cattle pastoralist activity (Guagnin et al. 2017).

Despite evidence for wild cattle (*Bos primigenius*) in Arabia into the Holocene (see review in McCorriston and Martin 2009), finds of wild cattle bones are few and far between, and archaeological consensus reasonably holds that domestic livestock was introduced. Debate continues as to whether Neolithization, with domestic cattle included, represented a mobile pastoralist expansion from the Levant in the north (e.g., Drechsler 2007; Uerpmann et al. 2000) or whether evidence points more to an indigenous development of specialized cattle pastoralism (Cleuzio and Tosi 1998; McCorriston et al. 2012), albeit on introduced stock.

The Kheshiya cattle assemblage, which provides morphological and metrical evidence of cattle species, status, and size, contributes to these debates. The age and sex data that the Kheshiya skulls yield also allow comment on the herding system from which the cattle derived.

Domestic Cattle Possibilities

Southern Arabian Neolithic domestic cattle could potentially derive from three broad sources: domestic European cattle (*Bos taurus*), or taurines; Asian zebu cattle (*Bos indicus*), or indicines; or early African domesticates (taurines, sometimes referred to as *Bos africanus*). Cattle domestication evidence—both genetic and osteological—sees frequent revision in the literature, but a brief summary shows which species and types of cattle should be considered in attempts to identify the species and status of the Kheshiya skulls.

Bos taurus shows good evidence for domestication from the wild aurochs (*Bos primigenius*) in southeast Anatolia and the northern Levant region, where the process appears to have begun by the mid-eleventh millennium cal BP, with morphologically distinct domestic cattle identifiable (Peters et al. 2005). There is genetic support for a single taurine domestication event (Decker et al. 2014; Magee et al. 2014). Domestic cattle spread to western Anatolia and the Aegean by the end of the tenth millennium cal BP (Arbuckle et al. 2014) and to the southern Levant (Horwitz and Ducos 2006) and southern Europe by the late ninth millennium cal BP. We can thus assume they were present in a southern Levantine context for possible dispersal south by this time.

Bos indicus underwent separate domestication on the Indian subcontinent, with some suggestion that they were under cultural control by the late tenth millennium cal BP in the northwest of the region (Patel and Meadow 2017). They had spread to the Middle East region by the end of the sixth millennium cal BP (Chen et al. 2009; Matthews 2002) and are first witnessed in Africa at a 2,000-year-old site in Kenya (Hanotte et al. 2002; MacHugh et al. 1997; Marshall 2000). Genetic evidence suggests that zebu/taurine introgression occurred once zebu reached Africa. While there is no evidence that zebu cattle were in regions bordering South Arabia by the time of the Kheshiya occupation, the evidence for seafaring activity and maritime exchange in the Gulf region from the late eighth millennium cal BP (summarized in Boivin and Fuller 2009) means that the presence of *Bos indicus* needs consideration at Kheshiya.

African cattle are more complex. Genetic evidence supports the idea of a separate domestication of *Bos taurus* in Africa (e.g., Decker et al. 2014; Magee et al. 2014), perhaps from local aurochs (as Grigson [2000] predicted from her morphometrical zooarchaeological study) but also possibly from a hybridization of incoming Near Eastern *Bos taurus* with the resident wild African auroch population (Magee et al. 2014). Most later Egyptian cattle breeds seem descended from founder domestic herds from the Near East (Olivieri 2015), although one haplogroup might stem from a more southerly *Bos primigenius* ancestor, and only in far later millennia do zebu arrive and hybridize. While the zooarchaeological evidence for Early Neolithic domestic cattle in northeastern Africa is controversial (see Stock and Gifford-Gonzales 2013), there is evidence that domestic cattle were present in East Africa at least by the middle of the seventh millennium cal BP (Marshall and Hildebrand 2002).

As McCorriston states in chapter 1, highlighting the aims of the RASA Research Project, Southern Arabia is at the crossroads between the Near East, East Africa, and South Asia—a factor that makes it germane to questions of domestic cattle dispersals and introductions. We cannot entirely dismiss the possibility of any introduced cattle interbreeding with remnant indigenous aurochs in Arabia. For example, Park et al. (2015) have found genetic introgression between domestic European/Near Eastern cattle introduced to the United Kingdom and indigenous British aurochs. That said, populations of *Bos primigenius* in Arabia were probably thin on the ground by the Neolithic.

The Kheshiya Cattle Skulls: What Was Found?

The Kheshiya skull ring originally consisted of about 40 cattle skulls forming the installed monument; an exact count was impossible because part of the site had eroded into a small gully immediately to the south, taking several skulls with it (see chapter 10, figure 10.17). Extremely careful excavation and lifting of the remaining in situ skulls yielded 35 cattle crania sufficiently intact to allow recording of zooarchaeological data to various degrees, depending on states of preservation. The "skull" technically includes all the separate bones of the cranium plus the mandible (lower jaw). The Kheshiya skulls were buried without associated mandibles but we retain the term *skull* here for ease of use. A single additional piece of animal bone was retrieved from excavations within the skull ring; this was identified as a fragment of cattle mandible, although it could not be associated with any individual skull. The site produced no other fragments of animal bone.

Each of the 35 cattle skulls and the single mandible fragment was allocated a 'lot' number upon excavation, and these same numbers were used for zooarchaeological recording and analysis. The terms *lot number* and *skull number* are used interchangeably in this chapter. Numbers range from 2 to 42 (although 6 to 10 are not used), with Lot 35 referring to the cattle mandible. Figure 11.1 shows the location within the monument of each of the 35 skulls excavated and analyzed. We can observe how the cattle skulls were placed close together, often touching, with frontals (tops of skulls) facing inward, nasals pointing down (chapter 10, figure 10.17). It is notable, too, that the oval ring of skulls has a gap in the western curve, maybe serving as an "entrance"; that the ring seems to show part of a second row of skulls immediately behind the first on the east side; and that there is a single skull placed in the center. The placement alone raises questions, which I return to later in discussion.

Methods: Identification, Morphology, Age, and Taphonomy

Original observation and data recording of the Kheshiya cattle skulls were undertaken in January 2006 in the Mukalla Museum, southern Yemen, where the collection was housed. A small team consisting of RASA project director Joy McCorriston, conservator Lisa Usman, zooarchaeologist Louise Martin, and ʿAbdalʿazīz Bin ʿAqīl, director of the General Organization for Antiquities and Museums, Hadramawt Province, worked together to achieve the four aims of the study trip:

1. To clean each skull to the level where zooarchaeological study could be undertaken

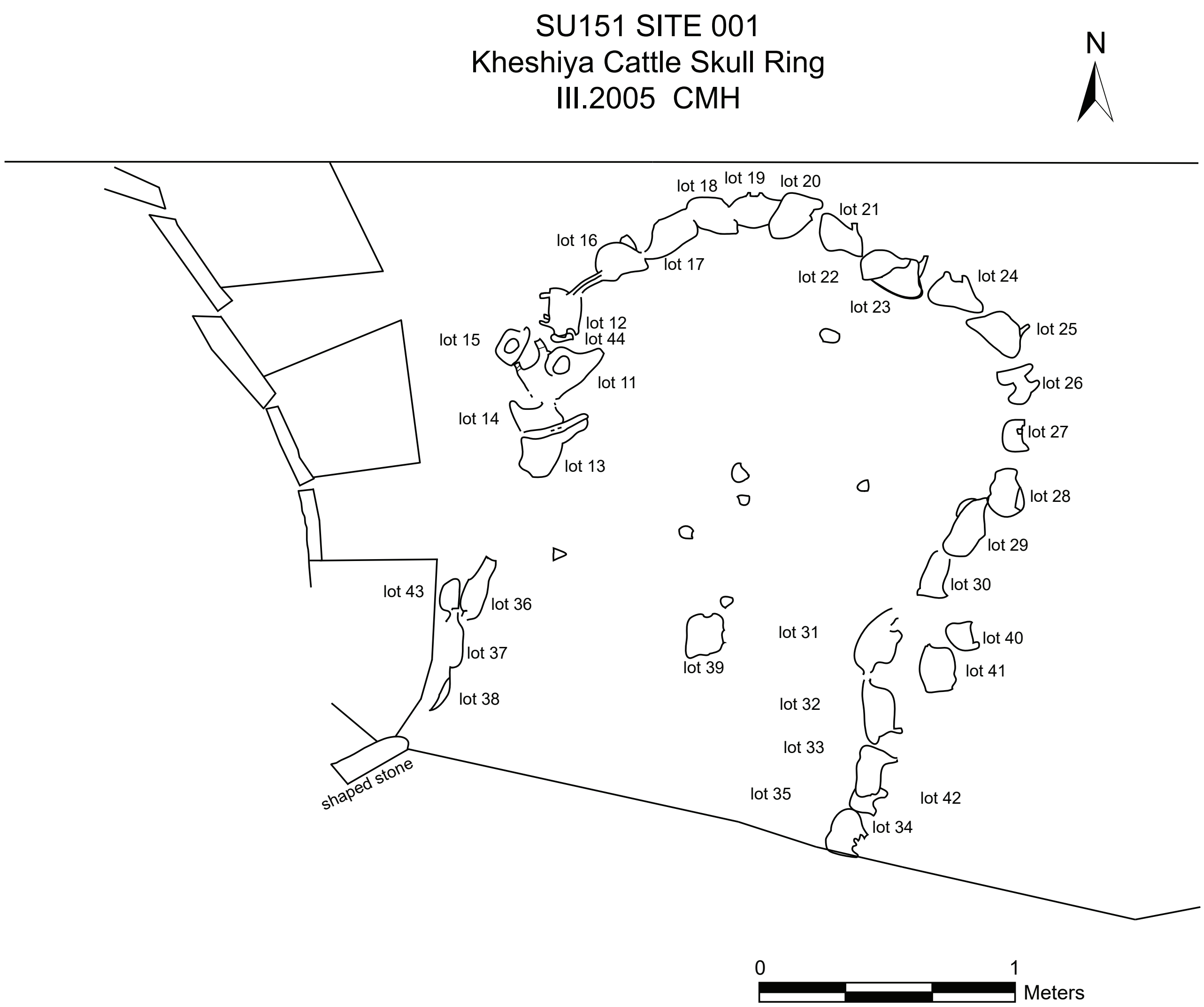


Figure 11.1. Plan of the Kheshiya monument showing the location of the 35 numbered cattle skulls described and discussed in chapter 11. *Drawing by Catherine Heyne, Illustration by Clara Hickman.*

2. To undertake detailed zooarchaeological recording related to the taxonomic status of the skulls, size and status of the cattle, and age of death of the animals; also to document any evidence for human modification and treatment of the skulls, or natural taphonomic processes
3. To create full documentation of the skull assemblage by means of a data and photographic archive
4. To stabilize and pack the skull assemblage for long-term storage in the Mukalla Museum

The director and staff of the Mukalla Museum kindly allowed the team to set up a temporary laboratory for the study within the museum. Appendix 11.1 provides an account of the process of unpacking, cleaning, and conservation of the skulls, explaining decisions taken to keep the skulls as intact and stable as possible to maximize data collection, given time and equipment constraints.

One main challenge to observation and recording was the fragile condition of the skulls. Despite excellent in-field excavation, lifting, first aid, and packing of the skulls in spring 2005 (chapter 10; see appendix 11.1), bone texture on all skulls was invariably dry, brittle, and prone to breakage and collapse, undoubtedly the result of millennia of seasonal changes in temperature and wetness/dryness of the Kheshiya burial environment, leaving bone leached out and very fragile. Furthermore, the skulls appear to have been originally only partially buried, with the posterior portion (all areas distal to the palatines/frontals, including horncores) exposed aboveground, with a high likelihood of subsequent repeated burial and reexposure. Horncores had therefore not survived beyond the occasional horncore base, and posterior parts of skulls were in very poor condition, if present at all.

On initial assessment, it became clear that the skulls were held together only by the fine silts laid down internally in their crania, so in the interests of both time and keeping skulls intact, we decided not to remove these internal deposits, or indeed any deposits in and around the skulls that was supporting bone in place. Deposit was removed selectively only from cranial areas providing the most useful zooarchaeological information, such as the maxillary tooth rows, palatines, frontals, lacrimals, and orbits. Throughout observation and recording, we avoided overhandling the skulls to reduce breakage. We studied the maxillary dentition first and then the palatine area, with skulls resting on their frontals, before turning skulls over to clean and make observations on the top part of the cranium.

Zooarchaeological Data Recording

A series of six cattle skull recording forms were developed specifically for recording the zooarchaeological data captured from the Kheshiya skulls. (Examples of Forms 1–4 are shown in appendix 11.2.)

Form 1, Basic: with fields for describing overall condition, bone surface weathering stages, presence/absence of burning, and any bone surface modifications, plus a table for scoring which skull parts were present

Form 2, Morphology: for recording nonmetrical morphological skull traits

Form 3, Aging Data: for recording dental eruption and wear stages, horncore texture, and cranial bone fusion

Form 4, Measurements on Cranium of *Bos*: for recording metrics taken on the cranium and maxillary dentition

Form 5: Image template line drawings of *Bos* cranium from von den Driesch 1976 (pp. 29–30:figure 8a, dorsal view, figure 8b, nuchal view, dorsal view, and nuchal view) for shading Kheshiya skull part presence/survival

Form 6: Image template line drawings of *Bos* cranium from von den Driesch 1976 (pp. 29–30:figure 8c, left side view, figure 8d, basal view) for shading Kheshiya skull part presence/survival

Identification

A range of large bovids potentially inhabited Southern Arabia during the Early and Middle Holocene, and care was taken to check taxonomic identification of each of the Kheshiya skulls against other possibilities. Because there are few comparative zooarchaeological datasets and the current wildlife is much diminished from earlier diversity, predicting the range of the Early Holocene native fauna of the region is challenging. Of the medium-size bovids (60–200 kg), the Arabian oryx (*Oryx leucoryx*) is likely to have been widespread in the past. Although there is no direct evidence that the addax (*Addax nasomaculatus*) or hartebeest (*Alcelaphus buselaphus*) ever inhabited Southern Arabia, their grassland/semidesert habitats—known from neighboring East and North Africa—mean that a wider distribution cannot be ruled out (McCorriston and Martin 2009:240–41). This may also hold true for the kudu (*Tragelaphus imberbis*). Of the larger bovids (above 200 kg), the African buffalo (*Syncerus caffer*) required consideration because of its known wide habitat range, even though it has not been directly evidenced in Arabia, apart from in prehistoric rockart (Rachad 2007).

Close observation of the morphology of the Kheshiya skulls, particularly their dentitions, allowed for these alternatives to be discounted, and all skulls were

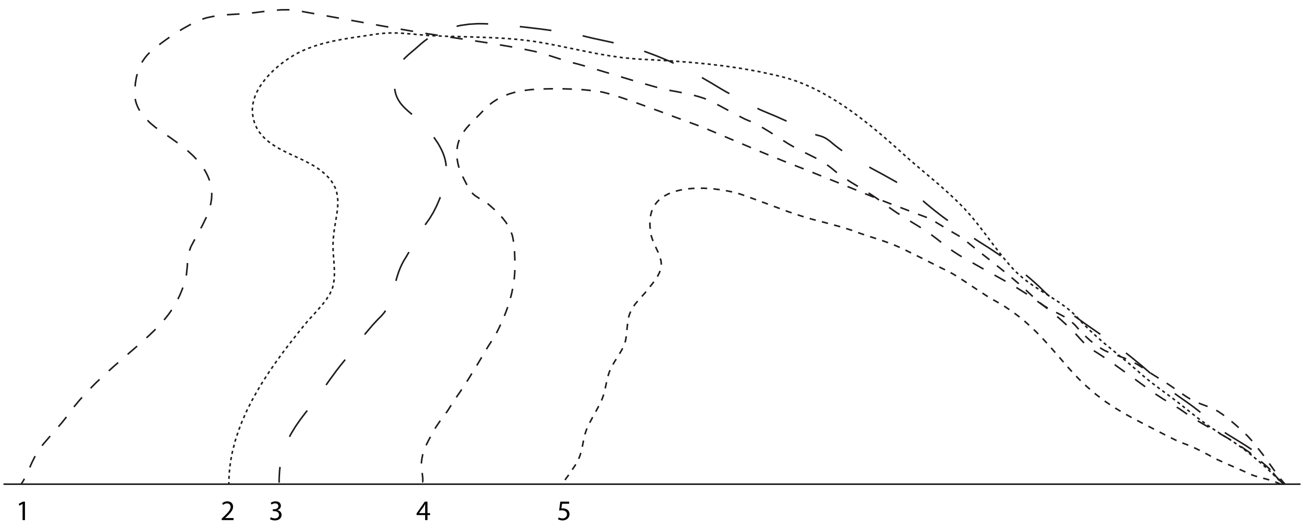


Figure 11.2. Cattle sagittal profile shapes for *Bos indicus* (after Grigson 1980:18, figure 11) showing adult forms (1–4) and a younger shape (5). Adults display a convex frontal profile, concave occipital area, and intercornual ridge facing upward and backward. *Drawing by Clara Hickman.*

identified as cattle (*Bos* sp). Whether the cattle represented were wild aurochs (*Bos primigenius*—evidenced in the Pleistocene and Early Holocene of Southern Arabia; see above) or herded domesticates, and if the latter, whether they were likely to belong to a domestic European cattle type (*Bos taurus*), Asia zebu (*Bos indicus*), or African cattle type, can be approached only through morphological and metrical analyses (described below).

Morphology: Nonmetrical Traits

Where possible, morphological features of the skulls were scored in an attempt to use these nonmetrical traits to assess the species of cattle present at Kheshiya and to gauge morphological variation between the individuals represented in the skull circle. Bear in mind that morphological variation may relate to taxonomic status (for example, taurine or zebu cattle), sexual dimorphism (male or female), wild or domestic status, and age.

Morphological skull features were recorded following criteria described by Grigson (1976, 1980), whose detailed studies of the craniology of four *Bos* species to assess their taxonomic relationships are exceptionally useful zooarchaeological aids (see also Grigson 1974, 1975, 1978). Grigson directly compares morphological criteria across *Bos* taxa, including taurines and zebu cattle, with line drawings highlighting the most useful distinguishing features. Ten separate traits were considered for the Kheshiya skulls to assess whether they had more taurine or zebu features. Unfortunately, preservation did not allow consistent observation/scoring of many of the traits, which are described below:

The sagittal profile was recorded where possible following Grigson's (1976, 1980) criteria. Grigson finds that the "the sagittal profile of *Bos indicus* differs very significantly in almost all of the skulls examined from that of *Bos taurus*" (1980:18), with *Bos indicus* displaying a convex frontal and concave occipital, with the intercornual ridge directed upward and backward (figure 11.2). *Bos taurus* has a flatter frontal profile, with either rounded or pointed intercornual ridges (figure 11.3). Only two Kheshiya skulls were complete enough for full sagittal profiles to be taken: Skulls 18 and 25. This was done using dental wax, heated in water, molded onto the skull in the sagittal plain (method follows Grigson 1976:115), and left to harden. The wax was then removed and the shape was drawn onto tracing paper. Grigson considers this the most important difference between *indicus* and *taurus* (1980: 30). Another four skulls gave an indication of sagittal shape but did not allow full profile.

The orbital rim is also considered a good criterion for *indicus*/*taurus* separation, with Grigson (1980:23) finding this feature in all *Bos indicus* she observed to be flat (see also Grigson 1976:123, figure 8), as opposed to having a sharp rim in *Bos taurus* (figure 11.4). Because it protrudes from the skull, the orbital rim of the Kheshiya assemblage often is damaged and was observable in only one specimen (Skull 41).

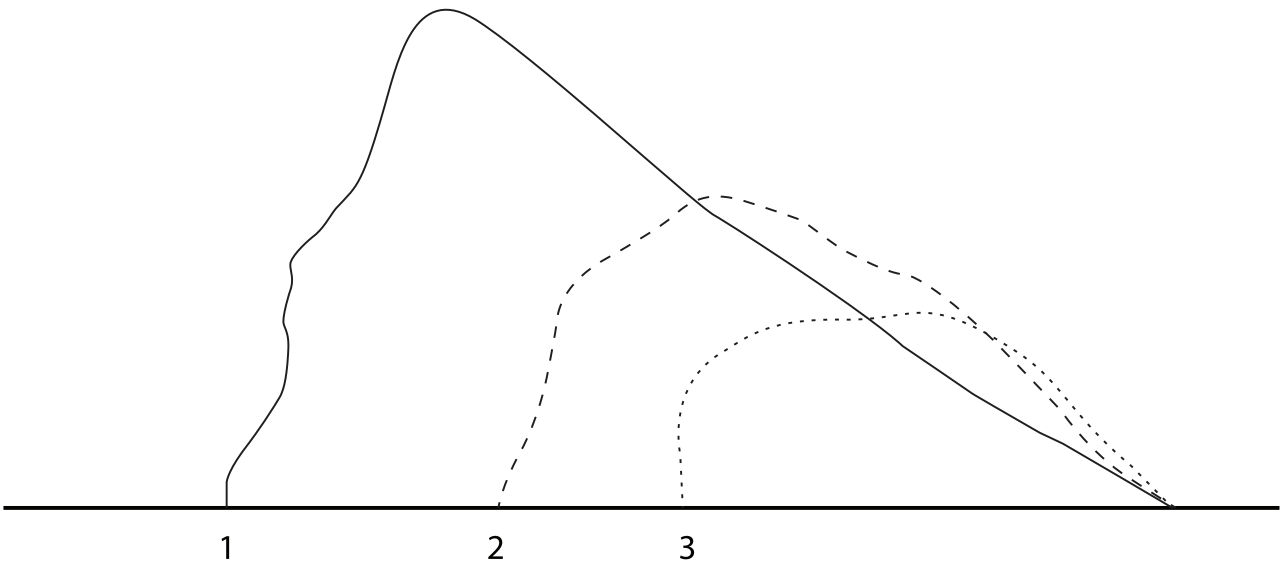


Figure 11.3. Cattle sagittal profile shapes for *Bos taurus* (after Grigson 1976:figure 5) showing the adult form (1) and profiles for younger animals (2, 3). The adult form displays a flat frontal profile with a rounded intercornual ridge. *Drawing by Clara Hickman.*

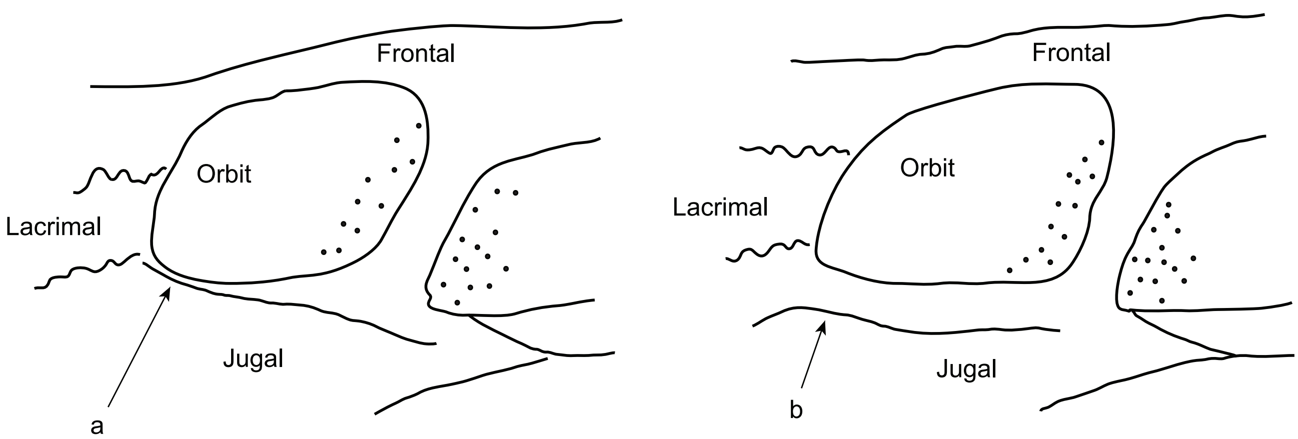


Figure 11.4. Forms of the cattle orbital rim. Left: *Bos taurus* with a sharp rim (a) (after Grigson 1976:123, figure 8). Right: *Bos indicus* form displaying a flat rim (b) (after Grigson 1980:23). *Drawing by Clara Hickman.*

The shape of the nasal–frontal suture was also often difficult to observe on the Kheshiya specimens, due to the frequent forward slumping of the skulls and bone breakage in this area. Grigson (1980:24, figure 21) shows that a simple inverted V shape tends to characterize *Bos indicus,* while *Bos taurus* often shows a more complex M shape (figure 11.5). This is an insecure separation criterion, however, with Grigson (1980:23) reporting exceptions in specimens of both species examined.

Grigson also found the frontal–lacrimal and lacrimal–jugal sutures to differ between the specimens of taurines and indicines she studied (Grigson 1980:23), with the frontal–lacrimal suture bowed downward in all taurines and the lacrimal–jugal suture bowed correspondingly upward (figure 11.6). In most but not all *Bos indicus* skulls, both sutures were straight. These sutures were observable in 14 of the Kheshiya skulls.

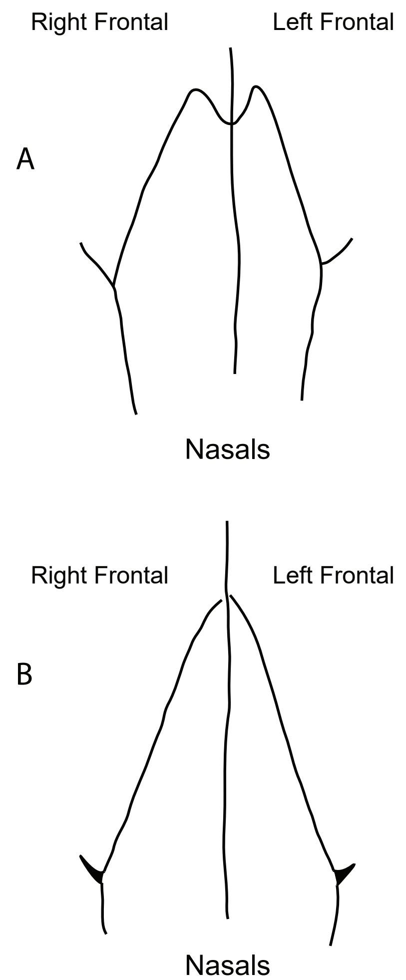


Figure 11.5. Forms of the nasal–frontal suture in cattle, following Grigson 1976, 1980. Top: The complex M shape seen in *Bos taurus* (A). Bottom: The simple inverted V shape (B) that tends to characterize *Bos indicus* (after Grigson 1976:125, Figure 11). *Drawing by Clara Hickman.*

Recording of the frontal profiles was attempted for 18 of the Kheshiya specimens. This shape should be observed between the horncores and viewed from above, but since many of the Kheshiya skulls did not have the horncore area surviving, the profile was often taken some centimeters anterior to this point. Grigson shows various frontal shapes of taurine breeds (1976:126, 1980:25) alongside a typical zebu profile between the horncores (figure 11.7). Taurines appear quite variable and can have convex or flat profiles, or rise in a boss, while *Bos indicus* is characterized by concave profiles (figure 11.7, profile 5). Grigson notes that the frontal profile is not a firm criterion, but it is fairly diagnostic (1980).

The intercornual ridge can also be distinctive between taurine and zebu cattle (Grigson 1976:128, 1980:26) (figure 11.8). Shapes 1–6 in figure 11.8 were all observed in taurine skulls, while 7 and 8 tended to be found in *Bos indicus*, although variations existed (Grigson 1980:26). These ridge forms were scored for the Kheshiya skulls in seven cases, where observation was possible.

Regarding horns and horncores, Grigson (1978, 1980:27–28) finds the overall shape and direction of these quite distinctive between taurines and *indicus*, with separation possible on the majority of the cattle skulls studied. While there is much breed-, age-, and sex-related variation, all *Bos indicus* skulls have horns that point upward and slope backward from their bases, unlike taurines, whose horncores leave the skull in an outward direction, whatever morphology the rest of the horn takes (figure 11.9). There is little difference between the actual shape of the horncore bases between the two species (Grigson 1980:28), so this was not recorded.

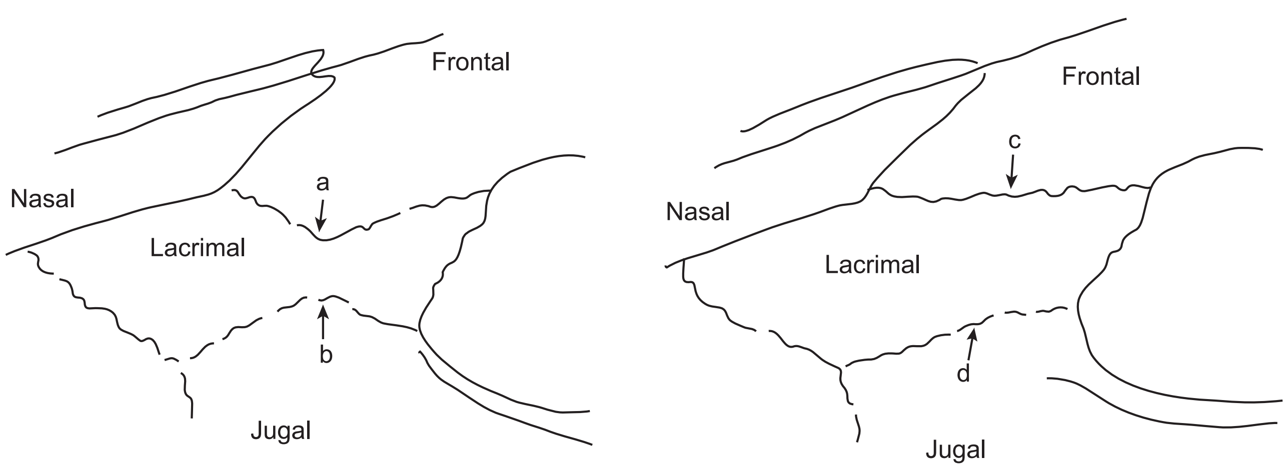


Figure 11.6. Forms of frontal–lacrimal and lacrimal–jugal cattle sutures that Grigson (1980:23) observed as tending to differ between taurines and indicines, with *Bos taurus* showing the frontal–lacrimal bowing downward (a) and lacrimal–jugal bowing upward (b), contrasting the relatively straight sutures (c) and (d) in *Bos indicus* (after Grigson 1976:124, Figure 9). *Drawing by Clara Hickman.*

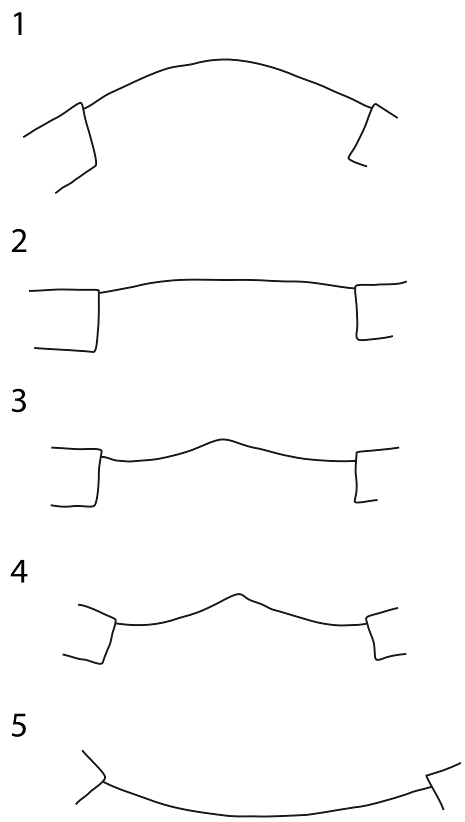


Figure 11.7. Forms of cattle frontal profiles (between the horns) observed by Grigson, with 1 to 4 showing various frontal shapes of taurine breeds, ranging from convex or flat profiles to those that rise in a rounded or pointed boss, alongside a typical zebu profile (5), which is concave. After Grigson 1976:126, 1980:25. *Drawing by Clara Hickman.*

Finally, the morphology of the posterior wings of the skull palate was an area that commonly survived in the Kheshiya skulls, so the shape was recorded following Grigson's observations (1976:126, figure 12, 1980:24–25, figure 22). There is much age- and sex-related variation in this character, but in general Grigson finds two morphologies: straight and broad, and convex and narrow (figure 11.10). The former is characteristic of adult taurines, and the latter is recorded for younger and female taurines and the few *indicus* skulls Grigson managed to study (1980:24).

In sum, of the 10 criteria described above, the most reliable for separating *Bos taurus* and *Bos indicus* appear to be the sagittal profile and the shape and direction of the horncores as they leave the skull. Grigson also found the orbital rim, frontal profiles, and intercornual ridges to be good discriminating criteria, if slightly less secure. Facial suture shapes seem less reliable as diagnostic criteria, and the morphology of the posterior wings of the palate is

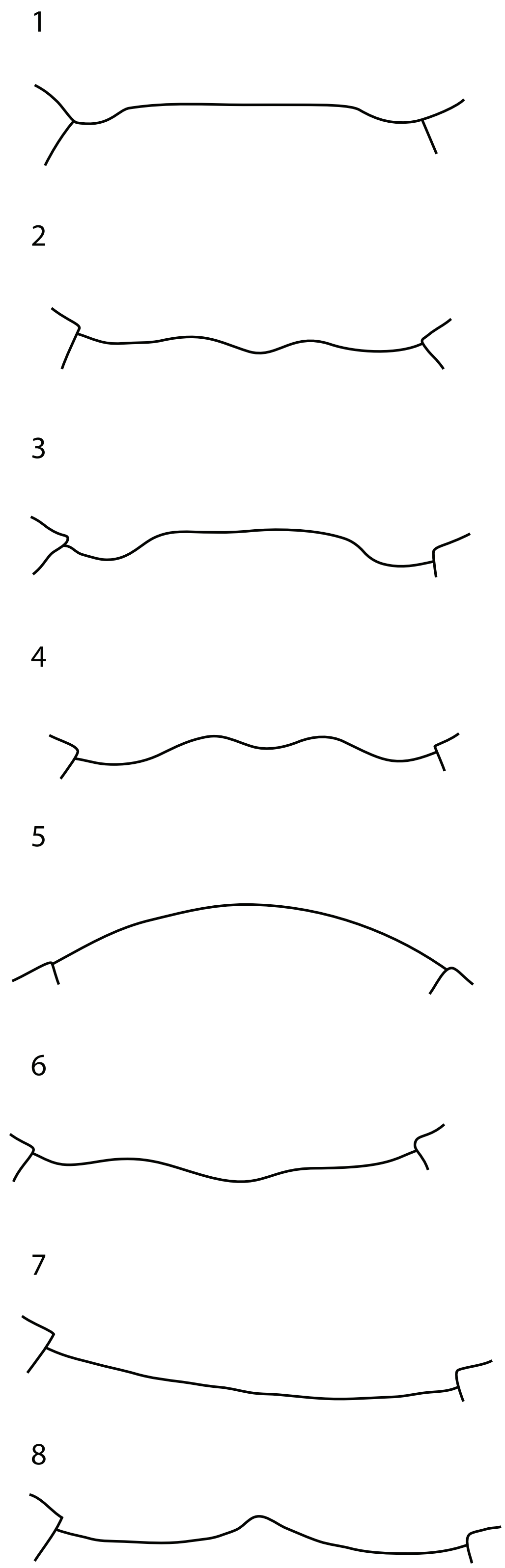


Figure 11.8. Forms of the intercornual ridge in taurine and zebu cattle, showing shapes 1 to 6 observed by Grigson in *Bos taurus* and shapes 7 and 8 tending to characterize *Bos indicus* (after Grigson 1976:128, 1980:26). *Drawing by Clara Hickman.*

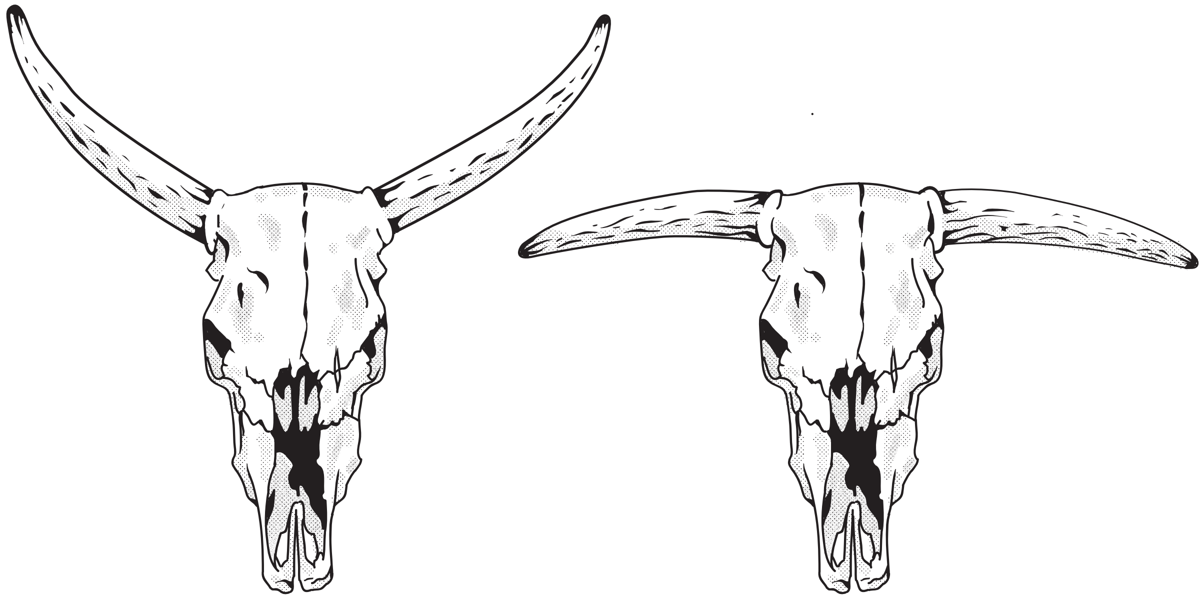


Figure 11.9. Left: horncore shape and direction of *Bos indicus*, showing skull with horns pointing upward and sloping backward from their bases. Right: *Bos taurus* skull showing horncores leaving the skull in an outward direction, whatever morphology the rest of the horn takes. *Drawing by Clara Hickman.*

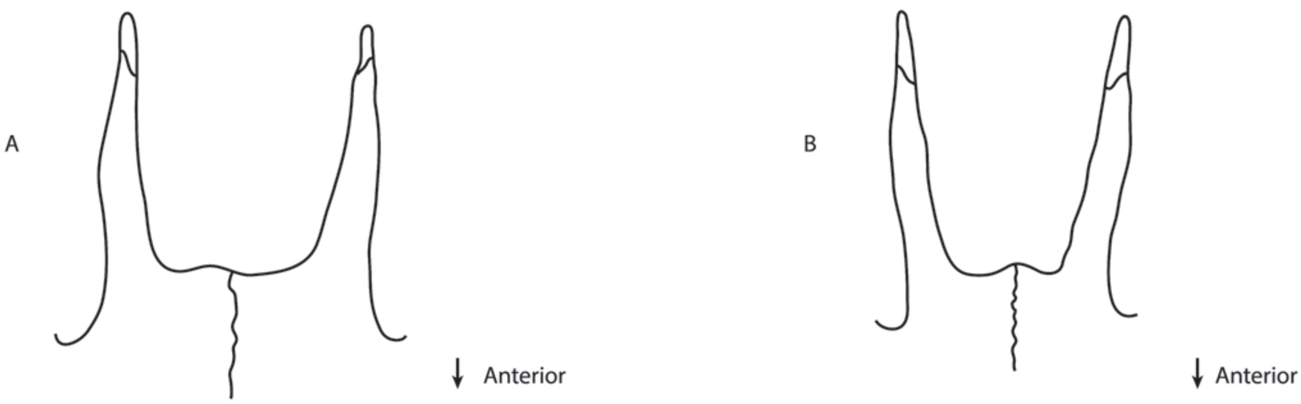


Figure 11.10. Two forms of the posterior wings of the palate in cattle. Left: The straight-sided and broader morphology of adult *Bos taurus* (A); right: the more convex-sided and narrow form (B), characteristic of younger and female taurines and noted in some *Bos indicus* skulls (after Grigson 1976:126, figure 12, 1980:24). *Drawing by Clara Hickman.*

highly variable according to age and sex, as well as species; hence it is less useful.

While Grigson's criteria give us extremely useful scoring systems for the nonmetrical traits of cattle skulls, we need to bear in mind that they were devised from studies of modern cattle, far distant from the Kheshiya cattle population(s) in both time and space. In her study, Grigson drew on a sample of about 24 modern *Bos indicus*, mostly from India, and a larger sample of *Bos taurus* skulls of various breeds, all from Britain. Geographical and temporal variation in cattle skull morphology should therefore be expected when interpreting criteria.

Biometrics

There are two reasons for undertaking biometrical analyses of the Kheshiya skulls: first, to explore the overall size of the skulls and implications for the wild/domestic status of the cattle (although their context and date strongly suggest domesticates); and second, metrical analysis allows for interpretation of sexual dimorphism and sex ratios of the skulls. Did the skulls belong to males, females, or both? All cranial metrics were taken where possible, even though only some are used in comparative analyses.

Measurements follow standards set by von den Driesch (1976). For cranial, tooth row, and horncore measurement, von den Driesch's Codes 1–47 were used (von den Driesch 1976:27–30, figure 8a–d) (see appendix 11.4). For individual teeth, standards for measuring ruminant teeth were followed (von den Driesch 1976:57) but applied to the maxillary dentitions at Kheshiya (that is, length [L] and breadth [B] of the molar teeth and P4 were added for completeness). All dentitions in the maxilla were erupted adult teeth. Tooth rows were measured along the alveoli on the buccal side, and individual tooth measurements were taken at the biting surface, following von den Driesch's standards. To capitalize on the fact that the dental arcades are the most intact areas of most skulls, three additional measurements were devised and taken. Measurements were taken between the left and right sides of the maxillary dentitions, at the alveolus on the lingual side, in the following locations: LM1: P2-P2 internal least breadth; LM2: M1-M1 internal least breadth; LM3: M3-M3 internal least breadth. All measurements were taken using a vernier caliper to 0.1 mm. Appendix 11.4 shows the full set of resulting osteometric data. Individual measurements marked as "estimated" were taken where bone surfaces were slightly eroded or fragmented but the dimension was still clear; these measurements were considered sufficiently accurate to be used in analyses. Measurements marked as "highly estimated" are less reliable and were not included in metrical analyses.

DNA

Three cattle maxillary teeth from separate Kheshiya skulls were sampled for preliminary testing for aDNA preservation, with unsuccessful results (appendix 11.3). Collagen preservation is likely to be poor in the Kheshiya environment; future studies might target the petrous temporal, which is proven to give better results than dentition (Hansen et al. 2017).

Aging Data: Dental Eruption and Wear, Skull Suture Closure, and Horncore Texture

Aging data were collected primarily through assessment of dental eruption and wear stages. The system described by Grant (1982) for cattle mandibular cheek teeth was adapted for the Kheshiya skulls. It included only their maxillary teeth (with no associated mandibles/mandibular dentition) because schemes for recording maxillary tooth wear stages were not found in the literature. Maxillary teeth have clear differences in morphology, proportions, and size compared to their mandibular counterparts, which needs to be taken into account in analysis, particularly when mandible wear scores (MWSs) are used to estimate age (or age stage) at death; rates of occlusal attrition through Grant's stages (1982:92, figure 1) are likely to vary between upper and lower dentitions.

For the Kheshiya skulls, the Grant tooth wear system was applied to both left and right maxillary cheek teeth. Teeth had sometimes fallen out and were missing; a single tooth had also been selected and removed in-field for sampling (normally M3 or M2). Thus the aim of recording both sides of dentition was, first, to check for asymmetrical wear and, second, to maximize chances of having a full set of molars with wear stages. (See "Results: Dental Aging," below.)

The coming into wear of the accessory pillar, which sits between the anterior and posterior cusps of cattle molars, has been proposed as a useful additional criterion for separating adult from older cattle (Halstead 1985). It was not used as a separate criterion in the current study (accessory pillar wear is included within Grant's original 1982 stages) since the pillar is now considered too variable in size to accurately reflect increased wear/age (Jones and Sadler 2012a:11). An alternative method for assessing age of death in older cattle that uses "the position of the cement/enamel junction and the root arch in relation to the alveolar border in molar teeth" (Jones and Sadler 2012a) was not published at the time of studying the Kheshiya assemblage, and so it was not recorded. It has proven difficult to observe these criteria from the Kheshiya cattle skull photographic archive because the maxillary alveolar border is frequently damaged. Hence the Jones/Sadler early to middle aging method (intended for mandibular dentitions anyway) was not attempted.

One further aspect of dental wear recorded for the Kheshiya assemblage was the movement and wearing of the distal end of the P4 into the mesial end of the M1, which sometimes occurred to a great extent where the P4 had wedged itself into the M1, forming a continuous occlusal surface. The aim was to view this alongside the dental anomalies (described below) that mainly appeared to result from premolar maleruption.

Skull suture closure also was recorded for various skull parts (see "Results: Cranial Suture Fusion," below), although poor visibility of sutures due to skull fragmentation and adherence of deposits limited observations. Areas most often visible and recordable were the medial–palatine suture and the maxilla–lacrimal–zygomatic sutures, all of which are relatively late fusing, plus the frontal halves, which are earlier fusing, and the basioccipital area, which is even earlier fusing, following Grigson's summary of data on cattle suture closure timings (Grigson 1982:20, appendix 1). Data tend to give broad age ranges for suture closure (ranging from one to five-plus years for adult animals), and there certainly will be much variation between cattle breeds across wide geographical areas and historical time frames. Nevertheless, by analyzing relative suture closure times, an analyst can assign very approximate age-at-death ranges. These ranges can be considered alongside ranges from dental data (best accuracy for early to middle age).

The skull recording form allowed for the documentation of horncore texture, useful to assess relative age (following Armitage 1982). Firsthand study of the skulls, however, found that in the few instances where horncore bases were preserved, none of the horncores survived beyond the first couple of centimeters from the skull, so this aspect of recording was abandoned.

Dental Pathologies and Anomalies

Two types of dental anomalies were observed and recorded. (See "Results: Dental Anomalies," below.) The first is tooth rotations—when a single tooth has erupted at an angle to the main line of the cheek tooth row but remained in occlusion. The instances of this in the Kheshiya assemblage were all observed with premolars, hinting at a link with maleruption. Tooth rotations were recorded, with details about which tooth and side of the jaw was affected and also the approximate angle of rotation, taking the buccal edge of the tooth row as a rough curved line and estimating the angle (in degrees) by which the rotated tooth diverged from that line. The second, very rare anomaly recorded was the absence of a particular tooth during the life of an animal.

Condition of Skulls, Breakage, and Treatment

The initial aim was to record which cranial parts were present and absent for each cattle skull to assess whether the skulls had seen any modifications prior to deposition. Cattle skulls used in installations in other Neolithic and later contexts from the broader Middle East/Anatolia/North African area often are not complete. At Neolithic Çatalhöyük in central Anatolia, for example, horns often were removed for separate installation, or anterior portions of the skull were removed to create the well-known bucrania (a term itself implying modification) that were built into domestic walls (Mellaart 1967; Russell and Martin 2005; Twiss and Russell 2009), with similar practices seen at nearby Early Neolithic Boncuklu (Baird et al. 2016:figure 6). The thousands of domestic cattle skulls buried at the Kerma necropolis in northern Sudan see varied modification through the fourth millennium cal BP, with an earlier practice of creating a bucranium of frontals, horncores, and nasals for deposition, while later examples had nasals removed too (Chaix 2007:173–75). The forms for the Kheshiya skulls, therefore, aimed at recording skull parts present (appendix 11.2; see Forms 1, 5, and 6).

It became apparent on lab examination that any skull parts absent had been broken not because of pre-depositional human modification but through post-depositional processes, either from the extreme burial environment (wetting/drying of the matrix; surface exposure) or the challenges of excavation and lifting. While retrieval was excellent, fragile skull parts often were broken off and fragmented, but they were carefully collected nevertheless. Skull part presence was recorded on the template diagrams (appendix 11.2, Forms 5 and 6) as a record of preservation; the process of close examination led to interesting observations about patterns of damage and breakage.

Bone Weathering

Bone surface weathering was recorded using Behrensmeyer's (1978) weathering stages, which define bone surface weathering in subaerial/surface contexts, with the aim—following further controlled experiments—of determining periods of time between bone deposition and eventually burial. This is relevant to the current study because there is a strong chance that rear parts of the Kheshiya skulls (including horns and horncores) remained aboveground, and examination of differential weathering patterns might aid understanding of the extent of original burial. Thus general weathering stages were noted across the skull frontals, since this is largest flat area of bone visible; where other cranial areas differed in weathering stage, this too was recorded.

Behrensmeyer's seminal article (1978) defined six weathering stages, which range from bone appearing fresh and still greasy (Stage 0), through increasing stages of surface cracking and exfoliation (Stages 1 and 2), to deeper cracks opening in bone (Stages 3 and 4), until bone eventually falls apart (Stage 5). There has been considerable subsequent discussion about whether stages can be usefully related to periods of time that bone has been left exposed aboveground before burial (e.g., Lyman and Fox 1989). Studies conclude that so many factors are at play—such as variations in bone size, element morphology, the microenvironment of burial, and temperatures and moisture (even before differences in prediscard treatment of bone is considered)—that weathering stages cannot be employed to read even approximate lengths of time between bone deposition and subsequent burial. It is now also acknowledged that bone weathering does not stop with burial, although it probably slows down, depending on the stability of the burial environment (Lyman and Fox 1989). Bone buried in deposits that continue to experience variation in moisture and temperature is likely to continue the weathering process, particularly if burial is shallow.

Beherensmeyer's scheme dealt with postcranial elements rather than skulls, and other observations (on human skulls) suggest that cranial bone weathers differently from long bones (e.g., Ross and Cunningham 2011:132, table 3)—for example, they exhibit surface pitting rather than cracking. Therefore, a slightly modified set of descriptors for the weathering stages was developed for use with the Kheshiya skulls (as described in "Results: Weathering," below).

Burning and Cut Marks

Skulls were examined for any signs of burning, heating, or charring, although none were found. Any cut marks were recorded by placement, number, and morphology.

Photographic Archive

Once cleaned, each skull was photographed from *six* angles (dorsal views, basal views, both lateral views, nasal and nuchal views), plus detailed close-ups of dentition, important morphological diagnostic features, and cut marks.

Results: Origin, Age, and Taphonomy

Data relating to the cattle skull analysis are here presented and discussed, focusing first on the cattle themselves, in terms of the species to which the skulls belonged, their size, status, ages at death, and sex balance of the cull. Second, data relating to the condition, treatment, and modification of skulls are assessed, with the aim of unraveling the cultural and natural processes that affected them prior to burial, during burial itself, and post-depositionally.

Table 11.1 summarizes the analyses to which each of the 35 skulls contributes information. The 35 skulls vary widely in terms of how much data they provide for various analyses, with many contributing to most areas of analyses. Other poorly preserved specimens, however, such as Skull 15, which had no surviving dentition and was too fragmentary to be measured, contribute less, although this skull could be assessed for weathering and cranial fusion data.

To summarize, table 11.1 shows that all 35 skulls could be assessed for bone surface weathering data, and some cranial fusion data could be assessed on each skull. Most skulls (n = 33) provided information on morphological traits and metrics, and there is a good sample of dental early to middle aging data (n = 32) for reconstructing ages at death. Cut marks were recorded on very few skulls (n = 4). Perhaps there were few because the other skulls never had any signs of butchery or preparation, or, more likely, because the fragmentary condition of many skulls obscured the visibility of cut marks. Dental anomalies, however, could potentially be observed on all 34 skulls because the dentition survived well, but in fact they are visible in only eight skulls, which is likely to be a roughly accurate frequency. Table 11.1 thus gives an indication of how representative the following discussions of results are in relation to the assemblage as a whole.

Taurine or Zebu Cattle?

The "Methods" section above describes how each cattle skull was scored where possible for nonmetrical morphological traits, with the aim of using these criteria to determine whether the skulls belonged to *Bos taurus or Bos indicus*. Appendix 11.5 shows the resulting data and comments for each skull recorded for 10 nonmetrical traits. It is notable how many traits were not assessable due to poor preservation. Very few skulls had posterior parts surviving, meaning that horncore shape and direction were visible in only a few cases, and sagittal profiles could not be taken in most. Orbits and facial sutures, too, suffered badly from breakage. Of the 35 potentially assessable skulls, the proportion of traits scored was relatively low, with the exception of the shape of the posterior wings of the palate, protected by its more internal skull location, which survived well.

Information in appendix 11.5 is summarized in table 11.2, which shows how many skulls exhibited morphological characteristics of either taurine or indicine cattle, following Grigson's (1976, 1980) criteria (see "Methods" section), or had more questionable criteria (leading to the "taurine?" and "*indicus*?" assignations). Where criteria were present but ambiguous, skulls were recorded as "indeterminate." The bottom row of table 11.2 shows how many of the 35 skulls could be scored for each trait; the right-hand column shows how many traits in the total Kheshiya skull assemblage could be counted as taurine, taurine?, *indicus*, *indicus*?, and indeterminate. Table 11.3 also summarizes the information by skull, showing how many morphological characteristics interpreted as taurine or taurine? and *indicus* or *indicus*? each skull exhibited.

An initial view of table 11.2 seems to suggest the presence of both taurine and *indicus* morphological traits in the Kheshiya skull assemblage, with more of the former in the totals. Further consideration needs to be given, however, to the reliability of each of the criteria—which Grigson notes as being variable in usefulness—particularly since 14 of the 35 assessable skulls display characteristics of both species within an individual skull (table 11.3).

Grigson found the most important criterion for separating taurine from indicine skulls to be the sagittal profile (1980:30), with all her study specimens being reliably separable using this skull shape. Kheshiya Skulls 18 and 25 allowed sagittal profile shapes to be taken (figures

Table 11.1. Table summarizing which zooarchaeological analyses each of the 35 Kheshiya cattle skulls provides data for, showing totals in each case (not including Lot 35, which is a mandible fragment). The right-hand column also shows which skulls provided tooth samples exported to University College London for our dental microwear and isotope study (Henton et al. 2014).

Skull/ Lot Number	Weathering	Posterior–Anterior Slumping	Morphological Traits	Cranial Metrics	Dental Metrics	Cranial Fusion	Dental Aging	Dental Anomalies	Cut Marks	Henton Isotope Study	Henton Microwear Study
2	x		x	x	x	x	x				
3	x	x	x	x	x	x	x	x	x		
4	x			x	x	x	x				
5	x	x	x	x	x	x	x				
11	x	x	x	x	x	x	x	x		x	x
12	x		x	x	x	x	x				x
13	x		x	x	x	x	x			x	x
14	x	x	x	x	x	x	x				x
15	x					x					
16	x	x	x	x	x	x	x				x
17	x	x	x	x	x	x	x			x	x
18	x	x	x	x	x	x	x			x	x
19	x		x		x	x	x			x	x
20	x	x	x	x	x	x	x			x	x
21	x		x	x	x	x	x			x	x
22	x	x	x	x	x	x	x			x	x
23	x		x	x	x	x	x			x	x
24	x	x	x	x	x	x				x	x
25	x	x	x	x	x	x	x				x
26	x		x	x	x	x	x				x
27	x	x	x	x	x	x	x			x	x
28	x	x	x	x	x	x	x	x		x	x
29	x	x	x	x	x	x	x	x			x
30	x	x	x	x	x	x	x				
31	x	x	x	x	x	x	x				x
32	x	x	x	x	x	x	x		x	x	x
33	x	x	x	x	x	x	x		x	x	x
34	x		x	x	x	x	x	x		x	x
36	x	x	x	x	x	x	x				x
37	x	x	x	x	x	x	x		x		x
38	x		x	x	x	x	x	x			x
39	x		x	x	x	x	x			x	
40	x		x	x		x					x
41	x	x	x	x	x	x	x	x		x	x
42	x		x	x	x	x	x	x			x
Total (35)	**35**	**21**	**33**	**33**	**33**	**35**	**32**	**8**	**4**	**17**	**28**

Table 11.2. A summary of information in appendix 11.5, showing the number of Kheshiya skulls that exhibit morphological characteristic of either taurine or indicine cattle, following Grigson's 1976 and 1980 criteria (see "Methods" section). Some exhibited questionable criteria leading to the taurine? and *indicus*? assignations; skulls with ambiguous criteria are listed as indeterminate. The bottom row shows how many of the 35 skulls could be scored for each trait; the right-hand column shows how many traits in the total Kheshiya skull assemblage can be assigned to taurine, taurine?, *indicus*, *indicus*?, and indeterminate.

Type	Sagittal Profile	Orbital Rim	Nasal–Frontal Suture	Frontal–Lachrymal Suture	Lachrymal–Jugal suture	Frontal Profile	Intercornual Ridge	Horncore Shape	Horncore Direction	Shape of Posterior End of Palate	Total Traits, All Skulls	Total Most Reliable Criteria (sagittal profile, horncore shape and direction)
taurine	2	0	1	0	0	14	2	4	1	8	**32**	**7**
taurine?	4	0	2	0	1	4	2	0	1	0	**14**	**5**
indicus	0	0	0	0	8	0	2	0	0	8	**18**	**0**
indicus?	0	1	5	1	5	0	0	0	2	3	**17**	**2**
intermediate	0	0	0	0	1	0	1	0	0	11	**13**	**0**
Total Assessable: 35	**6**	**1**	**8**	**1**	**15**	**18**	**7**	**4**	**4**	**30**		

Table 11.3. A summary of information in appendix 11.5, showing how many morphological traits interpreted as taurine/taurine? and *indicus*/*indicus*? each of the Kheshiya skull exhibits (following criteria of Grigson 1976, 1980; see "Methods" section, figures 11.2–11.10).

Skull/Lot Number	Taurine/Taurine? All Traits	*Indicus*/*Indicus*? All Traits
2	1	0
3	2	0
4	0	0
5	1	0
11	2	1
12	2	1
13	1	2
14	0	1
15	0	0
16	1	1
17	0	4
18	2	2
19	0	1
20	2	0
21	4	0
22	2	0
23	3	3
24	1	1
25	3	1
26	0	0
27	0	0
28	2	1
29	3	0
30	4	1
31	1	0
32	0	1
33	0	2
34	2	0
35		
36	2	3
37	1	1
38	0	0
39	1	1
40	0	1
41	2	3
42	1	1

11.11 and 11.12), and both show flat frontals characteristic of taurine cattle rather than the convex frontals of zebu. Figure 11.13 also shows a photograph of Skull 25 with the characteristic *Bos taurus* frontal profile, although the posterior end of skull is missing. Intercornual ridges do not protrude upward and backward as they would in zebu (Figure 11.2) but are more rounded, which is consistent with a taurine interpretation. Four other Kheshiya skulls (21, 23, 30, and 36) had enough of their frontals and occipitals surviving to gauge the sagittal profile shape, even if they were not sufficiently complete to be drawn. All four match the taurine profile. On the basis of this most distinctive and reliable criterion, therefore, no skulls are zebu-like, although the sample size is small (6 out of 35).

Horncore morphology is also considered reliable, with Grigson (1978, 1980:27–28) finding that the majority of taurines and zebu/indicines could be separated using their shapes and directions. As described above, horncores, horncore bases, and posterior parts of skulls preserved terribly at Kheshiya, probably because they protruded aboveground and were exposed at least initially after skulls were buried. Horncore shape and direction could be gauged from only seven skulls, and in each case from the small broken remains of horncore bases. Four specimens exhibited taurine horncore base shapes (Skulls 22, 23, 25, and 29) (figure 11.14); a further two skulls (21 and 41) showed horncores leaving the skull outward from the frontals, characteristic of taurines. Another two skulls were scored as having horncore bases with horns appearing to angle more backward, as they would in *indicus* (Skulls 17, 23), although in both cases this was noted as questionable because of the highly fragmented state of the skulls (figure 11.15). Considering that one of these tentative *indicus* shapes (Skull 23) was also recorded as having taurine-shaped horncores, identification seems inconsistent and the evidence is perhaps not strong enough to be sure of a presence of *indicus*-shaped horns. It seems prudent to conclude that while several examples have characteristic taurine horns (with three of the same skulls—21, 23, and 25—also having taurine-like sagittal profiles), two skulls have more backward-sloping horncores, which may hint at *indicus* shape or may simply represent taurine variation. It is worth mentioning here that some photographs of the skull ring upon excavation allow observations that laboratory study did not, where very fragile areas of horncore base were in some cases still supported by pillars of sediment deposits and horncore shape could be traced. Figure 11.16, for example, shows Skulls 13, 14, 11, and 12, with indications of horncores leaving their skulls outward from the frontals, as they would in taurines.

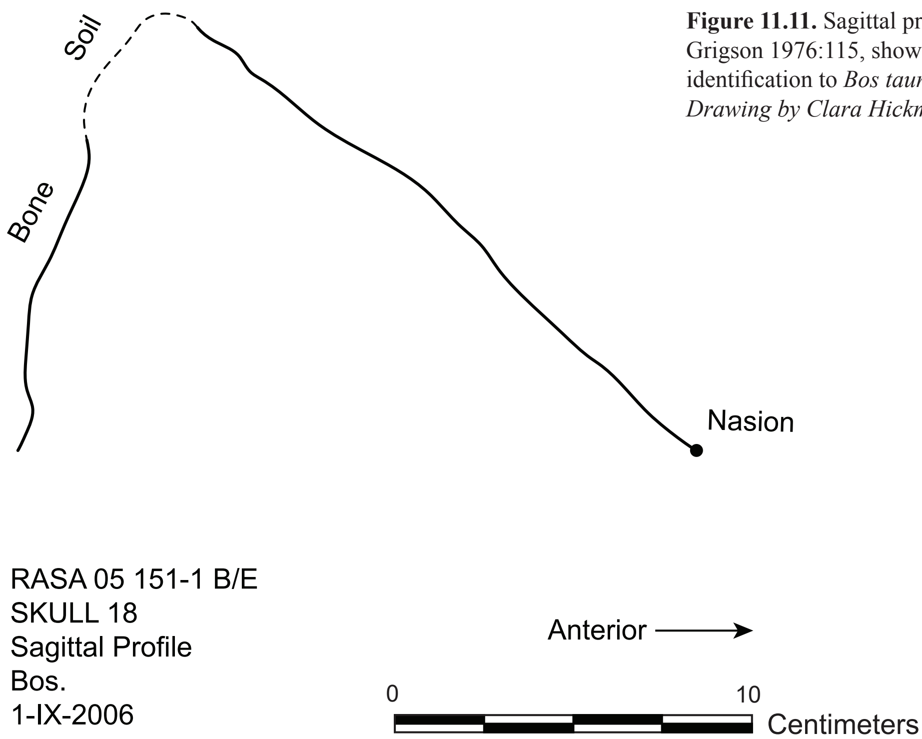


Figure 11.11. Sagittal profile of Kheshiya Skull 18, following Grigson 1976:115, showing flat frontal profile, consistent with identification to *Bos taurus* (compare to figures 11.2 and 11.3). *Drawing by Clara Hickman*.

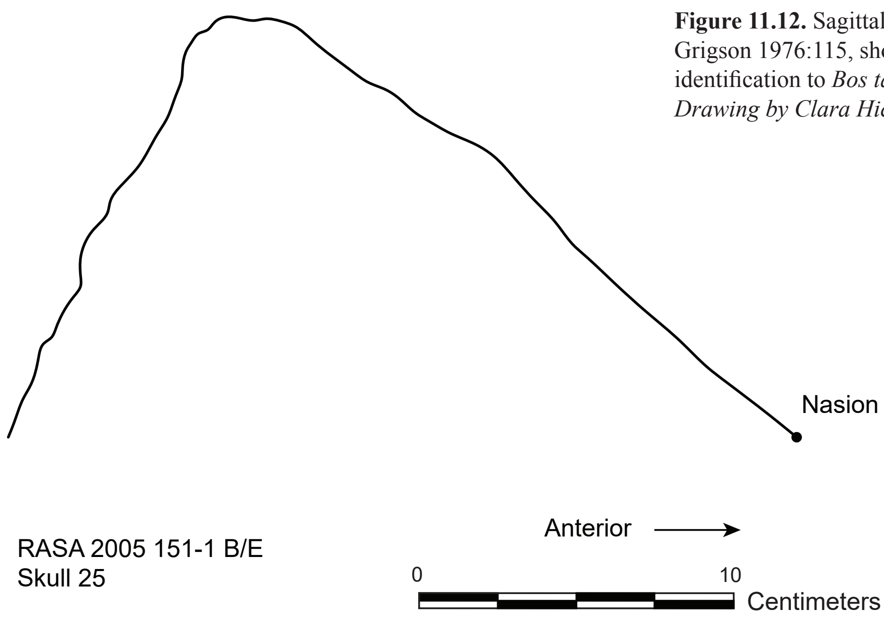


Figure 11.12. Sagittal profile of Kheshiya Skull 25, following Grigson 1976:115, showing flat frontal profile, consistent with identification to *Bos taurus* (compare to figures 11.2 and 11.3). *Drawing by Clara Hickman.*

The single orbital rim (zygomatic) from the Kheshiya skulls that allowed recording of its shape is flat (figure 11.17, Skull 41), which fits better with Grigson's (1980:23) description of *Bos indicus* rims than with sharp taurine forms. Grigson considers this a good diagnostic criterion.

Moving to less consistently secure criteria, Grigson states that the frontal profiles viewed from above are, with some exceptions, fairly diagnostic. Of the 18 Kheshiya skulls for which frontal profiles could be recorded, 15 are *taurus* shaped and none are *indicus* shaped. The intercornual ridge—also considered less reliable—was recorded for seven Kheshiya skulls, of which four showed taurine shapes while two (Skulls 17 and 23) had a slight boss in the center (figure 11.8, Shape 8), suggestive of the *Bos*

Figure 11.13. Skull 25, lateral view, showing the flat sagittal profile characteristic of *Bos taurus* (also shown in Figure 11.12). *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.14. Skull 23, superior view, showing highly fragmented posterior/occipital end, with hint of horncore base, and horncores leaving frontals in an outward direction, characteristic of *Bos taurus*. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.15. Skull 17, superior view, showing highly fragmented posterior/occipital end, with hint of horncore base, showing horncores leaving skull slightly angled backward, although questionable. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.16. Part of the Kheshiya cattle skull ring upon excavation in 2005, showing Skulls 13, 14, 11, and 12, with hints of horncores leaving their skulls in an outward direction from the frontals, characteristic of *Bos taurus*. *Photograph by Michael Harrower.*

Figure 11.17. Orbital rim of Skull 41. The flat rim (compare with Figure 11.4) is considered diagnostic of *Bos indicus* (Grigson 1980:23). *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

indicus morphologies recorded by Grigson (1976:128, 1980:26). Interestingly, these are the same two skulls observed above to have backward-angled horncores, as *indicus* does.

Bos facial suture shapes are less reliable indicators of species (Grigson 1980:23–24), with nasal–frontal suture morphology showing wide variation between taurines and indicines but with some characteristic forms (figure 11.5). Eight nasal–frontal sutures were scored for the Kheshiya skulls, with three being taurine-like and five with the simpler V shape of *indicus*, although these were all recorded as questionable due to much breakage in this skull area.

One frontal–lacrimal suture and 15 lacrimal–jugal sutures were assessed for shape, and all except two appeared straight rather than bowed, which Grigson (1980:23) tends to associate with *Bos indicus* rather than *taurus* (figure 11.6). This is puzzling since in several cases these morphologies were observed on skulls where more reliable criteria (for example, sagittal profiles) identified them as taurines. Suture criteria, therefore, seem unreliable, perhaps because in most cases the Kheshiya facial sutures were unfused and thus would not have been fully formed.

Finally, while the posterior wings of the palate often survived and could be observed and scored, they have quite variable morphologies, with some seeming to fit one or the other of Grigson's two observed shapes (figure 11.10); 10 others have intermediate forms, and some have shapes quite different from those described by Grigson. This criterion, therefore, was considered to have high variability—as Grigson noted—and was deemed unreliable.

In sum, this discussion of nonmetrical traits suggests that some criteria are more useful than others in the attempt to identify the Kheshiya cattle skulls to the broad species level of either *Bos taurus* or *Bos indicus*. Returning to the summary of traits in table 11.2, the extreme right column shows skull assignations based on sagittal profiles and horncore shapes alone—traits considered most reliable by Grigson. We can see that seven skulls appear strongly taurine, five questionably taurine, and two questionably indicine. As shown in table 11.4, when the least reliable criteria are excluded (facial suture morphology and the form of the wings of the palate), 19 of the 35 assessable Kheshiya skulls have traits that fit only a *Bos taurus* assignation, two skulls display both taurine and indicine morphologies (Skulls 23 and 41), a single skull (17) has two traits considered indicine, and none is taurine.

Table 11.4. Summary of how many morphological traits are indicative of *Bos taurus* and *Bos indicus* for each skull, excluding the least reliable criteria (facial suture morphology; form of the wings of the palate). Skulls still exhibiting *indicus* traits are highlighted.

Skull/Lot Number	Taurine Excluding Sutures and Wings of Palate	*Indicus* Excluding Sutures and Wings of Palate
2	0	0
3	1	0
4	0	0
5	1	0
11	0	0
12	1	0
13	1	0
14	0	0
15	0	0
16	1	0
17	0	2
18	2	0
19	0	0
20	1	0
21	3	0
22	2	0
23	2	2
24	1	0
25	3	0
26	0	0
27	0	0
28	1	0
29	2	0
30	3	0
31	1	0
32	0	0
33	0	0
34	1	0
35		
36	2	0
37	1	0
38	0	0
39	1	0
40		
41	2	1
42	0	0

It seems reasonable to view the evidence as suggesting that the Kheshiya skulls belonged to taurine cattle with some variation in horncore and posterior skull shape, which might be considered more zebu-like. It is difficult to make a strong case that any skulls are unambiguously identifiable as zebu, given that preservation, particularly of horncores and diagnostic skull areas, is poor and that traits exhibit ambiguity (for example, table 11.4). We should also acknowledge that this exercise in assessing morphological traits is based on a single published system (Grigson 1980) that draws on modern British cattle breeds and modern primarily Indian zebu stock. While extremely rigorous, Grigson's system was never intended to cover global and temporal variation in cattle morphology, and Southern Arabian Neolithic cattle are distant from Grigson's study samples both temporally and geographically.

This section therefore provides transparency about how the Kheshiya skulls were assessed and clearly documents details of their morphological traits for future users.

Cattle Skull Size

Although measurements were taken wherever possible on all skulls, the high degrees of fragmentation meant that most fragile bone areas and extremities could not be measured. Appendix 11.4 gives the full set of measurements for each skull, including those estimated. As described in the "Methods" section above, most follow von den Driesch (1976) and use her numerical codes.

Maxillary dentitions were the most intact and measurable areas of skulls with the length of cheek tooth row (Measurement 20), length of molar row (Measurement 21), and length of premolar row (Measurement 22) being possible to capture or estimate on at least 30 skulls of the total 35 assessed. Other dimensions that provided good samples are von den Driesch's Measurement 32, least frontal breadth (n = 18), and Measurements 4, 35, and 38, which provide about 20 data points each (appendix 11.4).

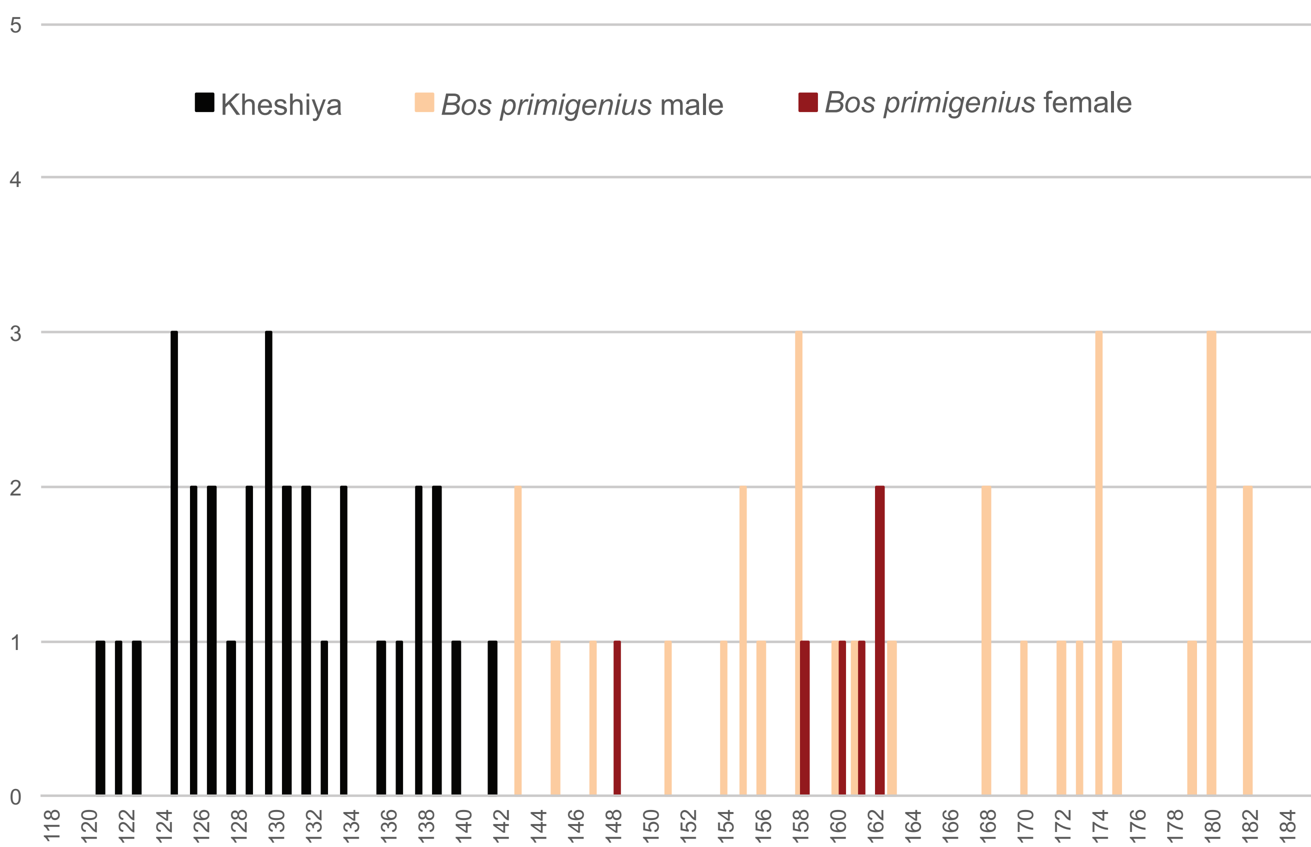
Size Comparison with Prehistoric Cattle in Arabia, Egypt, the Levant, and Anatolia

Although there is evidence for *Bos primigenius* in the Arabian Peninsula in the Neolithic, it is reasonably assumed that the Kheshiya skulls derived from herded domesticates, most likely European taurines, *Bos taurus*. Given that they are among the earlier domestic cattle in Arabia, it would be interesting to see how their size compares with regional wild cattle.

Since most *Bos* finds are postcranial, one difficulty is finding samples of *Bos primigenius* skull measurements for comparison. Where cranial finds survive, they tend to be mandibular or mandibular tooth fragments. Therefore, these measurements are available rather than maxillary measurements. No comparisons were found from the Arabian Peninsula. From Upper Egypt, a measurement of a Late Paleolithic *Bos primigenius* maxillary molar length (von den Driesch's Measurement 21) shows it to be far larger than any at Kheshiya (with the Egyptian specimen having a length of 95 mm compared to the largest at Kheshiya measuring 87.6 mm) (Baker and Gautier 1997). Linseele (2004) indeed finds that the Pleistocene African aurochs are as large as their European counterparts, although they grew smaller into the Holocene. In the Levant, where they occur more commonly at prehistoric sites, *Bos primigenius* remains consist mostly of long bones and trunk elements, with cranial portions often highly fragmented and not measurable (for example, at PPNB Kfar Hahoresh PPNB; Horwitz and Goring-Morris 2004). Even in the northern Levant/Euphrates Valley, where PPNB sites show cattle skulls and horns in installations, alongside evidence for local cattle domestication, published skull metrics are very few. At Middle/Late PPNB Halula, for example, measurements are given only for isolated maxillary molars (M1-M3) (Seguí 1999).

Turning to central Anatolia, where cattle bucrania installations from Late PPNB Çatalhöyük and nearby Boncuklu Höyük are believed to belong to *Bos primigenius*, the skulls appear vastly larger than those from Kheshiya. For Measurement 32 (least frontal breadth), Çatalhöyük has one skull measuring 320 mm (Russell et al. 2013, skull from 4040, Hodder Phase G, circa 9000–7500 cal BP), while the Kheshiya skulls range from 147 to 197.5 mm for the same dimension. A *Bos primigenius* skull from Boncuklu (Building 4, west skull) measures 250 mm across its least frontal breadth (Baird et al. 2016). Given both that domesticates are smaller than wild counterparts and that a north–south size cline is likely at play (with northerly examples

Figure 11.18. Maxillary tooth row lengths (von den Driesch Measurement 20) expressed in millimeters; Kheshiya cattle measurements (from appendix 4) compared to those of Danish *Bos primigenius* males and females (data from Degerbøl and Fredskild 1970:85, table 9). *Illustration by Louise Martin.*



of the same species tending to show larger body size [e.g., Davis 1981; Wright and Viner-Daniels 2015; Zeder and Hesse 2000]), it is not at all surprising that Anatolian wild aurochs are much larger than Southern Arabian domestic cattle. In addition, the central Anatolian examples are from the Konya Plain, which is considered prime wild cattle territory and where one would expect maximum body size (Russell et al. 2005).

Size Comparison with Prehistoric Cattle in Europe

The European record offers some comparatives. The valuable biometrical database of wild and domestic cattle (Wright et al. 2016) includes mostly postcranial measurements, and those that are cranial consist mainly of mandibular and loose teeth. The most useful collection for comparison of cattle skulls is that described in detail by Degerbøl and Fredskild (1970) from Denmark, which includes large samples of both prehistoric *Bos primigenius* and *Bos taurus*, with the advantage that they derive from a restricted geographical area, although over relatively long time spans. Many skulls are part of whole skeletons (from bogs), and most have horns attached, meaning that they can be identified as male or female. It would certainly be expected that prehistoric Danish cattle (both wild and early domesticates) were larger than domesticates from distant Southern Arabia. Wright and Viner-Daniels (2015) have demonstrated that aurochs display morphological variation even across Europe during the Pleistocene and Holocene, with a south–north cline (increase) in body size evident. In brief, more southerly habitats display animals with smaller body sizes than northern areas, with tentative evidence also for a west–east cline. Whether this size cline is temperature-related alone (following Bergmann's rule) or regulated by indirect factors such as variations in seasonality and forage availability, Wright and Viner-Daniels (2015) cannot yet determine. Thus, while we clearly expect size differences between the Danish *Bos* skulls and the Southern Arabian Kheshiya skulls, it is nevertheless informative to view the Kheshiya sample alongside this larger sample of known status and known sex *Bos* skulls.

Figure 11.19. Maxillary tooth row length (von den Driesch Measurement 20) expressed in millimeters; Kheshiya cattle measurements (from appendix 11.4) compared to those of Danish *Bos taurus* males and females (Degerbøl and Fredskild 1970:85, table 9). *Illustration by Louise Martin.*

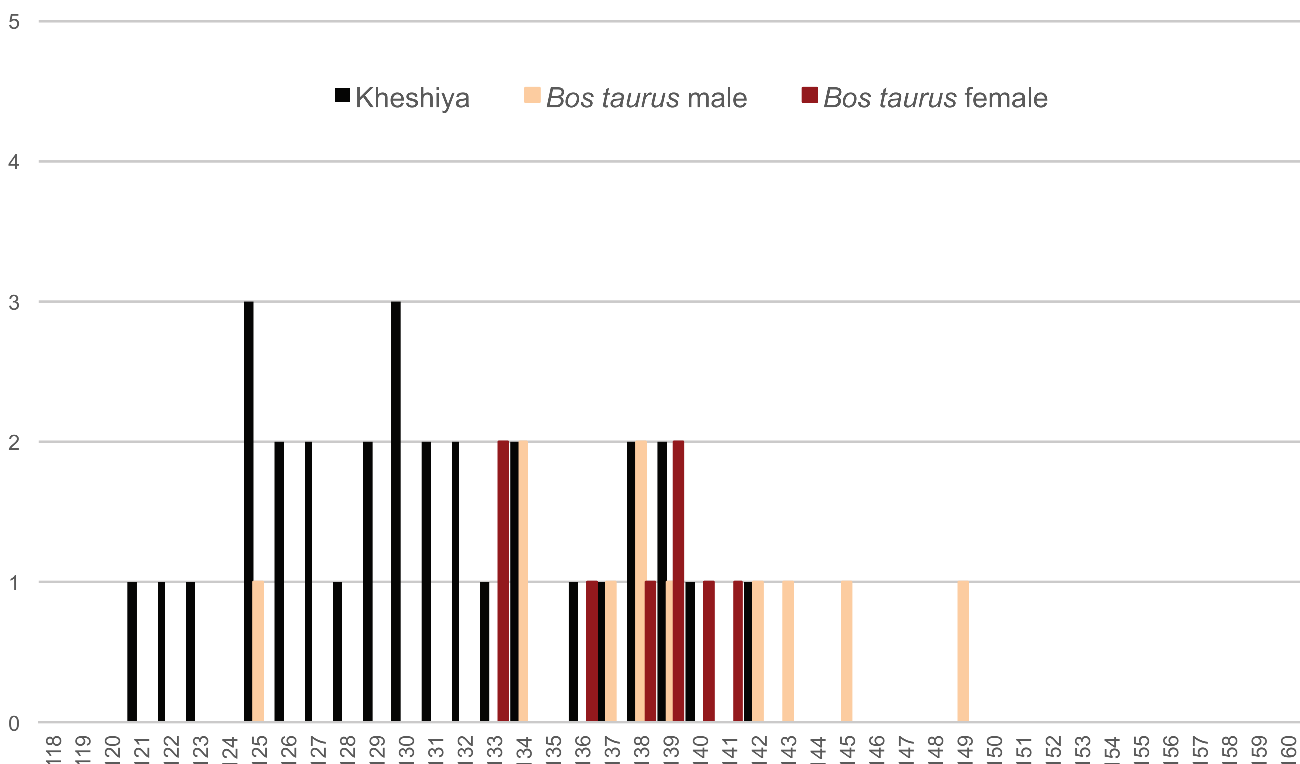


Figure 11.20. Least frontal breadth metric (von den Driesch Code 32) expressed in millimeters; Kheshiya cattle measurements (from appendix 11.3) compared to Danish *Bos primigenius* males and females (Degerbøl and Fredskild 1970:85, table 9). *Illustration by Louise Martin.*

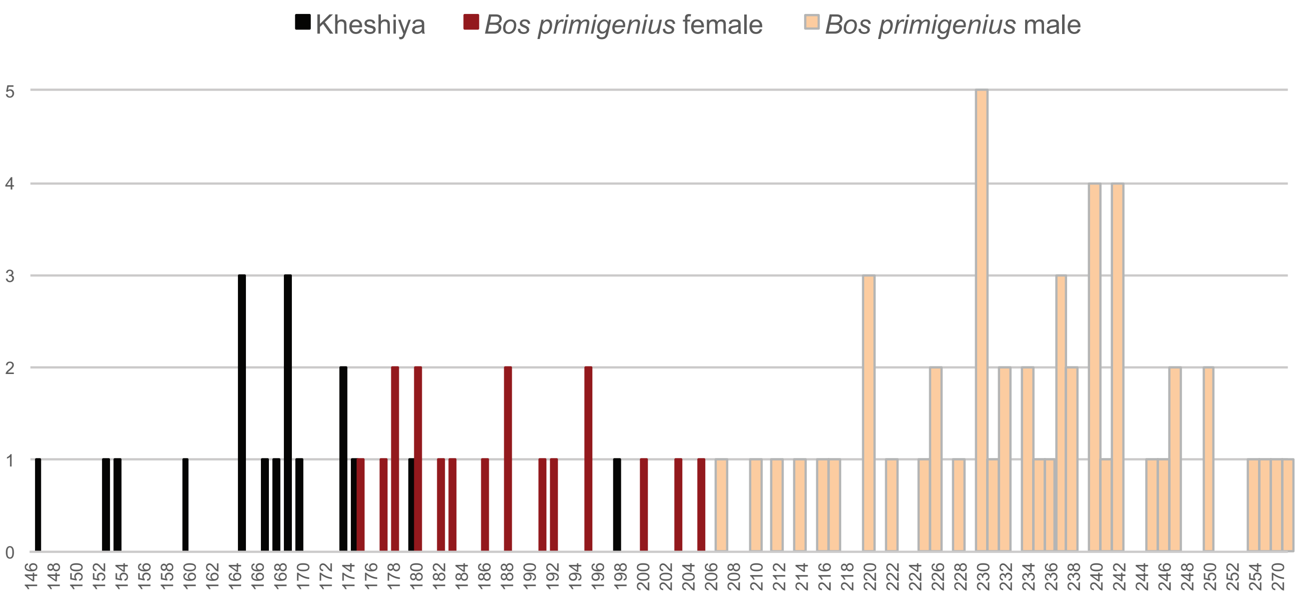
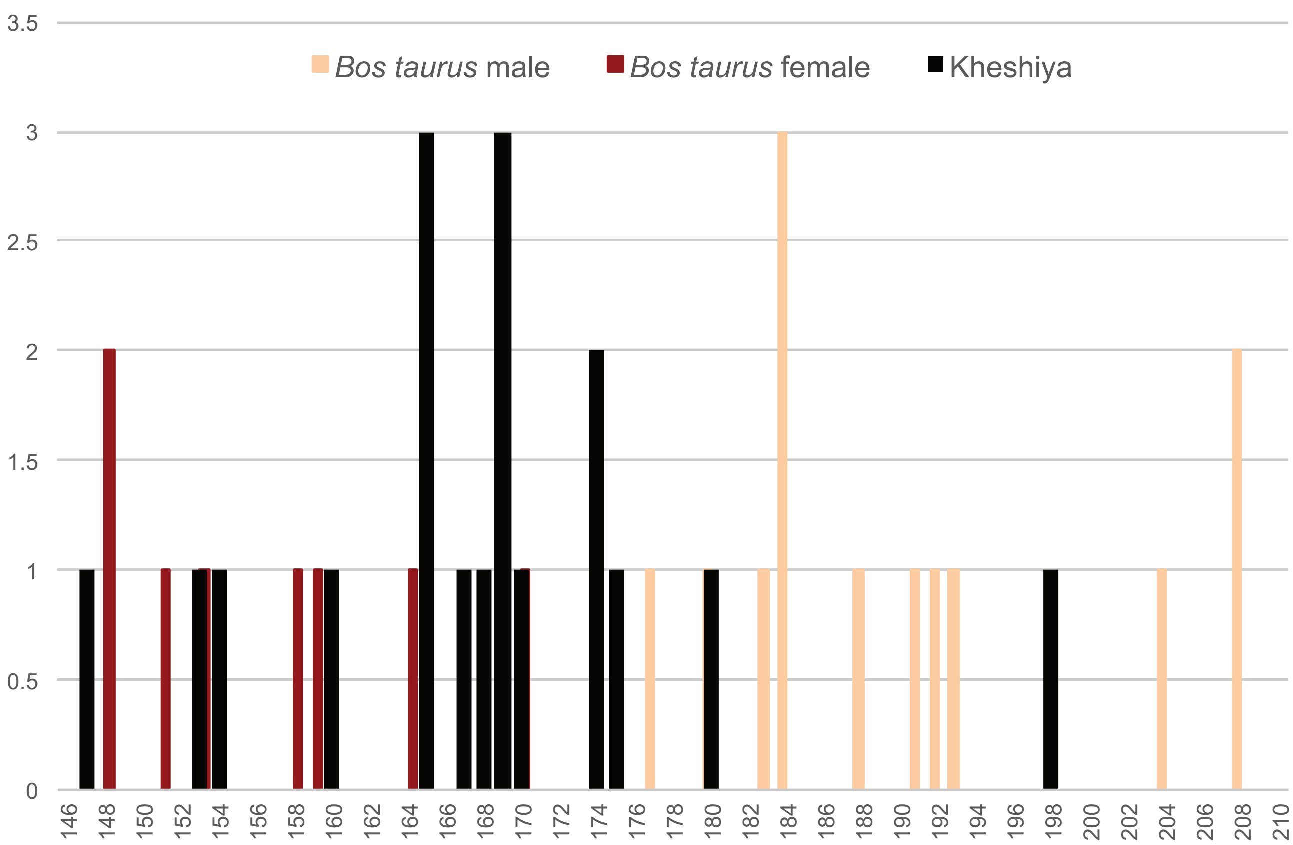


Figure 11.21. Least frontal breadth measurements (von den Driesch Code 32) expressed in millimeters; Kheshiya cattle measurements (from appendix 11.4) compared to Danish *Bos taurus* (Degerbøl and Fredskild 1970:68–69, table 2). *Illustration by Louise Martin.*



The following discussion draws on data comparisons with metrics published in Degerbøl and Fredskild (1970), unless otherwise stated.

Figure 11.18 shows a histogram that plots the length of maxillary tooth row measurement (Measurement 20) for the Kheshiya skulls alongside Danish *Bos primigenius* males and females. The *Bos primigenius* samples are, of course, much larger and do not overlap with Kheshiya sizes at all. The Danish samples display a wider range, probably because they derive from mixed locations and multiple time scales (and thus represent multiple breeding populations), with females at the lower end of the range. Grigson (1982) finds low sexual dimorphism in tooth or tooth row size, which is borne out in figure 11.18 by the complete overlap of the Danish male and female aurochs.

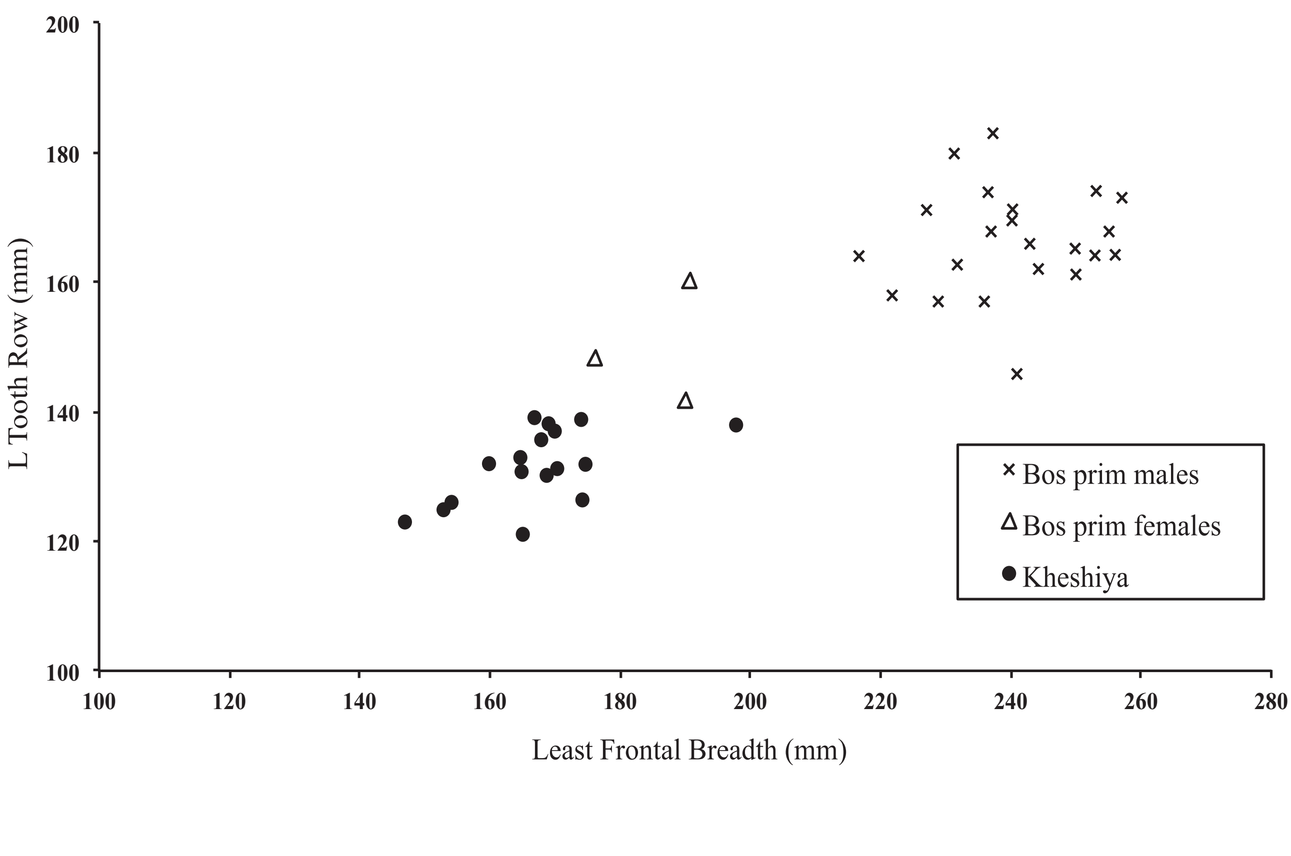
When Kheshiya tooth lengths are plotted against Danish *Bos taurus* data (figure 11.19), there is more size overlap between the two sample sets, although the Danish domesticates are still larger. Within the Danish sample, females again sit in the lower end of the range, although they completely overlap with males.

There are 18 Kheshiya data points for the least frontal breadth metric (von den Driesch Code 32) from the total of 35 skulls assessed. Figure 11.20 shows this measurement plotted for the Kheshiya specimens alongside Danish *Bos primigenius* males and females. Again, predictably, the Danish wild aurochs are larger than the Kheshiya cattle, although there is some overlap; the *Bos primigenius* males and females, however, completely separate using this measurement, indicating that the least frontal breadth is highly sexually dimorphic.

Although sample sizes for Danish domesticates are much smaller, the same dimorphic pattern holds when the least frontal breadth measurements are compared between the Kheshiya cattle and the Danish *Bos taurus*, with known males and females plotted separately (figure 11.21). It is notable that the overall size range is not dissimilar between the Danish and Southern Arabian cattle and that most Kheshiya measurements fall into the smaller (female) part of the range, with just one skull measurement firmly falling in the larger (male) part of the range.

Thus, while tooth row lengths are useful for highlighting overall skull size variation, they do not exhibit much sexual dimorphism in the cattle skulls plotted, but the least frontal breadth measurements exhibit sexual dimorphism in both wild and domestic cattle samples. Figure 11.22

Figure 11.22. Scatterplot showing least frontal breadth plotted against maxillary tooth row length (von den Driesch Codes 32 and 20) in millimeters; Kheshiya cattle measurements compared to Danish *Bos primigenius* sample (metrical data provided by Caroline Grigson, taken on same sample as Degerbøl and Fredskild 1970, but Grigson data allow least frontal breadth and length of tooth row data to be linked within the same skull). *Illustration by Louise Martin.*



is a scatter plot showing the two measurements plotted together for the Kheshiya and *Bos primigenius* samples. Note that the interrelationship of these two metrics for individual cattle skulls is not easy to see in Degerbøl and Fredskild's published data (1970). The *Bos primigenius* data in figure 11.22, therefore, is from Caroline Grigson (2007), who independently measured the same Danish collections, allowing least frontal breadth and length of tooth row data to be linked within the same skull.

Interpretation of figure 11.22 requires some caution, since only 18 of the 35 assessable Kheshiya skulls provided both measurements and therefore could be plotted; the skull ring originally consisted of more than 40 skulls, so those shown in figure 11.22 represent less than half of those originally buried. Nevertheless, an interesting pattern emerges. The scatter plot shows the Kheshiya skulls, as expected, to be far smaller in both dimensions than wild *Bos primigenius* from Denmark, with hardly any overlap. As demonstrated above, the least frontal breadth dimension clearly displays sexual dimorphism in both wild aurochs and domestic cattle, and we can see how the *Bos primigenius* metrics in figure 11.22 separate clearly into males and females. The same separation exists in the Kheshiya skulls, with the cluster of smaller skulls most likely representing females and the single larger skull probably representing a male. It is intriguing to note that the one large skull interpreted as a male, with the frontal breadth of 198 mm, is the one located centrally in the cattle skull ring (Skull 39).

Statistical Size Comparison with Cattle in East Africa

To further explore the sexual dimorphic element of the Kheshiya skulls, a metrical and statistical comparison was also made with cattle skulls from Kerma in Sudan, where thousands of *Bos taurus* bucrania derived from grave contexts have been studied in detail osteometrically (Chaix 2007). This provides a large sample of measured domestic cattle skulls that has a closer proximity geographically and temporally than the European comparisons described above. One of the largest Kerma graves has been selected here, Grave 253, which dates to the Middle Kerma period (4050 to 3750 cal BP) and contains 1,217 measured cattle skulls, including males, females, and probably also castrates (Chaix 2007:175, table 2).

Figure 11.23. Histogram showing Kerma Grave 253 cattle horncore basal circumference measurements (data from Chaix 2007:175, table 2), with solid line showing the kernel density estimate (KDE) of the distribution. *Illustration by Joe Roe.*

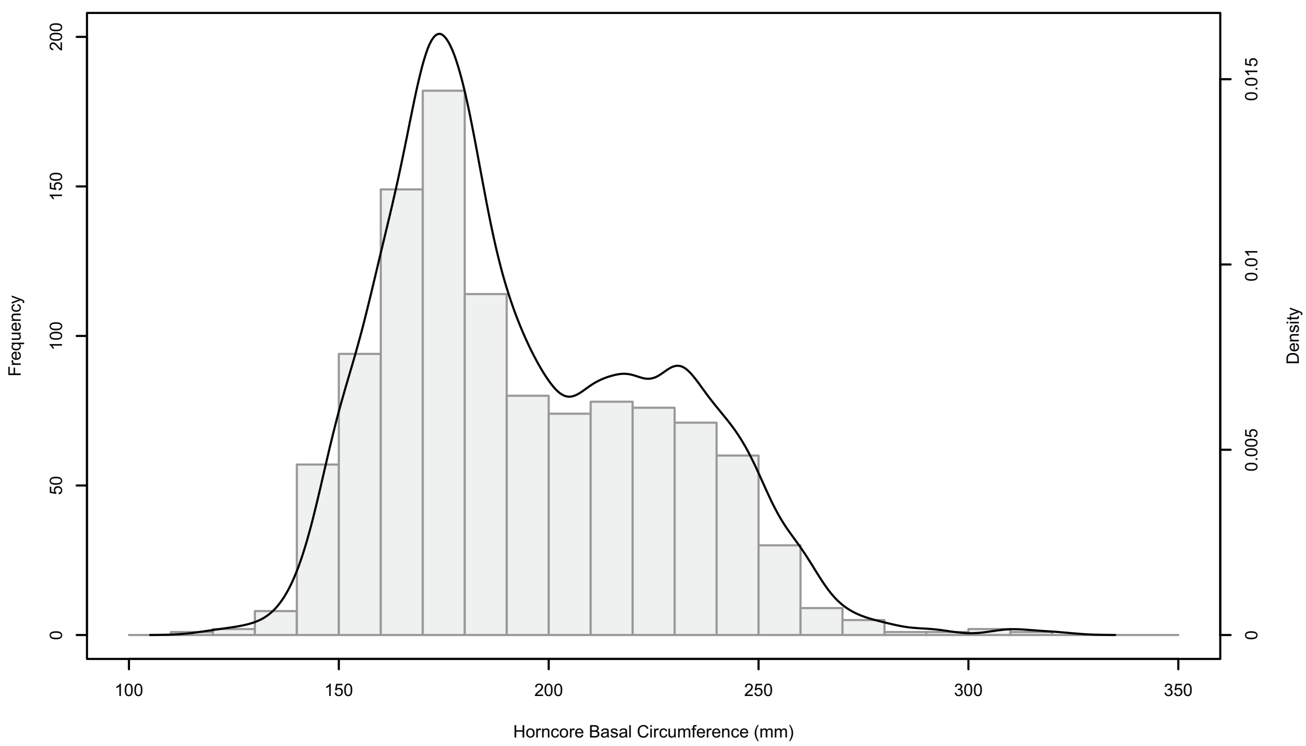
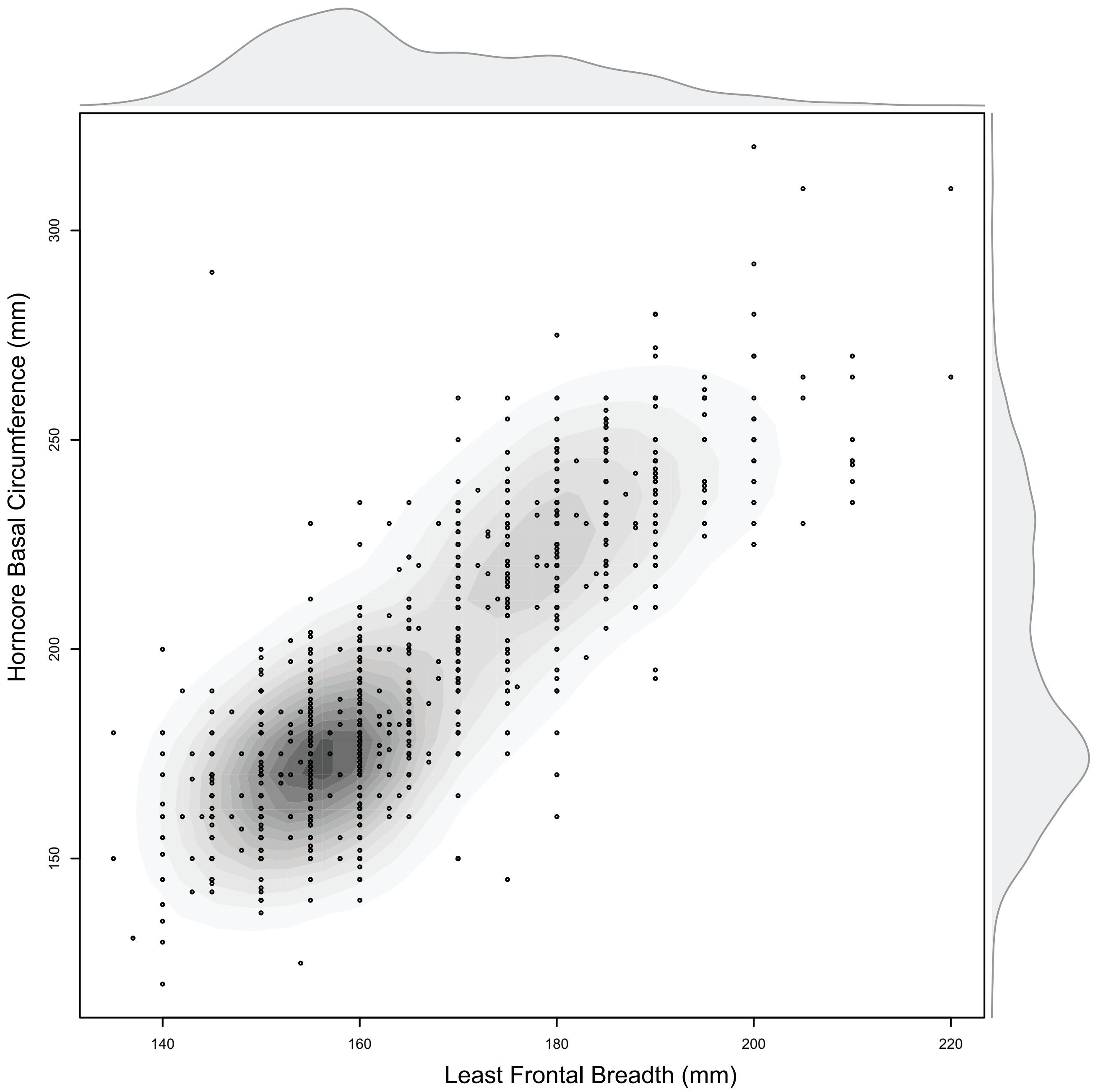


Figure 11.24. Biplot and 2D kernel density estimate of the horncore basal circumference and least frontal breadth measurements of the Kerma Grave 253 cattle skulls (data from Chaix 2007:175, table 2). *Illustration by Joe Roe.*



Two sets of osteometric data from the Grave 253 cattle were used (from Chaix 2007:216–28, table 13): the least frontal breadth (von den Driesch's Measurement 32; Chaix 2007:Measurement 5) and the horncore basal circumference (von den Driesch 1973:28, Measurement 44; Chaix 2007:Measurement 2). The first of these measurements can be compared with the Kheshiya sample; the latter provides confirmation of sexual dimorphism, because horncores sizes are distinctive between the sexes in cattle.

Figure 11.23 presents a histogram of Kerma Grave 253 cattle horncore basal circumference measurements, displaying bimodality. The solid line shows the kernel density estimate (KDE) of the distribution, which is essentially a smoothing of the histogram (following Beardah and Baxter 1996). Figure 11.24 is a biplot and 2D kernel density estimate of the horncore basal circumference and least frontal breadth measurements of the Kerma Grave 253 cattle skulls. Hartigan's dip statistic (Hartigan and Hartigan 1985) was used to verify that the distribution of measurements was not unimodal (as would be expected of a random variable from a single population), with the assumption that bi- or multimodality in a large sample of biometric data is likely to be a manifestation of sexual dimorphism. The distribution of horncore basal circumference, which is known to be sexually dimorphic in cattle (Grigson 1982), is significantly unlikely to be unimodal ($D = 0.030594$, $p < 0.001$). The distribution of least frontal breadth measurements is also unlikely to be unimodal at the same confidence level ($D = 0.06214$, $p < 0.001$), and it is positively correlated with horncore basal circumference (Pearson's $r = 0.842443$, $r^2 = 0.71$, $p < 0.001$). This confirms the findings of the metrical analyses based on European *Bos* data (described above) that the least frontal breadth measurement exhibits sexual dimorphism.

Figure 11.25 shows kernel density estimates for the least frontal breadth measurements from both Kheshiya and Kerma Grave 253 cattle skulls. Both samples show bimodality, with the Kerma sample showing more females and fewer males but still a fair proportion of the latter. The overall size range is larger at Kerma than Kheshiya, perhaps reflecting cattle that derived from different breeding populations (representing cattle tribute from across a wide landscape). The bimodality seen for the Kheshiya cattle metrics confirms a picture of mostly females and a single male skull, with the narrower range perhaps reflecting a tighter breeding group.

Dental Aging

Following approaches described in the "Methods" section above, table 11.5 shows the Grant (1982) cattle dental eruption and wear data for both left and right sides of the Kheshiya skull maxillary cheek teeth—P4, M1, M2, M3—where teeth were present. In 32 of the 35 total skulls, we could record early to middle aging dental data. While Grant's tooth wear system was intended for mandibular dentitions, there were no difficulties adapting the wear stages to maxillary teeth for this study; all observed wear could be matched with stages, despite obvious differences in tooth proportions between upper and lower teeth (maxillary being wider buccal-lingually), because underlying tooth structures are similar. Some teeth were missing (either fallen out and lost or removed as samples), but in most cases, except Skulls 15, 24 and 40, it was possible to create a maxillary wear score (MWS) based on Grant's

Figure 11.25. Kernel density estimates of the least frontal breadth measurements from Kheshiya (from appendix 11.4) and Kerma Grave 253 cattle skulls (data from Chaix 2007:175, table 2). *Illustration by Joe Roe.*

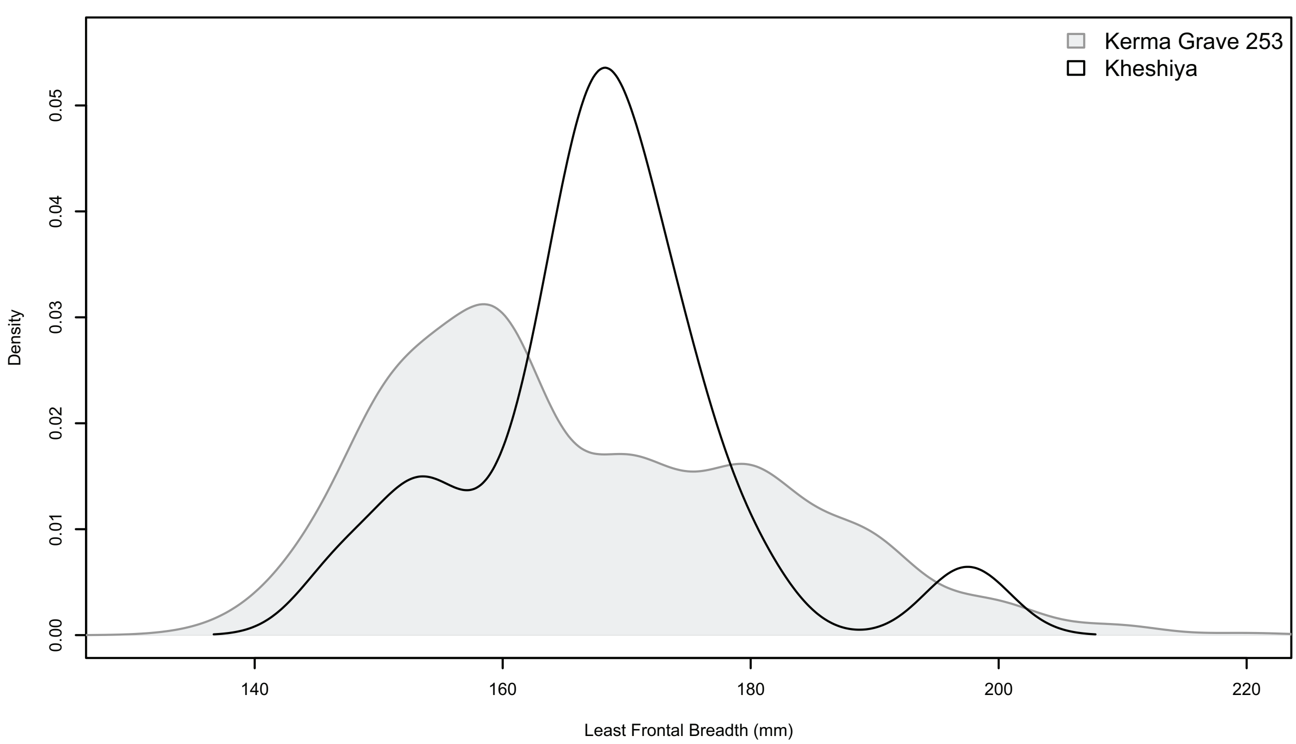


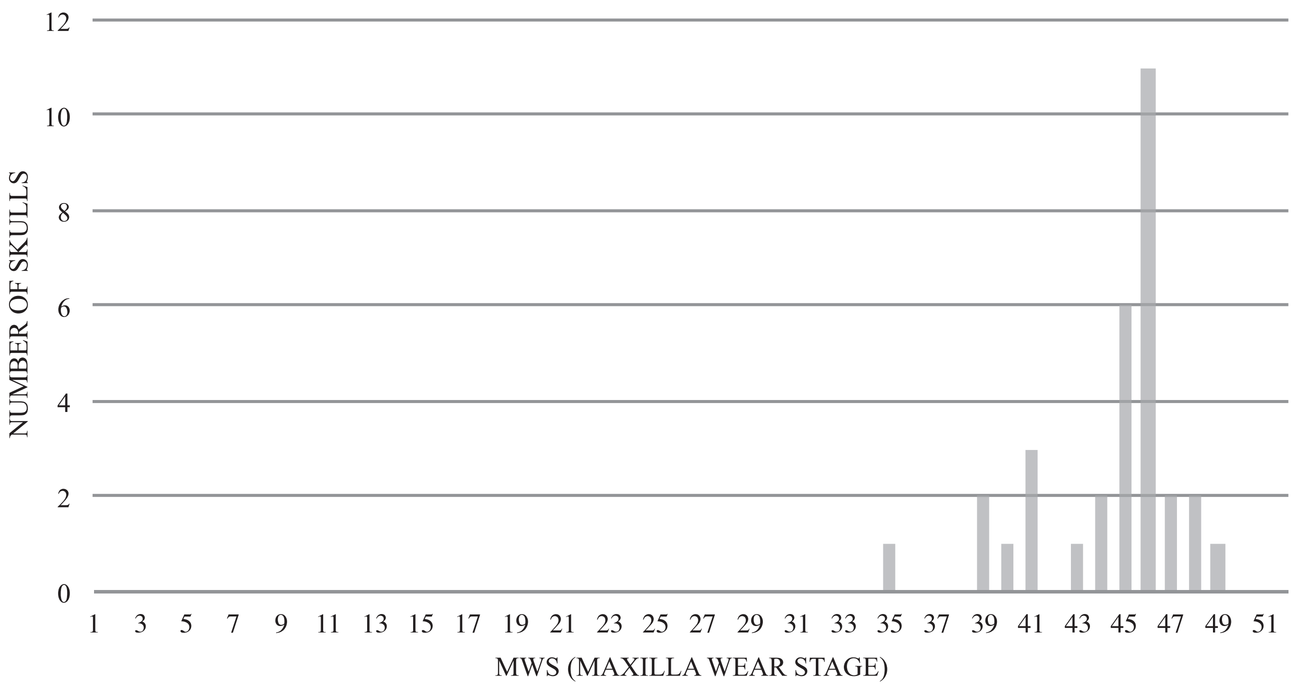
Table 11.5. The Kheshiya cattle skull maxillary tooth wear scores, following Grant (1982); Mandible Wear Scores (MWS) calculated by adding converted letter/numerical scores for M1, M2 and M3.

	Left Maxilla						Right Maxilla						
Skull/ Lot Number	**P4**	**M1**	**M2**	**M3**	**MWS**		**P4**	**M1**	**M2**	**M3**	**MWS**	**P4 Distal Wear into M1***	**Comments**
2	g	l	k	k	46							N	
3	g	k	j	g	41								
4	g	m	l	k	48							Y	Very heavy wear, enamel smooth, roots visible**
5	g	k	j	g	41							N	
11	g	l		k			g	l	k	k	46	N	
12		l	k	l	47		g	l	k	l			M3 heavier wear than M2
13	g	k	k	k	45								
14	g	l	k	k	46							Y	
15													No teeth present
16	g	l	k	k	46								
17	g	l	k	k	46							Y	
18	g	k	g	g	39								
19		k	g				d	k	g	c	35		
20	g	k	j	g	41								
21	g	l	k				g	l	k	k	46		
22	g	k	k				g	k	k	k	45	Y	
23	g	l	k				g	l	k	g	43		
24	g	l					g	l				Y	
25	g	k	k				g	k	k	j	44	Y	
26							g	k	k	k	45	Y	
27	g	l	l	l	48							Y	All teeth: lots of cementum on outer surfaces
28	g	l	k				g	l	k	k	46		
29	g	l	k	k	46							Y	
30	g	k	k	k	45								
31	g	l	k	k	46							Y	
32			k					k	k	k	45		
33	g	l	k	k	46							Y	
34	g	m	l	l	49							Y	M1 sides plus base of pillar worn; all roots visible
35													Mandible, no teeth
36	g	l	k				g	l	k	k	46		
37	g	k	k	k	45							Y	
38	h	k	h	f	39								
39	g	k	j	f	40								
40													No teeth, alveoli show adult dentition
41	g	k	k	j	44								
42	g	m	k	k	47							Y	

**Right maxilla tooth wear is only shown if left maxilla dentition is missing, incomplete, or if wear scores differ between the two sides. MWS shaded fields are those used for relative aging analysis. *This field not consistently noted. **Crown heights for Skull 4: P4, 17.3 mm, M1 13.5 mm.*

Figure 11.26. Dorsal view of Skull 31, showing left-side P4 distally worn into the anterior cusp of M1. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.27. The number of cattle skulls at each maxillary wear stage (MWS) (following Grant 1982), showing a narrow range between 35 and 49. *Illustration by Louise Martin.*



(1982) system, which sums the wear for the three molar teeth. Table 11.5 also shows instances where P4 was worn distally into the anterior cusp of M1. (Figure 11.26 shows an example of this in the left maxillary dentition of Skull 31.)

All skulls contain a full component of adult teeth, fully erupted and in wear. Some teeth have high individual wear stages (for example, Stage l or Stage m, in a range from a to p, where p is heavily worn). Maxillary wear stages range between 35 and 49 (figure 11.27), which is relatively narrow and reflects a cull that targeted adults (Grant 1982:98–99, table 2, finds adult cattle to have a range of 31 to 54). More than half of the skulls have a wear score of 45 or 46. On first appearances, the cattle seem tightly clustered in their ages at death.

Interpreting approximate ages of death is challenging in the unusual Kheshiya case, in large part because almost all studies that attempt to correlate recorded wear stages with actual age are based on mandibular teeth, which normally survive intact better than maxillae. The single study that draws on maxillary dentition (Andrews 1982) focuses only on young cattle. It is therefore necessary to use information on the timing of cattle mandibular wear stages for this study, knowing that although maxillary tooth stages follow the same patterns of increasing wear, the timing of those wear stages may not be mirrored between the two jaws. Indeed, Andrews and Wedderburn (1973) find that cattle maxilla teeth erupt later than mandibular counterparts.

In a study that tests various methods of scoring cattle tooth eruption/wear against known aged individuals, Jones and Sadler (2012a) found that Grant's wear stages correlate well with age in animals under three years of age, but in older animals wear stages cannot be linked to narrow age brackets. This means that the same MWS can be assigned to a wide spread of known aged animals (2012a:25, figure 13). For example, they find that MWS 46 has a particularly wide spread: It is assigned to animals killed anywhere between 6.2 and 13.3 years of age—a seven-year span—which makes MWS 46 difficult to interpret. Jones and Sadler, in contrast, find that MWS 47/48 predictably describe animals between 8 and 12 years old, and wear scores above 50 are fairly consistently recorded only in animals over 13 years of age.

What inferences can thus be made about the ages of death of the Kheshiya cattle? Following Jones and Sadler's findings (2012a:25, figure 13), one animal seems to have been killed as a younger adult, about 3 to 3.5 years old (MWS 35); a few skulls with MWS 39–41 could have been between 3.5 and 6.5 years old at death; the majority of skulls ($n = 20$) have an MWS between 42 and 46 and could have been anywhere between 6 and 13 years old at the time of death; five other skulls had an MWS between 47 and 49 and fall in the 8–12 bracket of the older age range.

To further narrow down the group of 20 skulls with the wide age range of 6 to 13 years, another scheme was applied. We examined individual tooth wear rather than the whole molar row (Jones and Sadler 2012a)—a scheme that can refine patterns. We see that 24 of the 32 Kheshiya skulls with dental early to middle aging data have M3s at Stage g or above (table 11.5), and of these, the majority of their corresponding M2s are at Stage k, which puts the animals in the oldest adult class, bordering the elderly stage (Jones and Sadler 2012a:15, table 2).

The terms *old adult* and *elderly* are relative to an animal's longevity, which itself can vary depending on breed and individual/herd life histories. Jones and Sadler (2012b) find no consistency in the records of cattle life expectancy, but their review of information for modern/recent *Bos taurus* breeds in Europe suggests that while some cattle can live 20 to 25 years, with occasional/rare females still breeding up to and above 15 years of age, domestic cattle aged above 20 are rare. In terms of age of last breeding, a study of early-twentieth-century dairy cattle showed that the last calving occurs generally around 12 years of age, with some females continuing until 13 to 15 years of age (Jones and Sadler 2012b:8).

The Kheshiya cattle are obviously distant in both time and space from well-studied modern European cattle populations, but we can use this information to build a picture of the relative ages of death within the Kheshiya assemblage, which are more realistic than actual ages. It is clear that none of the cattle were culled as juveniles or subadults, and only one is a young adult. The majority of cattle seem to have been older adults when culled—not elderly but in the upper range of their mature adult stages, perhaps at the ends of their reproductive lives, at least in the case of females. Bearing in mind that maxillary tooth wear stages are unstudied but thought to lag behind mandibular equivalents (and thus reflect older individuals), it seems wise not to attempt any more exact age assessments.

Cranial Suture Fusion

As with mammal long bone epiphyseal fusion, cranial suture fusion timings tend to have broad age ranges, and variation is expected within species due to animal breed, health, and nutrition (see Popkin et al. 2012). Data for the Kheshiya cattle cranial suture fusion is given in table 11.6, with approximate age estimates in the right-hand column (following Grigson 1982:20, appendix 1).

A fairly consistent picture of suture closure is evident: All but one of the skulls (Skull 24) have their frontal halves fused, which occurs in cattle over about seven years old (following Grigson's 1982 data); most skulls also have their medial palatine bones fused, which would place them in an older range, older than 10 years. That most facial sutures (maxillae, lacrimals, zygomatic) are unfused or fusing, however, indicates that animals were killed younger than about 15 years of age, which supports the dental wear results that show the cattle to have been culled generally as older adults, but not at extreme "elderly" age.

There are inconsistencies between the suture closure and dental wear data, however. Dental wear places Skull 19 as a young adult, but its skull shows no difference in cranial suture inferences from other individuals (estimated age at death 10–15 years?); similarly, the group identified through dental wear as "younger adults" (Skulls 3, 5, 20, 38, and 39) also shows no differences in suture closure from the overall trend. In zooarchaeological analyses, dental eruption and wear stages are considered more refined tools for estimating age at death than fusion analyses (e.g., Davis 1987), which may explain the variation seen here.

Table 11.6. Cranial suture closure data for the Kheshiya cattle skulls. Only selected sutures were recorded (those visible), on whichever side of the skull was preserved. *F = fused/closed; UF = unfused/open; JF = just fusing. Blank fields indicate no data available.

Skull/Lot Number	Basioccipital Area and Sphenoids	Parietals/ Temporals	Frontal Halves	Frontals/ Lacrimals (orbit)	Maxillae/ Lacrimals/ Zygomatics	Medial Palatine Suture	Frontal/ Lacrimals (on face)	Nasals, Fused Together	Age Estimate
Suture Closure Ranges	**2–3 Years**	**5–7 Years**	**7–10 Years**	**7–10 Years**	**10–15 Years**	**10–14 Years or > 15?**	**Extreme Age**	**Extreme Age**	**Years (very approximate)**
2					UF	F			10–15?
3			F		UF	F			10–15?
4						F			> 10?
5			F		UF	F			10–15?
11	F		F		UF/F	F			10–15?
12			F	F	JF	F			10–15?
13			F		JF	F			10–15?
14	F		F		UF	F			10–15?
15			F						> 7?
16	F				UF	F	UF	?	10–15?
17			F		UF	F			10–15?
18	F		F		UF	F		F?	10–15?
19					UF	F			10–15?
20					UF				< 15?
21			F		UF?	F?			10–15?
22			F		UF	F			10–15?
23	F			UF		F			about 10?
24	F		UF		UF	F			10–15?
25	F		F		UF	F			10–15?
26						F			> 10?
27					UF	F			10–15?
28	F		F		UF	F			10–15?
29	F		F		UF	F			10–15?
30			F		UF	F			10–15?
31			F		UF	JF			10–15 plus?
32	F				UF	F			10–15?
33			F		UF	F			10–15?
34			F		JF	F		UF	10–15?
mandible 35									
36	F	F	F		UF				10–15?
37	F		F		UF	F		UF	10–15?
38						JF			10–15?
39			F		UF				10–15?
40					UF			?	< 15?
41			F		UF	F			10–15?
42					UF	F			10–15?

Suture closure age ranges in right-hand column are from Grigson 1982:20, appendix 1, which summarizes data from other authors.

Table 11.7. Dental anomalies recorded in the Kheshiya cattle maxillary teeth, describing cases of premolar tooth rotation, malocclusion, and the single example of a tooth missing during the life of the animal. The right column shows the MWS for each skull, as in figure 11.27, indicating the relative age stages of the cattle.

Skull/ Lot Number	P4/P3 Tooth Rotation: Side and Degrees of Rotation	Malocclusion	Teeth Missing in Life	Comments	MWS
2				LHS P2 double ring of enamel	46
3	RHS P4 rotated 50–60°			(1) L+RHS P4 appear large in proportion to molars; rotation seems to be result of lack of space for tooth eruption? (2) Dentine stub between RHS P4 and M1 may be remnant of dp4, showing as very worn dentine pillar with tiny area of enamel. Interesting to note rotation only one side. (LHS is visible.)	41
4					48
5					41
11		RHS M3 worn into central peak.			46
12		?; see comment.		L+RHS M3 more worn than M2	47
13					45
14					46
15					
16					46
17					46
18					39
19					35
20					41
21					46
22					45
23					43
24					
25					44
26					45
27					48
28		RHS P4: steep anterior–posterior wear			46
29	LHS P4 rotated about 20°			LHS P4 pushing/wearing into M1.	46
30				RHS not visible.	45
31				LHS P4 pushing/wearing into M1.	46
32					45
33					46
34	LHS P3 rotated about 70°			Can’t see if RHS also rotated. Premolars missing.	49
35					mandible
36					46
37					45
38	L+RHS P4 rotated 25–30°			Both P4s rotated, unlike Skull 3.	39

Table 11.7. Dental anomalies recorded in the Kheshiya cattle maxillary teeth, describing cases of premolar tooth rotation, malocclusion, and the single example of a tooth missing during the life of the animal. The right column shows the MWS for each skull, as in figure 11.27, indicating the relative age stages of the cattle. *(continued)*

Skull/ Lot Number	P4/P3 Tooth Rotation: Side and Degrees of Rotation	Malocclusion	Teeth Missing in Life	Comments	MWS
39					40
40					
41			LHS P3	LHS P3 seems missing in life. P2 erupted into its space. P4 alveolus present but not enough space for P3.	44
42		RHS P4 higher in jaw than adjacent M1; malocclusion and suggesting not enough space for P4 eruption.			47
Total: 35	**4**	**4**	**1**		

Figure 11.28. Skull 3, close-up of right-side maxilla, showing P4 with a high degree of rotation and a worn dentine/enamel stub between the P4 and M1, probably a remnant of dp4, indicating P4 maleruption. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.29. Skull 34, showing maxillary left-side P3 with a high degree of rotation. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

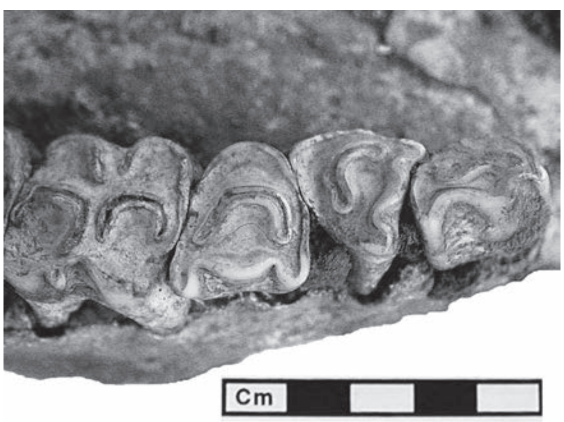


Figure 11.30. Skull 34, close-up of left-side P3 with a high degree of rotation, showing lack of space for tooth to erupt normally. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.31. Skull 38, showing maxillary left-side P4 with a low degree of rotation. (Right-side P4 was similarly rotated in this skull; not shown in the photograph.) *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Dental Anomalies

Dental abnormalities noted in the Kheshiya maxillary teeth are shown in table 11.7. Four instances of tooth rotation were observed (Skulls 3, 29, 34, and 38), each in premolars, with three P4s affected and one P3. Two cases show high degrees of rotation (figures 11.28, 11.29, and 11.30), and in one skull (38) P4 is rotated to a lesser degree on both the left and right sides of the jaw (figure 11.31).

Other dental abnormalities include malocclusion of P4 in Skull 28, an absence of P3 in Skull 41 (where there seems to be no space for it to erupt), and a dentine "stub" in Skull 3 (figure 11.28), which appears to be a remnant deciduous tooth (dp4). Each case seems to signify maleruption, and together with the tooth rotation examples, they suggest that some of the cattle experienced tooth crowding. Skulls 3 and 41, for example, show a lack of space for P4 to erupt into (noting that M1 is in place long before the premolars erupt).

Colyer's *Variations and Diseases of the Teeth of Animals* (1936; revised by Miles and Grigson in 1990) still serves as a useful reference for irregularities in mammalian dentition. Colyer found that major anomalies in ruminant jaws were fairly common (estimated at about 9 percent of reference jaws studied), and he describes how positional anomaly most often affects premolars, which can have extreme rotation because they erupt later than molars and sometimes find no space for eruption. There is also the suggestion that high proportions of tooth positional anomaly (about 30 percent), such as tooth rotation, can result from population isolation, likely due to founder effect (Miles and Grigson 1990) and breeding bottlenecks.

The Kheshiya sample size is small, but the overall proportion of dental irregularities they exhibit is 22 percent, with tooth rotations seen in 12 percent of assessable skulls. Following Colyer's study, the number of tooth anomalies in the Kheshiya cattle seems slightly higher than expected, which might hint at a degree of isolation in the Neolithic Southern Arabian cattle populations. Could this relate to a founder effect, or are the irregularities within the range of normal variation?

In either case, the Kheshiya skulls show clear evidence of tooth crowding, which itself results from jaw foreshortening, where teeth—not correspondingly reduced in size—are seen to touch, overlap, malerupt, or rotate. It has long been assumed that tooth crowding is one of a suite of markers of early domestication, especially in dogs and pigs but in other mammals too (Clutton-Brock 1999; Zeder 2012), wherein bone and tooth size reductions are out of sync. A recent study of wolves and dogs, however, where both the wild and domestic counterparts revealed tooth overcrowding (Ameen et al. 2017), shows that this idea needs reevaluation, and tooth crowding alone cannot identify domesticates. The same study found a high correlation between tooth crowding and tooth rotation, both traits that characterize the Kheshiya assemblage, whatever the underlying cause of the tooth crowding.

Condition of Skulls, Breakage, and Treatment

This section uses information on skull part presence, fragmentation, and treatment—recorded according to details described in the "Methods" section above—to examine how the skulls were originally deposited, subsequent site formation processes, what cranial elements survived, and what can be gleaned about any preburial treatment of the skulls.

Appendix 11.6 shows full data for each skull relating to condition, parts of the skull present, and treatment. Each skull was recorded for the presence of different skull areas, with the frontal eminence and occipital condyles representing the posterior, and nasals representing the anterior. The presence of maxillary dentitions was also recorded. The table in appendix 11.6 also notes the frequent cases in which information could not be assessed. Table 11.8 summarizes selected skull part presence from data in appendix 11.6.

As noted in the "Methods" section, initial examination of the skulls revealed a strong likelihood that they had all been initially buried intact, with no evidence that any cranial parts (apart from mandibles) had been removed prior to burial, even though skulls experienced much post-depositional fragmentation. Table 11.8 shows the presence of even the most fragile skull parts, the nasals, in 16 of the 35 skulls assessed (figure 11.14), while in the remainder they appeared broken off and probably fragmented beyond identification. This is not surprising given that the nasals, the most deeply buried skull parts, were pushed down into a deposit that hardened around them (chapter 10).

Counts of other cranial elements (table 11.8) show that rear skull areas survived more poorly than even the thin nasals, despite being more robust. The thick ridge of the frontal eminence (or parts of it) survived in only six skulls, and part of occipital condyles survived in only five skulls. As already noted in the discussion of skull morphology, horncores did not survive at all, but horncore bases were visible in four skulls and hinted at in another three. The whole rear skull area seems to have suffered from long-term exposure to the elements, or repeated burial/exposure to the point of complete degradation in most cases. This perhaps is not surprising given how close to the present ground surface they were found.

Table 11.8. Summary of the presence of selected cranial parts surviving for each of the Kheshiya skulls. The left column shows skulls that retain any evidence of the direction in which horncores leave the skull, based on fragments of horncore bases. Other columns indicate the survival of other skull extremities. The right column shows where maxillary tooth rows survived intact, on either one or both sides or partially. Data summarized from appendix 11.6.

Skull/Lot Number	Horncore Direction Visible? Y = Yes; (Y) = Partial	Frontal Eminence Present? Y = Yes; (Y) = Partial	Occipital Condyles Present? Y = Yes; (Y) = partial	Nasals Present? Y = Yes/Both; (Y) = Partial	Dentition Present? Y = L + R; L = Left; R = Right; (Y) = Partial
2					L
3					Y
4				(Y)	L
5					Y
11				Y	Y
12			(Y)		Y
13					Y
14					Y
15					
16				Y	Y
17	Y	Y	(Y)	Y	Y
18		Y		Y	Y
19					(Y)
20					Y
21	(Y)		(Y)		(Y)
22	Y	Y			(Y)
23	Y	(Y)		Y	Y
24					Y
25	(Y)	(Y)	(Y)	Y	Y
26					R
27				Y	Y
28					Y
29	Y				Y
30				(Y)	Y
31					(Y)
32					(Y)
33				Y	Y
34				Y	(Y)
36		Y	Y	(Y)	Y
37				Y	Y
38					Y
39				(Y)	Y
40				Y	
41	(Y)				Y
42				Y	Y
Total: 35	**4 (3)**	**4 (2)**	**1 (4)**	**12 (4)**	**27 (6)**

Figure 11.32. Skull 39, superior view, showing typical preservation of cranium and maxillae, with all skull extremities not surviving. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.33. Skull 14, showing a thermally-altered rock wedged into a break in the palatine wing area of the skull. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Cheek teeth preserved better. Of 35 skulls, 33 had at least one side of maxillary cheek teeth present, even if some teeth were missing, and often both tooth row sides survived. In two skulls (26, 40) all teeth had fallen out, although the loose teeth of Skull 26 could be refitted. One skull (15) was too poorly preserved to show any tooth root sockets. That tooth rows so often survived intact is notable since the maxillary bone supporting them is not strong; survival probably results from quick burial of the skull to the level of the teeth and points to the relative stability of the burial environment thereafter. Figure 11.32 shows a typically preserved skull (39) with all extremities missing but with cranium and maxillae intact.

Weathering

All 35 skulls provided data on bone surface weathering, summarized in table 11.9, which shows that the majority of skulls have fairly consistent weathering stages (Stage 3) on their frontal bones, which is the most commonly surviving skull part for assessment. Adapting Behrensmeyer's 1978 stages for the Kheshiya skulls (table 11.10 and "Methods," above), Stage 3 indicates that bone surfaces are rough, with pitting and some round-edged cracking, but whether this resulted from surface exposure (not lengthy—the bone does not show deep cracking/splintering) or continuous wetting/drying after burial is hard to tell. The degree of uniformity between skulls and the occasional higher-weathering Stage 4 noted around the rear areas of skulls—which were more likely to be exposed (see table 11.9: intercornual ridge, around horncores, orbits)—supports the idea of differential weathering. The anterior parts of skulls remained buried in a relatively stable fashion after installation (albeit in shallow deposits), while posterior areas from approximately the orbits backward protruded aboveground for some time, with exposure eroding away the backs of the skulls, before deposits later covered and stabilized the remaining skull parts, preserving them in situ.

Burning

The absence of any sign of burning on the skulls is notable only because the surface deposit inside the skull ring feature was ashy and the skulls appeared to have been pushed into it. That none of the skulls showed charring, or even the characteristic "browning" suggestive of contact with heat, indicates either (1) that the skulls were installed after the internal deposits were burned—that is, they were not in place at the time of any fire in the circle—or (2) that the fires that created the ashy deposit did not affect the skulls, which probably were protected by a skin/hide covering.

Table 11.9. Bone surface weathering stages recorded for the Kheshiya cattle skulls, following the descriptors adapted for this assemblage (from Behrensmeyer 1978) shown in table 11.10**.** Weathering stages were assessed on all frontals and noted for other cranial elements only if they differed from frontals.

Skull/Lot Number	Bone Surface Weathering Stage: Frontals	Bone Surface Weathering Stage: Other Cranial Elements
2	3	
3	3	
4	3	
5	3	
11	3	
12	3	4 around orbits
13	3	4 around zygomatics
14	3	
15	3	
16	3	
17	3	
18	3	
19	3	
20	3	4 around intercorneal ridge and orbit
21	3	4 in patches
22	3	4 in patches
23	3	4 around horncore bases
24	3	
25	4	3 elsewhere
26	3	
27	3	4 on nasals and anterior maxilla
28	3	4 on basiocciptals
29	3	
30	3	
31	3	4 in patches
32	3	
33	3	
34	3	
35 mandible	3	
36	3	
37	3	
38	3	
39	3	
40	3	
41	3	
42	3	

Table 11.10. Behrensmeyer's (1978) weathering stages and descriptors for bone surfaces, alongside descriptor adaptations made for the recording of the Kheshiya cattle skulls.

Stage	Behrensmeyer's (1978) Weathering Stage Descriptors	Behrensmeyer's (1978) Estimated Years since Death	Descriptor Adaptations for Kheshiya Cattle Skulls
0	No cracking or flaking; greasy; soft tissue present.	0–1	Greasy, fresh bone
1	Longitudinal cracking in long bones	0–3/4	Very slight rough frontal surface
2	Surface flaking, cracks(?), exfoliation started	2–6 or 7	Slight pitting on frontal surface
3	Bone surface rough, fibrous, round-edged cracks	4–15 plus	Surface rough, pitting, some round-edged cracking
4	Bone surface course, rough, fibrous; splintering, deep cracks opening	6–15 plus	Surfaces course, rough, fibrous, deep cracks opening
5	Bone falling apart, very fragile	6–15 plus	Bone falling apart

Figure 11.34. Skull 29, showing breakage between the rear part of the skull and the anterior (maxillae) part, with breakage across the wings of the palate. There is also a clear shift in angle between the two parts of the skull. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Fire-cracked rocks were found clearly lodged behind the skulls during excavation (see chapter 10, figure 10.5), with some stones finding their way into breaks in the skulls. In some cases, the stones appear as if they served as rough butchery tools wedged into chopped bone (figure 11.33, white arrow), although there is good evidence (presented below) that finer chipped stone tools were used in the butchery and preparation of the skulls. It is more likely that burned stones accidentally became incorporated into skull breaks through bioturbation of the earlier-laid ashy deposits.

Our interpretation is that the burned stones and ashy deposit relate to cooking/preparation activities of the cattle carcasses, and only later were the prepared skulls inserted into the burned surface to create the monument. (See chapter 10.) Of note here is that skulls must have been broken at the palatine wings (as in Skull 14, figure 11.33) before or during the process of skull installation for thermally-altered rocks to become wedged into this break. This is discussed further below.

Skull Breakage and Anterior/Posterior Slumping

During the process of cleaning the skulls for study, it was observed that in many, the rear parts of skulls were overhanging the anterior, as if pushed forward, which is observable as frontals that overlap lacrimals, nasals, and occasionally even maxillae bones. This contrasts with

Table 11.11. Occurrence of forward slumping of the rear parts of skulls and frontals over the anterior (nasals, lachrymals). The right column shows where the wings of the palate are broken and also the angle of slumping where evident. (Anterior angle of shift was examined when looking at maxillary teeth occlusally from anterior to posterior. Therefore, if a skull in the ground is described as "angled right," this means the cranium collapsed to its left.)

Skull/Lot Number	Forward Slumping of Posterior Skull, Frontals Shifted over Nasals/ Lacrimals; Y = Yes; (Y) = Likely	Posterior–Anterior Skull Breakage at Wings of Palatine, Anterior Angled Left (L), Right (R), or Indeterminate (INDET)
2		
3	Y	L
4		
5	(Y)	R
11	Y	R
12	no	
13	Y	
14	Y	R
15		
16	Y	L
17	Y	
18	Y	R
19	can't assess	
20	Y	L
21	Y	
22	Y	INDET
23	Y	
24	Y	R
25		
26	can't assess	
27	Y	R
28	Y	R
29	Y	L
30	Y	INDET
31	(Y)	
32	Y	R
33	Y	
34	Y	
36	Y	R
37	Y	INDET
38	can't assess	
39	Y	
40	can't assess	
41	Y	INDET
42	can't assess	
Total	**25/35**	**17/35**

Figure 11.35. Skull 37, anterior view, showing the frontals slumped forward over the nasals and lacrimals on both sides. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

finding all cranial elements flush at the sutures, which they should be anatomically. Table 11.11 shows that 25 of the assessable 35 skulls have this form of breakage and skull compression. Some display only slight shifting forward or "slumping" of rear skull parts (for example, 1 cm, Skull 28; see appendix 11.6); others have shifted more (4 cm, Skull 29). The wings of the palate on the underside of the skulls, which act as "bridges" between the heavier rear part of a skull and the lighter anterior portion, were also often broken (figure 11.34 and table 11.11), leading the skull to collapse, sometimes to one side or the other, or sometimes forward. The question posed here is whether the skull slumping resulted from natural processes or whether human butchery activities contributed?

We note first that in all skulls the lacrimal/zygomatic/maxilla sutures were not yet fused (or a few were just fusing; table 11.6), so facial bones were still separate in the skull and were not yet joined by advanced age. Slumping, therefore, occurred at areas of existing weakness in the skull. There is no suggestion that younger skulls collapsed more than older ones. (Some younger skulls are intact while some older specimens exhibit slumping.) Factors other than unfused sutures must have contributed.

The burial environment certainly played a part in skull breakage. Repeated wetting/drying of silts that built up internally in the skull cavities would have led to expansion and contraction of deposits, probably aiding the explosion of unfused facial bones and causing the frontals to shift over the nasals, as seen in Skull 37 (figure 11.35). Whether this shifting occurred soon after skull burial or over a longer term is not known. The heavier weight of the rear/upper part of the skulls, with horns attached, must also have added to forward/downward slumping after soft tissues had degraded, a process estimated to take anywhere from two to nine months in arid environments (Galloway 1997; Janaway 1996). As argued above in the discussion of weathering, if the rear/posterior parts of skulls (from the orbits backward) were unburied and exposed, gravity would exacerbate skull collapse.

Cut Marks, Butchery, Skull Preparation

In addition to natural processes, there is some evidence that human butchery practices impacted the skulls. Signs of skull processing and preparation are very few, but they probably reflect common wider practices. Table 11.12 shows three skulls (3, 32, 37) with evidence of cut marks on the wings of the palate, on one lateral side in each case. These multiple small cuts and notches appear to have been made from one side of the skull. They are too light and superficial to have intended to cut through bone itself; rather they suggest the removal of soft tissue (figure 11.36). A likely explanation for their placement is that they result from attempts to free and remove the tongue—a prized nutritious organ—from the skull, if the carcass/skull was lying on one side. If the palatine wings were not fragmented in so many of the Kheshiya skulls, perhaps more cut marks in this location would be seen.

The kind of cuts seen in figure 11.36 would not inflict any great damage to a skull, but if mandibles were separated from skulls before or after the tongue, as we know they were at some stage prior to burial, this could have caused greater damage. Mandible removal from cattle skulls often is achieved by chopping through the jaw's vertical ramus (see Rixon 1989:56) to smash the heel area of the mandible, thus freeing the mandible condyle from the skull. The single piece of identifiable bone from Kheshiya other than skull was a fragment of cattle mandible (Lot 35, figure 11.37) that

Table 11.12. Description of cut marks/butchery marks on the Kheshiya cattle skulls, alongside possible interpretations.

Skull/Lot Number	Cut Marks on Wings of Palate, Description	Cut Marks on Frontals/Nasals	Figures	Interpretation
3	On RHS lateral side of wing of palate, about eight small cuts and indentations seemingly made by a sharp cutting/scraping implement, each less than 1 cm in length; clearly old since they have similar patination to rest of the bone surface, despite being close to a modern break (but wing of palate has an original break on this side too).			Too light for mandible removal and not in right location; more likely for tongue removal; cuts made from right side of skull.
32	On RHS lateral side of wing of palate, small notches posterior to the old break; not very clear/sharp.			Too light for mandible removal; more likely for tongue removal; cuts made from right side of skull.
33		Cut marks on the frontals, near their meeting point with the nasals and lacrimals. LHS: about five very fine parallel cut marks, 1–1.5 cm in length with other light traces of similar cuts adjacent; RHS: three deeper also parallel cuts, about 1 cm in length; both sets of cuts are distinct and separate from each other (although we can't see if nasals also had cuts, since they are pushed beneath frontals); cuts are angled on anterior–dorsal direction; characteristic of chipped stone tool cuts.	11.38, 11.39, 11.40	Skinning marks, to obtain hide including skull shape? Cutting facial arteries for bleeding?
37	On RHS wing of palate, on lateral and ventral surfaces, a series of five small cuts, 3–4 mm long, sharp as if made with a chipped stone tool and in parallel lines.		11.36	Likely for tongue removal? Perhaps for separation of mandible from skull but seem too light. Decapitation would not leave marks in this location. These cuts are "notches" as if something cut on them, supporting the idea of tongue removal.

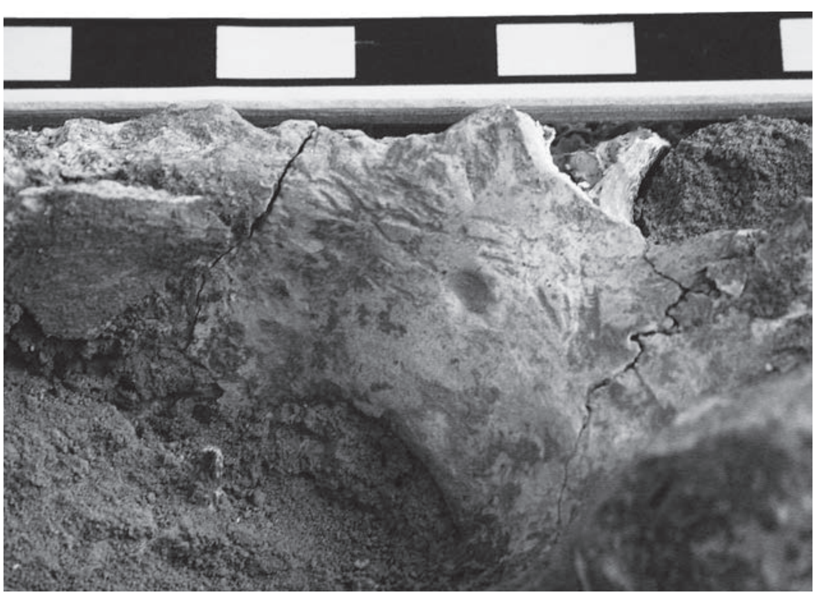


Figure 11.36. Skull 37, close-up of palatine wings, showing multiple light notch-like cut marks on lateral side. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

Figure 11.37. Lot 35 from Kheshiya, the only fragments of bone that are not cattle skulls, consists of fragments of (cf.) a cattle mandible, including a shattered mandibular heel fragment, an ascending ramus, and part of the coronoid process. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

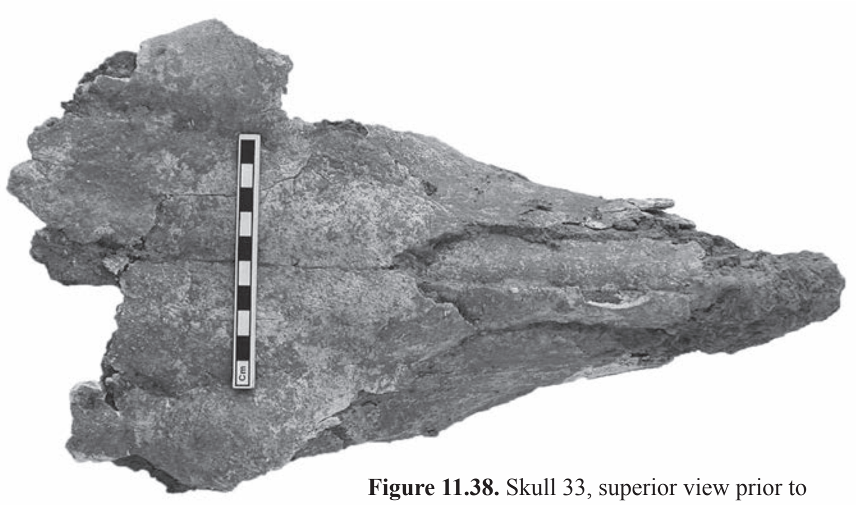


Figure 11.38. Skull 33, superior view prior to surface cleaning, which revealed the cut marks. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

includes a shattered mandibular heel area, ascending ramus, and part of the coronoid process—matching expectations of breakage incurred during mandible removal. There is no evidence as to whether mandibles were subsequently processed for cheek meat removal or marrow, but that might be likely if nutrients were intensively extracted from the cattle carcasses. It is also likely that the process of mandible removal dealt heavy chops and blows to the sides of skulls, potentially causing additional damage to skull structure and integrity. Most skulls slumped in one direction or another—to their left or right (table 11.11), in no particular pattern—and one wonders whether the breakage of palatine wings, and the collapse of the skull to one side, was in part caused by structural weakness resulting from heavy blows to free the mandible—blows that need be applied to one side of the jaw only (often the mandibular hinge area).

The skulls show no evidence of horn removal, which often is visible as cuts around the base of the horncores. In the Kheshiya assemblage, this area often survives. We can therefore assume that horns were left on skulls for visual effect—these were, after all, the main features of the installation that protruded above ground level.

The only other cut marks observed were on Skull 33 (table 11.12, figures 11.38, 11.39, and 11.40). Figure 11.38 shows the skull before cleaning revealed the cut marks; figure 11.39 shows the multiple small incisions on both the left and right sides of the anterior frontals, close to the point where they meet the nasals and lacrimals. The short, light cuts appear as “hatch” marks, close together and parallel, that seem to have been intended to disconnect or cut specific soft tissues. They superficially mark the bone but do not break it, and the sharp edges and multiple cuts are characteristic of chipped stone tools cutting into fresh rather than dry bone (figure 11.40) (Greenfield 1999; Olsen 1988). Figure 11.39 shows how the frontals of this skull had shifted a few centimeters over the nasal bones, making it impossible to gauge whether the cuts continued across the nasals.

The most obvious interpretation of these cut marks is that they relate to careful skinning—for example, producing a hide complete with cattle skull shape. The removal of a bovid hide often results in a continuous piece that includes two strips of cheek hide, and sometimes a thin strip of face/frontal hide too, where careful skinning has circumvented the horns and peeled off these face pieces. The cuts on Skull 33 may relate to face hide removal,

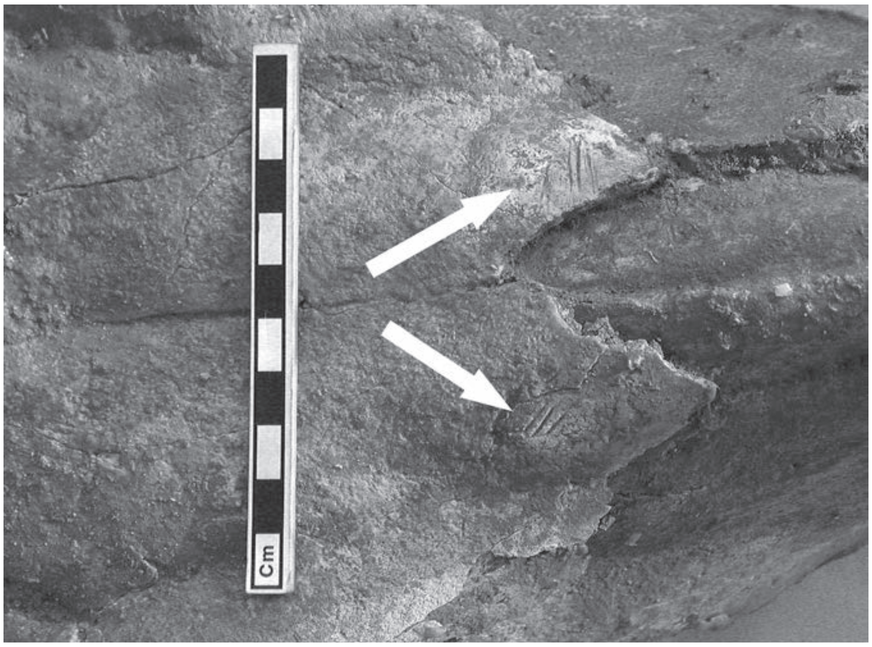


Figure 11.39. Skull 33, close-up of anterior part of frontals, showing multiple small cut marks on both the left and right sides (described in table 11.12). *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

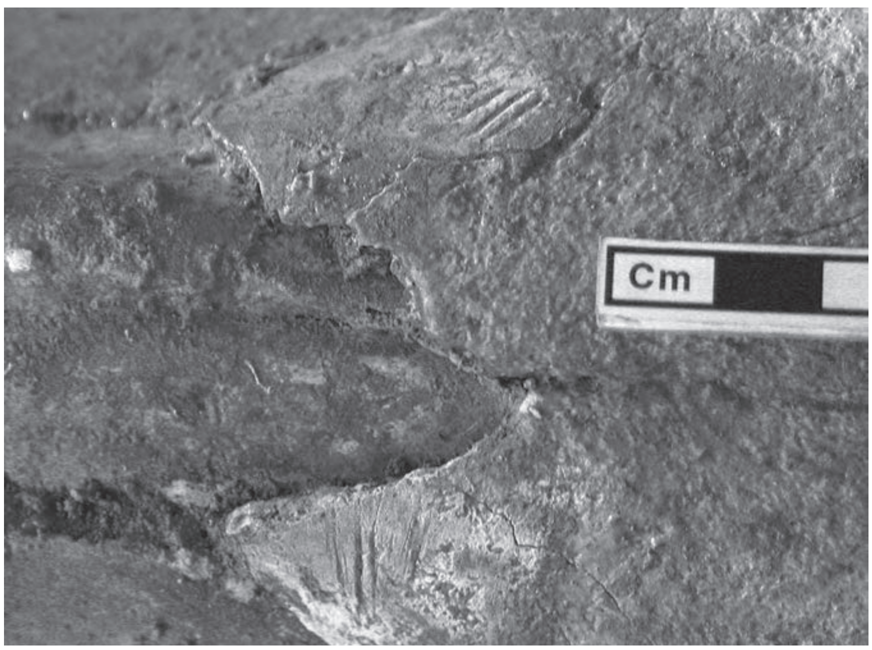


Figure 11.40. Skull 33, close-up of cut marks on anterior part of frontals, showing multiple fine parallel cuts, characteristic of chipped stone cuts into fresh bone. *Photograph by Louise Martin and Lisa Usman, digitally enhanced by Stuart Laidlaw.*

although placement seems slightly too high for skinning the cheeks and perhaps too low for frontal hide removal. The skull is too badly damaged to see whether any characteristic skinning marks existed around the horn bases (e.g., Binford 1981:105–41).

A close look at cattle soft tissue anatomy might suggest an alternative interpretation for consideration. These “nicks” (seen in figure 11.39) are exactly at the location of the main facial artery on either side of a bovid skull. In brief, the common carotid artery (which supplies blood to the head) splits into several smaller arteries, with the facial artery winding above and beneath muscles and other soft tissues, over the maxillae, to run over the surface of the lacrimals and frontals, ending up in the orbit to provide the front of the face with blood. The cut marks on Skull 33 would be well located to target the main blood supply to the front of the animal’s face, but for what reason? Cutting the facial arteries—both left and right—is certainly not an effective way to kill an animal, which normally is done by slitting the major common carotid artery in the neck/throat area. Neither does bleeding an animal to obtain blood to drink (e.g., Århem 1989, for accounts of Maasai practice) use this facial artery. Instead, it is done by nicking the jugular vein that returns deoxygenated blood to the heart—a procedure that is not life threatening to the animal. But slitting these smaller facial arteries on a live, stunned, or recently killed animal would produce strong spurts of blood just below the orbits. This, of course, remains completely speculative, but it is just possible that rather than signifying skinning marks, the frontal cut marks result from another practice that created bleeding from the face in a highly dramatic effect. Such a practice has not been found in any ethnographic literature on cattle ritual, but it is a reasonable suggestion to consider given cattle facial anatomy.

No other cut marks or butchery marks were found on the Kheshiya skulls, which does not mean that more were not originally present. Rather, poor bone condition has preserved only the marks reported here.

Discussion and Conclusions

The Kheshiya Cattle

The study of morphological traits of the Kheshiya skulls strongly suggests that they belong to taurine cattle, with no firm evidence for zebu (*Bos indicus*), although there does seem to be morphological variation within the assemblage. The identification of taurine cattle is not surprising given that zebu are not known to have dispersed westward into the Middle East area until the late sixth millennium cal BP, and they are not seen in Africa until a couple of millennia later.

Morphometric analysis shows that the Kheshiya skulls are far smaller than wild *Bos primigenius* equivalents, whether comparatives are larger samples from Pleistocene/Holocene Europe, smaller comparatives from Early Holocene Anatolia, or single comparisons made with Pleistocene East African aurochs. We can comfortably assume that the skulls come from domestic *Bos taurus*. In terms of skull size—using the limited preserved dimensions of the least frontal breadth of the skulls and maxillary tooth row lengths—the Kheshiya assemblage surprisingly overlapped with Holocene European cattle (from Denmark), although the latter have a larger range. Given an expected northwest-to-southeast size cline geographically (Wright and Viner-Daniels 2015), Arabian domestic cattle might have been expected to be much smaller than European counterparts. Kheshiya cattle are more similar in skull size to the Middle Kerma comparatives, which date to the early fourth millennium cal BP. Skull size is not a good indicator of overall body size in mammals (e.g. Dayan et al. 1991), and we have no postcranial elements from Kheshiya to allow cattle body size reconstruction. It is worth noting, however, that Chaix (2007:208) found that the Kerma cattle "possessed a strong build reaching an average stature of ca. 1.40 [m]," which might give an impression of the Kheshiya cattle height, if their morphologies broadly corresponded.

The identification of domestic *Bos taurus* at Kheshiya allows us to assume that the stock from which they derived originated in the Levant/Fertile Crescent area, or possible East Africa. The earliest domestic cattle finds from Southern Arabia—from eighth-millennium cal BP Manayzah (chapter 8 this volume; Martin et al. 2009)—do not allow species assignation. Based on Kheshiya evidence, it now can be assumed that the earlier Manayzah specimens, too, are taurines. The Manayzah specimens were present in the same region (Wādī Sanā) a millennium earlier. Likewise, it is tempting to think of the seventh-millennium cal BP cattle finds from Wādī ath-Thayyilah 3 in the highlands of Northern Yemen (Fedele 2008) as being of similar type stock.

In the Persian Gulf area, cattle remains from seventh-millennium cal BP Jebel al-Buhais 18 in Sharjah are too few and fragmentary to assess whether they belong to taurine or indicine cattle, although they too appear to be domestic (Uerpmann and Uerpmann 2008). By the fifth millennium cal BP, most sites in the Gulf region report the presence of European cattle, *Bos taurus*, while from Umm an-Nar on the Emirates coast, cattle are assigned to *Bos indicus*, although primarily on the basis of habitat expectations of dryness rather than cattle morphology.

Kheshiya, therefore, aids our understanding of domestic cattle stock origins in the south of Arabia, but to further document cattle introductions and dispersals, analysts need to develop more zooarchaeological and genetic research that supports archaeological evidence of trade and exchange networks.

The Herding System and Cattle Cull

Of the 35 cattle skulls that formed part of the zooarchaeological analysis, just over half provided metrical data that allowed assessment of sexual dimorphism. Results suggest that all the skulls in the outer part of the cattle ring that could be assessed were of narrower morphology and likely to be females; the skull in the center of the ring (Skull 39) was broader, is completely metrically separated from the others, and is very likely to be male. This is an intriguing finding, raising questions about the rationale and meaning behind the installation.

If we add to this picture the results of the dental aging analysis of the cattle, we find the cull to be highly focused on mature adult animals. There are no juveniles or subadults in the skull ring, and there was only one younger adult; the majority of cattle are older adults, not yet elderly, but as female cows they were probably beyond their useful reproductive lives. Dahl and Hjort (1976) report the life spans of recent African cattle to be 9 to 15 years (although an occasional animal living up to twenty years is known), and the dental aging evidence places the Kheshiya cattle in this age bracket. The Kheshiya cull can then be interpreted as consisting of mainly older adult cows, who were beyond calving—a "take-off" of expendable stock.

We have elsewhere extensively modeled the herd management systems lying behind the Kheshiya cattle ring cull or sacrifice (McCorriston et al. 2012), producing detailed ecological predictions of the herd sizes that could sustain a take-off of 40 head of cattle. We also modeled meat yields of such a sacrifice and worked through estimates of consumers and the social and subsistence implications for the Southern Jol herding landscape. The cattle age and sex data produced in this chapter contribute to our discussion; the evidence for the cull of older adult cows supports the idea of milk being a key component of the pastoralist strategy in the Southern Jol Neolithic. To ensure reproduction and safeguard milk production, pastoral nomads who rely on cattle milk keep as many females as possible (Dahl and Hjort 1976:35). In milking herds, fewer individuals survive into the older adult age classes (1976:48, table 2.5) because the predominantly female herd is slaughtered as individuals reach the end of their reproductive lives—an outcome seen in the Kheshiya females.

Returning to the single male skull in the center of the ring (adult, but at the younger end of the range), are we seeing here the sacrifice and special placement of a bull that probably served many cows in the herding landscape? While the majority of males are culled young for beef in most cattle pastoralist systems, a few would be selected for breeding purposes. Dahl and Hjort (1976:28) find that one bull in modern African herding systems regularly serves 50 or 60 cows, providing interesting thought for the Kheshiya context of a bull surrounded by post-reproductive cows.

We know from Henton's work on the oxygen isotopes in the cattle dental enamel (Henton et al. 2014) that groups of animals were herded in at least four distinct locations beyond the Wādī Sanā but within the wider Southern Jol landscape, which shows that the cattle cull was drawn from different herds with varied pasturing and mobility patterns. Henton also demonstrated through dental microwear analysis that the culled cattle all grazed on a diet of soft, clean forage in the weeks immediately prior to death, interpreted as being just after the monsoon season in late summer. The strong similarity in preslaughter diets among all culled animals is consistent with pasturing close to the site of Kheshiya (Henton et al. 2014:128) and is in marked contrast with the variety of herding regimes evident in the dental enamel data. The combined isotope and microwear evidence gives a picture that the Kheshiya cattle derived from different herds that converged in one vegetation zone—likely close to the site itself—in the post-flood/monsoon season, prior to being culled (2014:129). We speculate that the seasonal aggregation and ritual cattle slaughter seen at Kheshiya not only was an occasion for consolidating social networks through feasting, and negotiating access to grazing and other resources (Henton et al. 2014; McCorriston 2011) but may also have provided a context for exchanging cattle and organizing cattle breeding regimes. The installation of the bull skull surrounded by females might commemorate these activities. The dental abnormalities in the Kheshiya assemblage also argue for cattle exchange and interbreeding within the wider landscape, since these abnormalities tend to be characteristic of genetic bottlenecks.

Construction of the Monument

Finally, how does the bone surface modification and taphonomic data presented in this chapter add to our understanding of carcass processing of the Kheshiya cattle, skull preparation prior to installation in the monument, and skull ring depositional history? A few details add to McCorriston's (2011) rich description of how the sacrifice and ring construction took place.

The intact nature of the skulls when they were buried in the ring, with delicate nasals and teeth unbroken or chipped, strongly suggests that the cattle were culled nearby, not at other disparate locations and assembled here (cf. Davis and Payne 1993). Whether whole large herds accumulated at the Kheshiya location in the late-summer, post-monsoonal season (Henton et al. 2014), or whether just those animals selected for slaughter did so, we will never know, but the selection of these similarly aged animals implies intimate knowledge of the life stages of individual animals and careful herd management decisions (e.g., Galaty 1989).

Whether the frontal cut marks on a single skull (Skull 33) reflect skinning activities or the more intriguing suggestion of slitting the facial arteries to stimulate spurts of blood from the face (of a live or recently dead animal) is difficult to tell. But other cattle skinning marks seen in the zooarchaeological literature (e.g., Lisowski 2014) tend to show cuts farther back on the frontal, which might encourage a rethinking of the skinning interpretation.

Decapitation of carcasses left no visible signs—the occipital condyles were too poorly preserved, and the atlas/axis is absent. Only one skull shows evidence of careful face hide skinning (Skull 33). While all carcasses obviously would have been skinned, it is not clear if only this skull had its face hide removed or whether we cannot see it in other skulls because the preservation of their parts and surfaces is too poor for us to be certain.

Mandibles seem to have been removed by a heavy blow or chop across the ramus to release condyles, maybe serving to also weaken the side of the skull at this point. Mandible removal made the skull narrower for burial but also allowed easier access to the tongue—a delicacy—for which two skulls show evidence of extraction. Presumably, to keep the skulls intact, the nutritious brain was not extracted; crania were installed complete and show no signs of breakage.

McCorriston (2011) fleshes out discussion of the large quantities of fresh meat, blood, and other products that the Kheshiya cattle cull would have produced and considers in detail the alternatives of immediate feasting, preserving meat, or redistribution of joints. Because other cattle skeletal elements are absent at Kheshiya, interpreting consumption activities requires broader social and ecological approaches, as our synthesis shows (McCorriston et al. 2012).

As expected, skulls showed no evidence of horn removal; the smooth keratin horn sheaths presumably gave the desired effect to the whole installation. The horn form of these Neolithic Arabian cattle is not known, and taurine horns can be as variable as those of any cattle (Grigson 1978). The adult females in the outer part of the ring would have had long slender horns, certainly interlocking with those of their neighbors, while we can assume the central male skull carried maximum-size horns that protruded prominently into the space.

Apart from mandible removal, none of the skulls shows any modification. The point was not to fashion them into bucrania for household display, as seen, for example, in Neolithic domestic installations (Baird et al. 2016; Mellaart 1967), or just to remove the horn-carrying part of the skull, as seen in the Kerma examples (Chaix 2007), which allowed them to be laid flat with horns extending upward. The Kheshiya skulls fitted their purpose, with no further tailoring or shaping, perhaps indicating quicker manufacture and a shorter-term impact for mobile people.

Bone surface weathering patterns indicate both that skulls were buried relatively rapidly after they were prepared and that rear skull parts—from the orbits backward—suffered from surface exposure. Over time—whether the short or long term—occipitals, the intercornual ridge, and horns disintegrated completely.

Whatever activities took place in the center of the skull ring left no traces on the skulls; none show signs of burning, which might suggest that open fires were not nearby. It is estimated that within a year of burial (Galloway 1997), soft tissues would have degraded, cranial cavities filled with silts, and skulls collapsed downward, exacerbated by wetting and drying of the shallow deposits and the pull of gravity. After these routine processes of taphonomic decay, the skulls thankfully were stabilized by deposition, and they survived the 6,000 years until excavation.

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Appendix 1

The Conservation and Treatment of the Kheshiya Cattle Skulls: Report of Procedures Undertaken in the Mukhalla Museum to Aid the Study and Stabilization of the Assemblage

Lisa Usman and Louise Martin

We are extremely grateful to ʿAbdalʿazīz Bin ʿAqīl, director of culture for Mukalla at the time of the study, for his many forms of assistance with work in the Mukalla Museum and for his enthusiastic and generous support of the project. We are also indebted to the staff of the museum for their kind assistance, providing space and equipment for the work.

The conservation aspect of the project aimed to prepare the 35 Kheshiya cattle skulls for zooarchaeological analysis, to provide elementary conservation and stabilization under time-limited conditions, and to pack the material for long-term storage. To this end, one room in the museum was converted into a temporary laboratory for the period of study, December 29, 2005–January 12, 2006.

Review of Methods of Packaging Skulls upon Excavation, On-Site, Spring 2005 (from Observation)

Upon excavation in spring 2005, each skull was lifted and packed for transport to the museum in Mukalla. The first layer of packing material was newspaper, followed by strips of sheet taped together with masking tape and finally a plaster of paris bandage to provide rigid support. The newspaper and sheet were wrapped around the skull as a barrier layer between the skull and the outer bandage, which was wet when applied. Each skull was labeled and packed in a metal box (normally five to a box) and supported with foam to prevent damage during transport. Given the constraints of time and materials in the field, the method proved extremely successful and the skulls were safely transported to the museum.

Note: Prior to packing, a single tooth was extracted from each skull to serve as a sample for scientific analyses (for example, DNA, ^{14}C, isotope, and dental microwear analyses). These samples were exported to the University College London Institute of Archaeology, where they underwent further analyses.

Opening Skull Packages

On unwrapping skulls for study, we removed the rigid plaster bandages using a scalpel, angled to avoid risk of the blade touching the bone. The bandages were prized apart and the skulls gently lifted out of the support onto plastic trays. The remaining packing material was cut open when the skulls were on the trays, leaving a layer of paper and sheet beneath them. Lifting and turning of skulls was avoided as much as possible due to their fragile state; trays allowed for movement and study to be carried out without the need to overhandle the objects.

Skull packages were opened with occlusal surfaces of maxillary teeth facing upward. Our assessment was that frontal bones stood a better chance of surviving with the weight of the skull resting on them than dentition.

Observation of Skull Condition

Most of the soil around the skulls was removed during excavation, but much deposit remained on the surfaces and inside the crania. In most cases, the internal deposit appeared to provide key internal support for the cranium, and therefore it was not removed. The deposit consisted of fine silty particles, compact and hard when dry. Teeth had survived in good condition, while the bones of the palatine and maxillae were mostly highly fragmented; nasals and pre-maxillae often were missing altogether. The posterior area of the palatine was mostly encased in deposit, which made assessment of this area difficult. There was no evidence that horncores had survived; indeed, posterior areas of the skulls (which would have been uppermost in the ground and may have been exposed) had suffered badly.

Cleaning

Due to time constraints, only selective cleaning of the skulls was undertaken. Focus was on areas of the skulls required for zooarchaeological recording, and cleaning attempted to maximize information collection. Deposit that acted as the internal “glue” and held skulls intact was not removed. If time permits, a comprehensive cleaning (involving the complete removal of deposit) could be carried out on the better-preserved skulls, with consolidation of fragments and adhering of joins as each fragment is separated from the soil. This is recommended if any skulls are to be displayed in the future.

For the most part, the soil was harder than the bone it adhered to. Removal was carried out using acetone and a pipette, and gentle scraping away of deposit using a wooden or plastic tool to prevent scratching of the bone's surface. For the teeth, for the most part, it was possible to brush soil away using a soft brush.

Bone fragments that fell away were consolidated using a dilute solution of Butvar. When they dried, they were wrapped in acid-free tissue paper and packed with the skull. It was decided not to consolidate the whole skull, as this would have made the soil even harder to remove, and it is hoped that further work may be undertaken on the skulls in the future. When breaks occurred on morphologically diagnostic features during cleaning, they were repaired using Paraloid B-72 in acetone.

Basal sides of skulls (or dorsal views) were cleaned, studied, and documented first. Then skulls were turned over onto a foam support covered in layers of acid-free tissue. Skull cleaning and study was then undertaken on ventral sides.

Packing

After completion of cleaning, study, recording, and documentation, the skulls were prepared for packing. (Specialist packing materials were limited.) At this stage, each skull was sitting on a foam support and on sheets of acid-free tissue on its own tray. Further layers of acid-free tissue were placed on the top, and the sheets from underneath were brought up over the sides and fastened to the top sheet using masking tape. Once securely sealed, the skull and tray were wrapped in cling film. This was chosen as it held the skull firmly in place, preventing movement if the tray was tipped. Because cling film is transparent, skull numbers and labels were wrapped into it, making labels readable without the need to open the wrapping and thus preventing the labels being separated from the skulls. Cling film also can be easily removed (and reapplied) without damaging the tissue paper, should further study be required. The plastic trays provided excellent support and allowed easy movement of the cattle skulls without causing any damage. The skulls were left in the Mukalla Museum to await placement in custom-made metal boxes for longer-term storage.

Appendix 2

Cattle Skull Recording Form 1

Basic

Site:
Skull number:

Recorded by:
Date(s) recorded:

Photographs:

Overall condition:

Surface weathering—highest:
Surface weathering—lowest:

Burning—degree and location?

Other surface modification? Describe:

Presence of skull parts				
	Left	Left	Right	Right
	> 50%	< 50%	> 50%	50%
Frontal				
Parietal				
Temporal				
Occipital				
Perioticum				
Interparietal				
Palatine				
Sphenoid				
Zygomatic				
Lacrimal				
Nasal				
Maxilla				
Premaxilla				

Horncore

Base				
Corpus				
Tip				

Presence of parts on diagram? | Yes | | No | |

Appendix 2

Cattle Skull Recording Form 2
Morphology

Site:
Skull number:

Recorded by:
Date(s) recorded:

Nonmetrical traits:

Sagittal Profile		**Complete**		**Estimated**		**Not Done**	

Orbital rim		**Flat/*indicus*:**		
		Sharp/*taurus:*		

Nasal–frontal suture		***taurus* shape:**		
		***indicus* shape:**		

Frontal–lacrimal suture			
	Frontal–lacrimal suture:	**straight?**	**bowed?**
	Lacrimal–jugal suture:	**straight?**	**bowed?**

Frontal profile from above:					
	1	**2**	**3**	**4**	**5**

Intercornual ridge:						
	1	**2**	**3**	**4**	**5**	**6**

Horncore shape:

Horncore direction:

Shape of horncore base:

Shape of posterior end of palate:

Comment:

Appendix 2

Cattle Skull Recording Form 3
Aging Data

Site:
Skull number:

Recorded by:
Date(s) recorded:

Dental Eruption and Wear (after Grant 1982, adapted for maxilla)

Left Side	Grant	Comment
	TWS	
dp2		
P2		
dp3		
P3		
dp4		
P4		
M1		
M2		
M3		

Right Side	Grant	Comment
	TWS	
dp2		
P2		
dp3		
P3		
dp4		
P4		
M1		
M2		
M3		

MWS	

MWS	

Horncores (after Armitage 1982, surface aging method)

Left core
Right core

Horncore rings?
Left
Right

Suture closures (after Grigson 1982)

Comment:

Appendix 2

Measurements on the Cranium of *Bos*

(after von den Driesch 1976)

Site:
Skull Number:

Measurement	mm	Modifier Code
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		
32		
33		
34		
35		

Code:	0-1	Standard measurement
	2	Estimated
	3	Influenced by pathology
	4	See comment
	5	Unfused/young
	6	Burned
	7	As preserved (for artifacts)

Tooth measurements, adapted from mandible

Measurement*	mm	Modifier
L of dp4		
B of dp4		
L of P4		
B of P4		
L of M1		
B of M1		
L of M2		
B of M2		
L of M3		
B of M3		

*all taken near biting surface

Crown heights—add here:

Appendix 3: Kheshiya Cattle Teeth Ancient DNA Pilot Study

Cecilia Anderung and Anders Götherström

Three cattle teeth from Kheshiya (SU151-1) in Yemen were selected from the samples imported to UCL, based on visual good preservation:

Kheshiya DNA id. RA1
Locus 009, Lot 37. Maxilla P3, P4, both worn

Kheshiya DNA id. RA2
Locus 009, Lot 32. Maxilla M1/M2, worn

Kheshiya DNA id. RA3
Locus 009, Lot 33. Maxilla M3, worn

Methods

The specimens were sampled in a dedicated ancient DNA facility at Uppsala University in Sweden. Bone powder was removed from the specimens using a dental drill, producing small holes with a diameter of 2–3 mm. The work surface was sterilized between each sampling procedure and a new drill bit was used for each sample.

About 70 mg of bone powder was incubated at 55°C with 100µg Proteinase K in 1 ml of 0.5M EDTA buffer. Thereafter the DNA was extracted using previously published methods (Bouwman and Brown 2002; Svensson et al. 2007; Yang et al. 1988).

The mtDNA control region was amplified in three overlapping fragments: 157, 176, and 139 bp, respectively. PCR was carried out using 2µl of extracted DNA, 2.5 units of HotStarTaq DNA polymerase (Qiagen), 1X Qiagen PCR buffer, 2.5mM MgCl, 200µM of each dNTPs, and 0.2µM of each primer in a total volume of 25µl.

Results

None of the three samples generated a readable sequence. Considering the geographic origin of the sample (Smith et al. 2003), future work could involve the designing of primers that will amplify shorter DNA fragments; this would probably increase the amplification success rate. As some samples produced a smell of collagen during sampling and collagen survival is correlated with DNA survival (Anderung et al. 2005), it is suggested that further DNA analyses of specimens from this region should involve preservation analyses.

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Appendix 4: Kheshiya 151-1 Cattle Skull Measurements

Code	Description	2	3	4	5	11	12	13	14	15	16	17	18
		Skull Numbers											
Cattle Skull Metrics (following von den Driesch 1976)		**2**	**3**	**4**	**5**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Code	**Description**												
3	basal length, basion to prosthion												
4	basion to premolar		240*				250*	240*	235*		250*	255*	
5	premolar to prosthion												
12	greatest length of the nasal: nasion to rhinion												
17	dental length: postdentale to prosthion												
18	oral palatal length: palatinooral to prosthion												
19	lateral length of the premaxilla												
20	length of cheek tooth row (measured along the alveoli)	130	127.3	134	129.3	140*	133.2	128.8	124.5*		125.5	130.8	139*
21	length of molar row (measured along the alveoli on the buccal side)	75.8	74.6	83.3	76.9	73.2*	82.2	80	75.1		76.2	77.8	85
22	length of premolar row (measured along the alveoli on the buccal side)	51.3	52.7	51.9	55.2	55*	52.1	52.3	51.9*		46.7	54	53*
23	greatest inner length of the orbit												
26	greatest breadth of the occipital condyles												
24	greatest inner height of the orbit												
27	greatest breadth at bases of paraoccipital processes						156.8						
28	greatest breadth of the foramen magnum												
30	least occipital breadth						122.4						
31	least breadth between the bases of the horncores											140*	
32	least frontal breadth						164.6					169.6	167*
33	greatest breadth across the orbits = greatest frontal breadth						193*					196.5*	195-7*
34	least breadth between the orbits												
35	facial breadth across the tuberosities		145*		144*	152.7	147*	153.3*			139.7	148	149.3*
36	greatest breadth across the nasals					50**							
37	breadth across the premaxillae on oral protuberances											128.1	
38	greatest palatal breadth, measured across the outer borders of the alveoli		116.2		117.5		130*	130.9			126.6	130.8	116.6
46	least (dorso-basal) diameter of the horncore base												
LM1	P2-P2 internal least breadth		67.4*		64.6*			70.5*			63*	76.2*	
LM2	M1-M1 internal least breadth		77.6		75.2			83.5*			75.5	86.8	74
LM3	M3-M3 internal least breadth		75.3		75.1	79.1	79.1	83.4			77.6	77.3*	75*
Tooth Measurements (adapted from von den Driesch 1976 for mandible)		**2**	**3**	**4**	**5**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	measurements taken on left or right side?	L	L	L	L	R	R	R+L	L		R	R	L
L P4	length of P4 measured near the biting surface	17.6	17.3	18.3	18.4	18.6	20.6	16.8	17		16.4	18.2	19.2
B P4	breadth of P4 measured near the biting surface	17.4	18.4	20	16.5	18.1	22	16.3	17.7		17.1	16.6	14.1
L M1	length of M1 measured near the biting surface	21.6	21.6	19.6	24.3	23.6	20.1	24	18.6		22.5	21.8	27.5
B M1	breadth of M1 measured near the biting surface	23.1	20	22.4	18.9	21	24.4	19.6	20.6		21	18.6	20.2
L M2	length of M2 measured near the biting surface	26.3	24.5	27.2	25.6	26.4	27.1	27.8	25.4		26.3	26.3	28.7
B M2	breadth of M2 measured near the biting surface	22	19.2	23.5	17.9	20.3	23	19.4	20.8		21.4	19.6	19.3
L M3	length of M3 measured near the biting surface	30	27.7	29.8	28	26.6	30.7	27.6	26.1		28.5	29.4	29
B M3	breadth of M3 measured near the biting surface	22.5	18.8	23.4	17.9	20.7	22.1	19	20		21.2	19.6	18.1
	(lengths of teeth are often less than breadths because of heavy mesio-distal wear)												
Horncore Measurements Taken in the Field, in Situ (by M. Harrower)													
44	horncore basal circumference												
45	greatest diameter of the horncore base											5.7*	
46	least diameter of the horncore base											5.0*	

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	36	37	38	39	40	41	42	Total
																			430*				1
	245*	260*		260*		240*			250		240*	230*			230*	250*	240**	265*	280		290*		19
																			135*				1
																				2 -7*			1
																			270*				1
																			225*				1
																							0
	132	138*	125.5*	125.4	131.1*	136		124.7	120.5	132	129.5*	121.6	130*	134	122.6	127.5	138.5	141.8	138		137	127.2	31
	77.8	87.6	74.4	75.7	83.9	78.5	77.3	76.8	74.2	75.5	79.7	79	80.2	81.8	77.5	78.4	84.5	83.9	86		82	76.6	32
	53	56*	46.8*	51.3	52*	55.4		47	46.5	52.1	46.2	45.9	50**	53	46.8**	50.8	54.3	58.3	54.5		52.5	53.5	31
	47*																						1
																88							1
	56*																						
																							1
									49*							35.8							2
									117*							121*							3
		140*	110*	150*							127*					145-60							6
	160	169.1	154*	152.9	165**	168*			165	174.7	169.3		180**		147*	174*	174*		197.5*		169.4		18
	190.9*		230*	184*						205*	250**				197**	250*	197*		225*		197*		13
																			154*				1
	146.9			137	139*	125*			142*	148.8*	161.3*	146.3		146.8	135			160*	142.4		154*	145.5	22
		55*							47*	50**				45.8*	50*		51*		42*	52	41*		10
																							1
	121.3			120.5	124	114			124.5	125.4	131.6	130.4		131.3	118.4	141.7		133.2	128.4		121		21
			60*	42*																			2
				58.9		58.7				66*				70.1	65.1*	72.5*			69.2		57.7*		13
	76.6			75.1		72.5				79.9		83.6		84.9	75.7	94.7*			82.3		74.9*		16
	73.4*			71.5*		64.3*				76.1				74.6	67.8*	96*			82.5		74*		17
19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**Total**
R	R	L+R	R	R	L	R	R	L	R	R	L	L	R	L	L	L+R	L	L	L		R+L	R	
17.2	16.9	18.2	16.9	18	17.2	17.9	16.6	15.5	18.7	16.6	18.4	15.8		15.6	16.9	19.1	18.2	18.2	19		18	18	
12.7	14.2	20.8	16.7	17.9	18.2	16.4	19.2	17.5	19.2	20	15.9	18.6		19.5	19.5	20.7	18.4	15.5	16.4		16.6	19.1	
26	25.8	23.9	18.3	22	23.2	23.1	20.8	22.1	19.2	20.4	23.5	22.1	24.3	22.3	20	21.1	23.6	27.2	25.5		23.6	20.1	
18.6	18.3	23.6	19.1	19	21.2	20.6	21.4	21.6	20.7	20.6	19.1	21.7	20.1	21.7	22.2	22.8	20.3	20	19		20.2	20.9	
26.9	27	28.9	25.7	25.2	27.3	26.8	25.5	24.5	25.6	26.3	28.4	25.7	27.6	28.4	25.7	26.6	28.2	29	29.2		28.9	25.6	
16.3	18.2	22.8	20.2	21.2	21.4	21.9	20.7	21	21.4	21	20.4	21.9	22.1	22.3	22.6	22.9	20.6	20.2	19.3		23	22	
23.2	26.2	32.4	27.2	26.8	31.5	29	29.2	28.7	28.5	28.8	31.1	31.1	28.9	33.2	29.1	31.3	31.9	30	30.7		30.9	28.8	
13.8	16.5	21.9	20.2	18.5	21.1	20.1	21.1	21.5	20.3	20.1	20.4	22.6	22.3	22.6	21.8	22.4	20.2	19.6	19.6		18.9	22.5	

																17.4*						
				4.9*												5.6*	5.3*					
				4.3*												4.7*	5.1*					

*Estimated measurement

**Highly estimated measurement

Appendix 5

Skull/Lot Number	Sagittal Profile	Orbital Rim	Nasal/Frontal Suture	Frontal/ Lacrimal Suture	Lacrimal/Jugal Suture	Frontal Profile
2	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
3	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	Type 2, relatively flat on anterior of frontals
4	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
5	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	Type 2, flat across frontals
11	can’t assess	can’t assess	*taurus* shape	can’t assess	straight	can’t assess
12	can’t assess	can’t assess	can’t assess	can’t assess	straight	Type 2, flat across frontals
13	can’t assess	can’t assess	can’t assess	can’t assess	straight	Type 2, flat across frontals
14	can’t assess	can’t assess	can’t assess	can’t assess	straight	can’t assess
15	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
16	can’t assess	can’t assess	can’t assess	can’t assess	straight	Type 2? Very flat between orbits; can’t see posterior to that.
17	can’t assess	can’t assess	(*indicus* shape?)	can’t assess	can’t assess	can’t assess
18	taurine	can’t assess	(*indicus* shape?)	can’t assess	bowed/straight intermediate	Type 3: slight boss
19	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
20	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
21	taurine?	can’t assess	can’t assess	can’t assess	can’t assess	Type 2 or 3
22	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	Type 2
23	taurine?	can’t assess	can’t assess	can’t assess	can’t assess	Type 2 or 3
24	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	Type 2
25	taurine	can’t assess	can’t assess	can’t assess	straight	Type 3: slight boss
26	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
27	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess	can’t assess
28	can’t assess	can’t assess	*taurus* shape?	can’t assess	straight	Type 2
29	can’t assess	can’t assess	*taurus* shape?	can’t assess	can’t assess	Type 2?

Intercornual Ridge	Horncore Shape	Horncore Direction	Shape of Posterior End of Palate	Comments
can’t assess	can’t assess	can’t assess	broken but broad and flat	
can’t assess	can’t assess	can’t assess	medium width; U shaped	
can’t assess	can’t assess	can’t assess	can’t assess	
can’t assess	can’t assess	can’t assess	narrow and V shaped, but U shaped where meets with wings of palate	
can’t assess	can’t assess	can’t assess	broad and flat	
can’t assess	can’t assess	can’t assess	broad and U shaped	
can’t assess	can’t assess	can’t assess	narrow and V shaped; spines thin and pinched	
can’t assess	can’t assess	can’t assess	broken but has one-half has narrow wing	
can’t assess	can’t assess	can’t assess	can’t assess	
can’t assess	can’t assess	can’t assess	narrow and intermediate between V and U shaped	
Type 8	can’t assess	angled backward?	V shaped	
can’t assess	can’t assess	can’t assess	V shaped	
can’t assess	can’t assess	can’t assess	narrow and V shaped	Check if narrow, V-shaped end of palate is age-related.
Type 4	can’t assess	can’t assess	broad and U shaped	
can’t assess	can’t assess	taurine	broad, straight, and U shaped	
Type 4 or 8	taurine	can’t assess	can’t assess	Horncores must be very small (about 4 cm) at base—female?
Type 8	taurine	angled backward?	narrow and V shaped	Horncores seem very small.
can’t assess	can’t assess	can’t assess	very narrow and V shaped	
can’t assess	taurine	can’t assess	narrow, intermediate between V and U shaped	Seems to be a long narrow skull?
can’t assess	can’t assess	can’t assess	medium width; U shaped	
can’t assess	can’t assess	can’t assess	V shaped, thin walled, not similar to either of Grigson’s forms	
can’t assess	can’t assess	can’t assess	broad and U or W shaped	Left side of posterior end of palate flattened.
can’t assess	taurine	can’t assess	broad and U shaped/flat	

Appendix 5 *(continued)*

Skull/Lot Number	Sagittal Profile	Orbital Rim	Nasal/Frontal Suture	Frontal/ Lacrimal Suture	Lacrimal/Jugal Suture	Frontal Profile
30	taurine?	can't assess	can't assess	can't assess	straight	Type 3: slight boss
31	can't assess	can't assess	can't assess	can't assess	can't assess	Type 2
32	can't assess	can't assess	can't assess	can't assess	straight?	can't assess
33	can't assess	can't assess	can't assess	can't assess	straight?	can't assess
34	can't assess	can't assess	can't assess	can't assess	bowed?	Type 2?
35	mandible					
36	taurine?	can't assess	*indicus* type?	straight?	straight?	Type 2?
37	can't assess	can't assess	*indicus* type?	can't assess	can't assess	Type 2/3? Relatively flat with slight boss in center.
38	can't assess	can't assess	can't assess	can't assess	can't assess	can't assess
39	can't assess	can't assess	can't assess	can't assess	can't assess	can't assess
40	can't assess	can't assess	*indicus* type??	can't assess	can't assess	can't assess
41	can't assess	flat (*indicus* type?)	can't assess	can't assess	straight?	can't assess
42	can't assess	can't assess	can't assess	can't assess	straight?	can't assess

Intercornual Ridge	Horncore Shape	Horncore Direction	Shape of Posterior End of Palate	Comments
Type 2/4?	can't assess	can't assess	broad and U shaped	Horncore bases appear small, about 51 mm anterior/posterior on left side.
can't assess	can't assess	can't assess	narrow and U shaped (unlike either of Grigson's shapes)	
can't assess	can't assess	can't assess	broad and V shaped	
can't assess	can't assess	can't assess	narrow and V shaped	
can't assess	can't assess	can't assess	narrow and U shaped	
can't assess	can't assess	can't assess	can't assess	LHS horncore base seems very small, about 4 cm anterior/posterior.
can't assess	can't assess	can't assess	broad and V shaped	
can't assess	can't assess	can't assess	asymmetrical: left side more V shaped; right side more U shaped; unlike either of Grigson's forms	
Most like Type 1? But assessed anterior or ridge.	can't assess	can't assess	narrow and convex, re Grigson's characteristic shape for *indicus* (Grigson 1976:126, b)	
can't assess	can't assess	can't assess	can't assess	
Most like Type 1? But assessed anterior or ridge.	can't assess	Taurine? Poor preservation but must leave skull outward.	narrow and convex, re Grigson's characteristic shape for indicus (Grigson 1976:126, b)	
can't assess	can't assess	can't assess	broad and flat/U shaped, as Grigson 1976:126, a.	

Appendix 6

Skull/ Lot Number	Surface Weathering	Burning	Frontal Eminence Present	Occipital Condyle Present	Nasals Present	Dentition Present (Y = L+ R; L = Left; R = Right)	Breakage between Basal Tubercles and Palatine; Direction of Shift from Frontal Aspect	Thermally-Altered RocksEmbedded near Palatine
2	3	none	no	no	no	LHS	can’t assess	can’t assess
3	3	none	no	no	no	LHS + RHS	yes; anterior skull shifted left	no
4	3	none	no	no	yes, RHS	LHS	can’t assess	can’t assess
5	3	none	no	no	no	LHS/RHS	yes; anterior skull shifted right	can’t assess
11	3	none	no	no	yes	LHS/RHS	yes; anterior skull shifted right	yes
12	3 and 4 around orbits	none	no	part	no	LHS/RHS	no	can’t assess
13	3 and 4 around zygomatics	none	no	no	no	LHS/RHS	can’t assess	can’t assess
14	3	none	no	no	no	LHS/RHS	yes; anterior skull shifted right	yes
15	3	none	no	no	no	no	can’t assess	can’t assess
16	3	none	no	no	yes	LHS/RHS	yes; anterior skull shifted left	no
17	3	none	yes	yes (part)	yes	LHS/RHS	yes	no

Cut Marks on Wings of Palate	Cut Marks on Frontal/Nasals	Comments on Condition	Which Tooth Sampled for UCL
can't assess	can't assess	Posterior part of skull, behind palate, fallen apart. No palate, no premaxilla, no nasals; only maxillae present, but rest in highly fragmented state.	RHS M3
yes	can't assess	Breakage of post-palate wing midway between basioccipital and palatines, leading to slight shifting between anterior and posterior part of skull and some forward movement of frontals over lacrimals.	none
can't assess	can't assess	Just an LHS maxillary tooth row surviving intact (minus P2) in part of maxilla, with rest in fragments. Bone surface shows leaching.	LHS P2?
no	can't assess	Palates, maxillae, and tooth rows very well preserved; all teeth present; only RHS P2 missing (sampled?). Frontals very crushed, but there appears to be some forward movement of frontals over lacrimals (which are crushed and missing), indicative of breakage between anterior and posterior parts of skull.	RHS P2?
no	no	Both sides of dentition present (except LHS M2, probably sampled), with RHS premaxilla present and basioccipital but not occipitals; can see into cranial cavity. Anterior skull broken from posterior skull across post-palatine wings, across the zygomatics and orbits, leading frontals to shift forward about 1 cm. Two stone pieces lodged beneath LHS orbit.	LHS M2?
no	can't assess	One of best-preserved posterior skulls. Has parts of basioccipital present but still no frontal eminence, so can't assess profile or intercorneal ridge. Premaxilla and nasals not present. Dentition: RHS complete; LHS has only M1, M2, and M3. (Others may be sampled?) Notably no slumping or squashing. Is this an older skull, hence more fused?	LHS P2, P3, P4?
can't assess	can't assess	Frontals present but no intercorneal eminence, and orbits are missing, but some basioccipital present. Both LHS and RHS dentitions present. Some hint of asymmetry between anterior and posterior of skull but difficult to see. Not much slumping apparent but nasals (LHS) slightly pushed below frontal, indicating some slumping.	RHS M1
no	can't assess	Basioccipital to premaxilla is present, but frontal eminence missing, as are nasals. Both LHS and RHS dentitions present, with P2s missing both sides. It's notable that there is no burning, even though fire-cracked stone is wedged between RHS basioccipital and wing of palate. The stone is wedged deeply here, seemingly intentionally, and just where skulls are normally broken. There is slumping of this skull: the LHS orbit overhangs lacrimals and zygomatic.	LHS or RHS P2?
can't assess	can't assess	Very poorly preserved, just a 15 cm lump of soil matrix with some frontal fragments adhering and some parts of internal skull. No dentition and not much else visible.	assume none
no	no	Frontals present but no intercorneal eminence and no basioccipitals/occipitals. Nasals present both LHS and RHS; dentition present both LHS and RHS (but RHS premolars fallen). Appears to have had much post-depositional movements: nasals sunk between maxillae; frontals shifted over nasals; frontals overhanging lacrimals, which then overhang maxillae (on both sides). Seems related to breakage between anterior and posterior skull and state of (un)fusion.	RHS M2?
can't assess	no	Preservation relatively good, with basioccipitals, part of frontal eminence present, and posterior parts of nasals. Horncore direction can be assessed from RHS horncore base. Both LHS and RHS dentitions present. Frontals have shifted forward over nasals, and both are separated from the maxillae, with a wide gap between all sutures.	LHS M3

Appendix 6 *(continued)*

Skull/ Lot Number	Surface Weathering	Burning	Frontal Eminence Present	Occipital Condyle Present	Nasals Present	Dentition Present (Y = L+ R; L = Left; R = Right)	Breakage between Basal Tubercles and Palatine; Direction of Shift from Frontal Aspect	Thermally-Altered RocksEmbedded near Palatine
18	3	none	yes	no	yes	LHS/RHS	yes; anterior shifted right	no
19	3	none	no	no	no	yes, but many teeth missing	can't assess	can't assess
20	4 around posterior frontal and orbit; 3 anterior frontal and maxilla	none	no	no	no	LHS/RHS	yes; suggests anterior shifted left	yes
21	3 and 4	none	no	yes (part)	no	LHS/RHS, but many teeth missing	can't assess	no
22	4 highest and 3 lowest	none	yes	no	no	LHS/RHS, but many teeth missing	yes	no
23	4 around horncore bases; 3 elsewhere	none	partially	no	yes	LHS/RHS	none apparent	no
24	3	none	no	no	no	LHS/RHS	yes; anterior shifted right	no
25	4 on frontals; 3 elsewhere	none	yes (small part)	yes (part)	yes	LHS/RHS	yes; anterior shifted right	no
26	3	none	no	no	no	RHS but teeth missing	can't assess	can't assess
27	4 on parts of nasals and anterior of maxillae; 3 elsewhere	none	no	no	yes	LHS/RHS (some fallen)	yes; anterior shifted right; inferred, but see comment	can't assess

Cut Marks on Wings of Palate	Cut Marks on Frontal/Nasals	Comments on Condition	Which Tooth Sampled for UCL
no	no	Relatively good preservation, with some basioccipitals present and both nasals; can assess frontal and sagittal profiles; both LHS and RHS dentitions present but with some missing premolars. Breakage between anterior/posterior of skull, across palatine wings, with shifting forward of frontals over lacrimals and both buckling under and over nasals. Slightly more overhang on RHS than LHS because of angle of break/slump.	RHS M3?
can't assess	can't assess	Very poor survival; just frontals and some anterior skull intact, including maxillae, but many teeth on both sides have been lost, and no skull parts anterior of maxillae are present. Maybe poorly surviving because appears younger?	?
can't assess	can't assess	RHS of skull better preserved; orbit present but rim broken off; no occipitals. Whole seems leached and highly fragmented. Posterior skull pushed forward over anterior; orbit broken and pushed over lachymals. Seems that posterior skull collapsed forward. There is fire-cracked rock stuck into LHS frontal, above orbit.	LHS M3?
can't assess	can't assess	Highly fragmented; RHS tooth row better preserved but LHS all fallen; maxillae fragmented. Some parts of frontal visible. Much leaching of bone. Frontals shift forward, more on RHS than LHS, and overhang maxilla on RHS by about 2 cm. Parts of occipitals preserved.	LHS M3?
no	can't assess	Highly fragmented, especially LHS and anterior of maxillae. The posterior part of palate hasn't survived, but this is the only skull where the intercorneal ridge survives. Teeth on both sides have fallen. Nasals are missing. Bone surface is leached; weathering high in places. Frontals have shifted forward over lacrimals and maxillae a few centimeters.	LHS M3?
no	no	Fair condition; most of skull length present but premaxillae absent and maxilla broken at anterior end; occipitals missing; can see traced shape of base of RHS horncore in soil. Maxillae and nasals mostly survive, as do lacrimals. Tooth rows complete and in good condition (observation made that if skulls were heated/burned, we may expect teeth to show cracking, which they don't). Front of skull seems relatively in place, with not much anterior shifting, although frontals have shifted over nasals slightly, in symmetrical fashion.	LHS M3
no	can't assess	Bone surface quite leached; preservation patchy, with fragments lost, but there are hints of the base of RHS horncore. Breakage between anterior and posterior of skull, with palatine wings broken and shift of 2-3cm between anterior and posterior parts. Frontals have separated by 2 cm along their fusion line but stay parallel. Did this occur though wetting and drying, with expansion and contraction pulling them apart? Frontals were unfused anyway. Frontals (especially LHS, because of slumping being more on this side) also overhang maxillae, so overlapping lacrimals too.	RHS M3?
no	no	This skull preserved well enough to take intercorneal ridge morphology and sagittal profile. Premaxilla doesn't survive but occipital is still present (but without complete condyles); tooth rows complete. Note dental anomalies on both LHS and RHS M1.	LHS M3
can't assess	can't assess	Very little surviving intact except RHS molar row, with premolars missing; part of palatine is in place, but otherwise soil holding tooth row in place.	?
can't assess	no	Very fragmentary. Nothing survives posterior of palate and forward of maxilla. LHS has full tooth row, but P2 and P3 are fallen (modern breaks); RHS all teeth fallen. Only nasals and maxillae present, with nasals sunk under maxillae, left more so than right, where there's a 1 cm gap, indicating shifting forward of frontals (not present) over anterior part of skull and with that some asymmetry, probably with anterior skull broken from posterior and shifting right (from inference).	RHS M3

Appendix 6 *(continued)*

Skull/ Lot Number	Surface Weathering	Burning	Frontal Eminence Present	Occipital Condyle Present	Nasals Present	Dentition Present (Y = L+ R; L = Left; R = Right)	Breakage between Basal Tubercles and Palatine; Direction of Shift from Frontal Aspect	Thermally-Altered RocksEmbedded near Palatine
28	4 on basioccipitals; 3 elsewhere	none	no	no	no	LHS/RHS	yes; anterior shifted right	no
29	3	none	no	no	no	LHS/RHS	yes; anterior shifted left	no
30	3	none	yes	no	RHS present	LHS/RHS	not visible but probable (see comment)	no
31	3 and 4 in places	none	no	no	no	LHS/RHS (some missing)	yes; anterior shifted right	no
32	3	none	no	no	no	LHS (M2 missing); RHS (only M1, M2, M3 present)	yes, anterior shifted right	no.
33	3	none	no	no	yes, LHS/ RHS	LHS/RHS	not visible but likely (see comment)	no

Cut Marks on Wings of Palate	Cut Marks on Frontal/Nasals	Comments on Condition	Which Tooth Sampled for UCL
no	can't assess	This skull has more of the basioccipital region present than most and is in good condition, but back of frontals and top of occipitals are gone, so can't assess frontal eminence of sagittal profile. Occipitals are clear in this specimen, particularly ventral (underside). Posterior of skull broken from anterior on a slight angle, with a break showing on RHS palatine wing. Posterior skull has shifted forward. For example, zygomatics overhang maxillae and lacrimals by about 1 cm on each side.	LHS M3
no	can't assess	Full set of teeth on RHS. LHS has only P2 missing (maybe sampled?). Premaxilla is present but covered in soil. Basioccipital present but occipital condyles are not; can see foramen mangnum even though flattened off. Whole of occipitals seem shaved off vertically, so we see a cross section of the back of the skull, including shape of horncore bases as they leave the skull. Breakage between anterior and posterior of skull has led to shift forward of posterior skull at an angle; can see RHS maxilla and zygomatics, but they are buried deeply in deposit on LHS. This results in RHS frontal and orbit overhanging maxilla by about 4 cm (hiding lacrimals). The angle shift of the front of the skull seems to have "twisted off" the nasals.	LHS P2?
can't assess	no	Basioccipital present but only fragments of occipital; can see intercorneal ridge, and although sagittal profile is not complete, it can be estimated. Frontals have shifted over maxillae, leaving an overhang. Zygomatics are broken, probably due to this shifting. RHS nasal is present but ruckered at the suture with the frontals. RHS of skull more squashed than LHS. Can assess small part of horncore shape at base.	RHS M3
no	can't assess	Leaching on surface of bone; teeth have gritty deposit on occlusal surface. Parts of basioccipitals present but seemingly little else of the occipital area. Palatines and maxillae survive, but everything anterior of the maxillae (teeth ara) is broken. LHS tooth row is complete but P2 fallen; RHS: M3 presumably taken as sample. P4, M1, and M2 present. (P2, P3, P4 fallen but would have been there originally.)	RHS M3
Yes; small notches on wings of palate, not very clear/sharp.	can't assess	From occipital view, very little visible surviving. Posterior of skull shifted forward over anterior and large overhang must have been present because much soil fills the "overhang" (estimated shift of 2-3 cm). Zygomatics are present, shifted over RHS and LHS maxillae. Posterior to zygomatics, frontals have fragmented a lot, showing mainly the soil within the cranium; bone seems to have broken off.	not clear
can't assess	Yes; there are cut marks on the frontals, near their meeting point with the nasals and lacrimals. LHS: c5 very fine parallel cut marks, 1–-1.5 cm in length, with other light traces of similar cuts adjacent; RHS: 3 deeper also parallel cuts, about 1 cm in length. Both sets of cuts are distinct, separate from each other (although can't see if nasals also had cuts, since they are pushed beneath frontals). See figures 11.39, 11.40	Fair condition. Skull is present until midway along diasterma. RHS premaxilla is present but fragmented (modern breaks), indicating that it would have all been present originally. Posterior skull does not survive—nothing of occipitals/basioccipitals. Teeth all present (although LHS P2 fallen and RHS M3 sampled). Frontals (fused) have moved forward/anterior over nasals, lacrimals, and maxillae by about 3 cms, but don't appear to be "twisted" between anterior and posterior of the skull as some are. Nasals appear pushed together.	RHS M3

Appendix 6 *(continued)*

Skull/ Lot Number	Surface Weathering	Burning	Frontal Eminence Present	Occipital Condyle Present	Nasals Present	Dentition Present (Y = L+ R; L = Left; R = Right)	Breakage between Basal Tubercles and Palatine; Direction of Shift from Frontal Aspect	Thermally-Altered RocksEmbedded near Palatine
34	3	none	no	no	yes, LHS/ RHS	LHS/RHS (some fallen)	no	no
35	3	none	mandible; not skull					
36	3	none	yes	yes	yes, part of LHS	LHS/RHS	yes; anterior skull shifted right	no
37	3	none	no	no	yes, LHS and part of RHS	LHS (M2/M3 fallen); rest missing; RHS present	Yes; not clear which direction, since there isn't angle difference between anterior and posterior skull. Note in comments that palatine wing area is not broken. Therefore forward slumping still possible if palatine wings are intact.	no

Cut Marks on Wings of Palate	Cut Marks on Frontal/Nasals	Comments on Condition	Which Tooth Sampled for UCL
no	no	This skull has less leaching than some. There is no premaxilla; no occipitals present; all modern breaks. Tooth row LHS is complete; RHS M3 taken for sample(?), with only M1 and M2 remaining. Has a dental anomaly: LHS P3 rotated. No evidence of skull being at different angles between anterior and posterior, and little collapse forward is evident, except that zygomatics are pushed forward slightly (about 1 cm), especially on RHS but not on lacrimals or nasals.	RHS M3
		This is a mandible fragment, not a skull.	
no	no	Skull has complete occipital condyles (showing that even spongy bone preserves—maybe this skull was buried more deeply than most?) and enough of the occipitals that we can see the base of the horncores (but no horncore circumference) and to the sagittal profile. RHS teeth complete but whole tooth row fallen. Occipitals very fragmented. Anterior part of skull gone; even maxillae fragmented. Anterior and posterior parts of skull broken apart at different angles, with anterior shifted right and more buckled up. There is some shift of frontals forward, but they don't overhang much. Frontals are generally well preserved.	LHS M3
Yes; series of five small cuts, 3-4 mm long, sharp, as if made with a stone tool, and in parallel lines, on RHS basioccipital area, lateral side of palatine wings. Function? Are these for tongue removal? Separation of mandible from skull? Decapitation would not leave marks here. These cuts are noted as "notches" as if something cut on them—supporting the idea of tongue removal?	no	Teeth: LHS has complete row, P2–M3; RHS M2, M3 fallen and rest missing (maybe one was sampled?). Good length of skull but very little survives around occipitals. Can see into cranial cavity. RHS maxilla badly broken. Part of frontal may have adhered to Skull 36 adjacent, since that had extra frontal fragments stuck to occipital condyle area. This skull is unusual in that palatine wings are not broken, but there is still forward movement of frontals over nasals and lacrimals by 3–4 cm.	?

Appendix 6 *(continued)*

Skull/ Lot Number	Surface Weathering	Burning	Frontal Eminence Present	Occipital Condyle Present	Nasals Present	Dentition Present (Y = L+ R; L = Left; R = Right)	Breakage between Basal Tubercles and Palatine; Direction of Shift from Frontal Aspect	Thermally-Altered RocksEmbedded near Palatine
38	3	none	no	no	no	yes, LHS/RHS	can't assess	no
39	3	none	no	no	yes, LHS	yes, LHS/RHS	no	no
40	3	none	no	no	yes, LHS/ RHS	RHS alveoli only	can't assess	can't assess
41	3	none	no	no	no	yes, LHS/RHS	yes; can't tell angle of shift	no
42	3	none	no	no	yes	LHS/RHS (LHS has P2/ P3 missing)	can't assess	can't assess

Cut Marks on Wings of Palate	Cut Marks on Frontal/Nasals	Comments on Condition	Which Tooth Sampled for UCL
no	can’t assess	Present from basioccipital to palate/maxilla, just at point of diastema. All teeth present except RHS P2 (maybe taken for sample?); P3 fallen but present. Otherwise, dentition in good condition, although encrusted with grit. Bone has leaching on surface. Note: strange post-palate-area asymmetry (morphological, not relating to breakage) and rotation of P4 on both LHS and RHS.	P2 RHS?
no	no	Whole length of skull present (roughly), but premaxillae are broken off and whole posterior skull area very fragmentary. So basioccipital present but occipitals crumbled away. No horncores. Teeth in excellent condition—RHS M3 removed for sample. That posterior skull is much more fragmentary indicates that it was exposed, whereas the anterior is not. Bone surface pitted; doesn’t seem to be root etching but there is leaching. Frontals overlap nasals through slippage, and nasals are pushed back into frontals, but frontals, zygomatic, and lacrimals are “flush,” not collapsed on an angle. Field/lab observation: this skull seems narrow; tooth rows appear closer together than on some skulls; teeth themselves more gracile. Curiously, metrical analysis doesn’t match this observation. It is interesting that this is noted as the “longest” skull and is in the center of the circle.	RHS M3
can’t assess	not on nasals; can’t assess frontals	Highly fragmentary. Only maxilla parts survive; both LHS and RHS and parts of palatines. RHS maxilla has some alveoli, seemingly of P4, M1, and M2, but no dentition. There is nothing surviving posterior of the maxillae. Surface shows erosion that may be root etching or normal exposure weathering.	none?
no	no	Condition fairly good (has evidence of field conservation). From occipital to diastema present, although very fragmented around posterior end of skull. No horncores but there are hints of horncore direction; can’t take skull profile. Has full sets of teeth, except RHS M3 was taken for sample, and LHS P2 seems to have been absent in life. Frontals are in place but have shifted anterior over the lacrimals/maxillae, and probably this movement broke the zygomatics. Hence the orbits seem too far forward and there is an “overreach” between the frontals and maxilla. This movement probably pushed off the nasals, which are missing.	M3 RHS
can’t assess	no	Mainly tooth rows and maxillae held together. Nasals are fallen and fragmented but present. Nothing survives anterior of the palate/maxilla and some fragments of premaxilla. There are also some fragments of the posterior part of the skull but no clear bone surfaces. Tooth rows in good condition (complete, except for LHS P2 and P3 are missing—maybe one taken as sample?). Lots of small fragments collected; probably represent broken skull.	LHS P2/ P3?