Early North African Cattle Domestication and Its Ecological Setting: A Reassessment

Michael Brass[1]

Abstract Nearly four decades have passed since an independent North African centre for cattle domestication was first proposed in 1980, based on the Combined Prehistoric Expedition's work in the Nabta Playa—Bir Kiseiba region of southern Egypt, and the initial rigorous debates between Andrew B. Smith and Fred Wendorf, Romuald Schild and Achilles Gautier. More recently, geneticists have entered the fray with determinations on the spread of haplotypes, and the timing thereof, that extend the scope and increase the complexity of the debate. Here, a new look at the botanical data and a re-analysis of the geology of Bir Kiseiba–Nabta Playa rejects the ecological foundations of the early African domestication model, while a detailed examination of the published osteological and radiometric data from the same area reveals a more nuanced picture than has been recognised to date. These results are placed into context by a wider review of the genetic and other archaeological evidence from the Western Desert of Northeast Africa, where no other cattle remains designated as domesticated have been found. It is concluded that (a) *Bos* remains from the early Holocene at Nabta Playa—Bir Kiseiba were those of hunted aurochs; (b) domesticated caprines were likely present in Northeast Africa before domesticated cattle; and (c) the domesticated cattle spreading across Northeast and northern Africa, including Nabta Playa—Bir Kiseiba, from the late seventh millennium BC or early sixth millennium BC onwards were descendants of *Bos taurus* domesticated in the Middle Euphrates area of the Middle East.

Keywords North Africa · Origins of pastoralism · Cattle · Holocene · Ovicaprids

✉ Michael Brass
michael.brass@ucl.ac.uk

1 Institute of Archaeology, University College London, 31–34 Gordon Square, London WC1H 0PY, UK

🖉 Springer

Introduction

This paper presents a reassessment of the botanical, faunal and geomorphological data from Nabta Playa—Bir Kiseiba to determine whether or not an early Holocene timeframe for cattle domestication, as proposed by the Combined Prehistoric Expedition (Gautier 1987; Wendorf et al. 1984, 2001; Wendorf and Schild 1980, 1994), remains a plausible explanatory model. It begins with a summary of the arguments by the main scholars involved in the debate, to provide context, and an outline of the data brought to bear so far. In a paper in *African Archaeological Review*, addressing early cattle domestication, Stock and Gifford-Gonzalez (2013) agreed the DNA evidence favoured a Near Eastern origin for domestic cattle but, critically, they did not re-examine the geological and botanical data from Nabta Playa—Bir Kiseiba. Nor did their paper, or the Combined Prehistoric Expedition's faunal reports (Gautier 1984, 2001), look at the stratigraphical distribution of the cattle bones from the area and their associated radiocarbon dates. I turn to the original geological report (Issawi and el Hinnawi 1984) to argue that more water was present on the surface during the early Holocene than acknowledged in the early cattle domestication model, and draw upon additional geological reports (Haynes and Haas 1980; Haynes 2001), which have been little cited in the debate, in support. I also draw upon comparisons with other archaeological and modern semi-arid regions to refute the claim that the ecology of the Nabta Playa—Bir Kiseiba area during the early Holocene was capable of supporting only small game animals and gazelle, which is the underpinning of the early cattle domestication model (Gautier 2001; Wendorf et al. 1984; Wendorf and Schild 1994).

The re-assessment also encompasses the middle Holocene of Nabta Playa. Wasylikowa's (2001) botanical study of the middle Holocene botanical remains did not list the water requirements of all the families and genera of plants, which is done here. Nabta Playa's faunal materials are also examined and evaluated. The radiocarbon distribution dates for the cattle remains are made explicit for the first time: using Gautier's (2001) own measurements and distinction between morphologically domesticated and wild cattle, combined with the data from Smith's (1984) and Grigson's (2000) papers, the available data shows a later appearance for domesticated cattle at Nabta Playa—Bir Kiseiba than had previously been assumed.

The results are then integrated into a review of the genetic and archaeological data from elsewhere in the Eastern Sahara, the current patterns in the study of domestication from the Near East and spread of domestic cattle and caprines in the Arabian peninsula. It is concluded that the first archaeological visibility of domesticated cattle derives from the mid sixth millennium BC onwards and that the most plausible explanation is that they originated from a founding population in the Near East, although the possibility of limited genetic introgression from African aurochs (*Bos primigenius*) is not ruled out.

Summary of the Main Arguments to Date for and Against an Early North African Centre of Domestication

The neighbouring archaeological sites of Nabta Playa and Bir Kiseiba (Fig. 1) are situated c. 100 km west of Abu Simbel (Nile Valley). The latest published faunal lists by Gautier (2001) assign 22 *Bos* (cattle) bones to the first occupational phase, the El Adam Humid Interphase (Table 1), and two to the subsequent El Ghorab Humid Interphase (Table 1). While fragmentary cattle remains dating to the early Holocene have been found in subsequent excavation seasons (Jórdeczka et al. 2013), no quantitative figures or detailed analyses have been published.

The Combined Prehistoric Expedition argued and continues to argue (Jórdeczka et al. 2011, 2013) for the remains to be assigned domesticated status (*Bos taurus*), on the basis that the reconstructed ecological conditions were inadequate for aurochs to have been supported without human intervention and control. It was this argument, and the presence of early pottery, which led them to designate these earliest occupation layers 'Neolithic' (see Smith 1992, 2005, 2013 for a critique of the history and terminology). Their independent African domestication model hypothesised that these early Holocene cattle were brought from the Nile Valley, where there was adequate pasture and water, when the rains returned to the desert (Wendorf and Schild 1994).

The independent African domestication model has been extensively debated since 1980 (Brass 2007, 2013; Clutton-Brock 1993, Di Lernia 1999, 2004, 2013; Gautier 1984; 2001; Marshall and Hildebrand 2002; Riemer 2007; Smith 1984, 1986; Stock and Gifford-Gonzalez 2013; Wendorf and Schild 1994; Wendorf et al. 1984, 2001). The arguments have traditionally revolved around the criteria for determining domesticated status. Di Lernia and Smith have also underlined
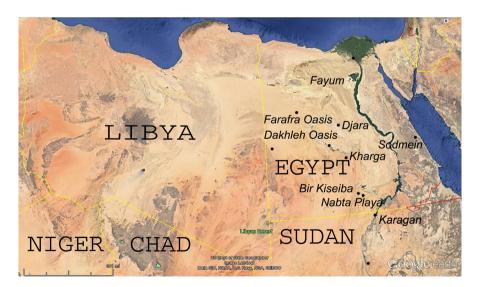

Fig. 1 Map of Northeast Africa showing the location of the major sites mentioned in the text

Table 1 Approximate BC ranges for the different Nabta Playa—Bir Kiseiba phases calibrated using OxCal 4.2 (IntCal13) from bp dates in Wendorf et al. (2001)

Phase	Uncalibrated bp	Calibrated BC
El Adam Humid Interphase	9500–8700	8800–7700
Post-El Adam Arid Phase	8700–8600	7700–7600
El Ghorab Humid Interphase	8600–8200	7600–7100
Post-El Ghorab Arid Phase	8200–8100	7100–7060
El Nabta/Al Jerar Maximum	8100–7300	7060–6200
Post-Al Jerar Arid Phase	7300–7200	6200–6050
Ru'at El Ghanam Middle Neolithic	7200–6600	6050–5550
Post-Ru'at El Ghanam Arid Phase	6600–6500	5550–5480
Ru'at El Baqar Late Neolithic Humid Interphase	6500–5850	5480–4700
Post-Ru'at El Baqar Arid Phase	5850–5700	4700–4500
Bunat El Ansam Final Neolithic Humid Interphase	5700–4500	4500–3200
Modern phase of hyper-aridity	4500–present	3200–present

anthropological and terminological problems, while Usai (1997, 2005) has questioned the stratigraphic relationship between the few fragmentary early Bos remains and the radiocarbon-dated samples assigning them to the early Holocene.

Smith (1986, 1992, 2005, 2013) countered that an environment capable of supporting gazelles (*Gazella dama*, *Gazella dorcas*) and hares (*Lepus capensis*) would have provided enough vegetation cover for addax (*Addax nasomaculatus*), elephants (*Loxodonta Africana*), oryx (*Oryx dammah*) and rhino (*Diceros bicornis*, *Ceratotherium simum*), which can survive in dry climates. He also queried the absence of Bubal hartebeest (*Alcelaphus buselaphus*) amongst the Nabta Playa—Bir Kiseiba faunal remains when *Bos primigenius* and hartebeest are found together at Palaeolithic sites in the Nile Valley, where they co-inhabited similar ecological environments. Pasture and bodies of water adequate to support domestic cattle, gazelles and hares would also have been sufficient for larger semi-arid adapted animals such as oryx, addax, giraffe (*Giraffa camelopardalis*) and ostrich (*Struthio camelus*), which are amongst the animals present for parts of the year in the semi-arid Wadi Howar in northern Sudan. Elephants are present in parts of the Namib desert. Hartebeest occur in a variety of ecologies, including semi-arid environments (Capellini and Gosling 2007). With no ecological zone known today containing only hares and gazelles, Smith contends that the faunal records at Nabta Playa are fragmentary and incomplete, but they could also simply reflect deliberate social choices. A well-known example of the latter is the early Holocene fauna from the Acacus Mountains where Barbary sheep (*Ammotragus lervia*) predominated (Di Lernia 2001).

Smith (1984) undertook an inter-regional comparative analysis of African and European wild and domestic *Bos* using the standard animal method, namely in this instance the metapodial distal width, and the distal width of the humeri. The results placed the cattle remains from the El Nabta/Al Jerar Maximum site of E-77-1 within

the known size range for *Bos primigenius*. The subsequent Ru'at El Ghanam Middle Neolithic remains are ascribed by him to domesticated cattle. Consequently, Smith (1986, 1992, 2005, 2013) proposed an alternative model which claimed that domesticated cattle, sheep (*Ovis ammon* f. aries) and goats (*Capra aegagrus* f. hircus) arrived from the Near East shortly before 6000 BC, in the late seventh millennium BC. In support, he also argued that indigenous, independent domestication of cattle in Northeast Africa would have entailed a radical shift in how animals are viewed and exploited amongst hunter-forager societies lacking a concept of human ownership of animals. Although there was management of Barbary sheep during the Late Acacus period (c. 8100–6300 BC) of the central Sahara, which may be construed as a form of ownership and a change from the way animals were viewed prior to the introduction of Near Eastern domesticates into North Africa, Smith (2013, p. 16) counters that this was 'probably as a result of long-standing predation strategies', and states that:

> We must ask why these strategies did not continue towards domestication, as seen in the goats from Iran? Was it because domestic animals came in from the outside, making Barbary sheep irrelevant in the equation? Or was it because a lack of the sedentary stage around fixed resources, such as domesticated plants, did not result in the animal resources coming under pressure by increasing human numbers, requiring greater manipulation of the herds? (Smith 2013, p. 16)

Consequently, he believes that this ideological shift towards private ownership with socially hierarchical communities occurred after Northeastern African hunter-collectors came into contact with trickles of immigrants from the Near East familiar with handling domesticates, resembling the way domestic stock were introduced into southern Africa (Smith 2016).

In an attempt to shed new light on this debate, Caroline Grigson (2000) re-examined the *Bos* remains from Nabta Playa—Bir Kiseiba. She compared the results with her measurements on wild and domesticated cattle fossil remains from the Nile Valley, and concluded that the Nabta Playa—Bir Kiseiba cattle fell within the range of *Bos primigenius*. However, her study has been criticized for failing to account for the possibility of size variability in *Bos primigenius* populations between her European, Levantine and Haua Fteah (North Africa) samples and their wild counterparts in the Nile Valley (MacDonald 2000, p. 5).

Additional criticism has been levelled at the employment of linguistic and mtDNA data in support of the early domestication model by Wendorf and Schild (1994). The methodological basis of Christopher Ehret's (1993) linguistic reconstruction has been criticised in general by Kevin MacDonald (1998) and, in specific regard to early *Bos*, by the current author:

> Ehret has bracketed a period around 8000 BC for Proto-Northern Sudanic (part of the Nilo-Saharan language family), which includes words indicative of the exploitation of Bos. But such an analysis is risky as most linguistic roots describing wild or domestic Bos are neutral and the same words that later were

applied to domesticated *Bos* may well have been originally applied to their wild ancestors. (Brass 2003, p. 104)

The mtDNA originally analysed by Bradley et al. (1996) was claimed to reveal a late Pleistocene divergence between African and European *Bos primigenius*, supporting the hypothesis that African *Bos primigenius* were the primary source for the early Saharan domesticated cattle. Despite its subsequent incorporation by Wendorf and Schild (1998) into their early domestication model, the study did not shed light on the timing or the mechanisms involved in the domestication process.

In conjunction with recent reviews of genetic data suggestive of introgression of Y-chromosomal data from African *Bos primigenius* into African *Bos taurus* descended from Near Eastern stock (Achilli et al. 2010; Bonfiglio et al. 2012; Olivieri et al. 2015; Perez-Pardal et al. 2010; Stock and Gifford-Gonzalez 2013), a re-examination of the archaeobotanical, faunal and geomorphological data from the early and middle Holocene periods in the Nabta Playa—Bir Kiseiba region is appropriate in order to determine whether the ecological underpinnings of the early African independent domestication model are valid.

Early Holocene Ecological Shifts in the Nabta Playa—Bir Kiseiba Region

The Nabta Playa—Bir Kiseiba area is located within two different present-day rainfall zones of influence: the winter Mediterranean rainfall zone and the summer rainfall Inter-Tropical Convergence Zone (ITCZ) (Fig. 2a, b). With the onset of what Haynes (2001, p. 121) termed the 'Neolithic pluvial' or what others have called the African Humid Period or 'Holocene optimum' (Kuper and Kröpelin 2006), the ecology underwent a change from hyper-arid to semi-arid conditions (Brooks 2005). The ITCZ belt shifted c. 250 km northwards in the second half of the tenth millennium BC (Haynes 2001); eventually, the isohyets shifted northwards by 400–550 km (Nicoll 2004; Ritchie and Haynes 1987; Wickens 1982, p. 25). By c. 8500 BC, the Sahelian semi-desert zone had advanced up to the 24°N latitude (Kuper and Kröpelin 2006), while Neumann (1989) states that summer rainfall occurred from the 22° latitude southwards. This was the start of the El Adam period at Nabta Playa (22°31′59″N), which was then on the new northern margin of the summer rainfall Sahelian belt. More broadly across the Sahara, fluvial networks developed which supported standing bodies of water (Drake et al. 2011; Hély et al. 2014), with temporal lags between increased rainfall and human re-occupation of the desert related to local geomorphological and hydrogeologic factors (Nicoll 2001).

Deflated depressions became playas. Their water came from local recharging of the water tables, which caused them to rise above the new depressed ground level (Haynes 2001), or were sheetwash lying on top of the water table a couple of metres below ground level. Nabta Playa and, in particular, Bir Kiseiba, are examples of the former (Issawi and el Hinnawi 1984), and their water varied in intensity and volume affecting the extent of available vegetation cover. At Nabta Playa, the lower portion of the basin formed a large seasonal lake where 'surface water would last for several weeks or months after the seasonal rains' (Wendorf et al. 2001, p. 1).

Fig. 2 Modern landscape views at Nabta Playa **a** from E-75-6 and **b** valley of the stelae. Copyright Giulio Lucarini, reproduced with permission

Remnants of the ancient shore lines have been found at El Gebel El Beid Playa to the Northeast of Nabta Playa, the Kiseiba escarpment and other playa basins: 'The formation of some of the Bir Kiseiba playas can probably be related to the truncation of the land surface by deflation almost to the level of the water-

table during the Early Neolithic' (Haynes 2001, Issawi and el Hinnawi 1984, p. 41). In a little-referenced but important article, Haynes and Haas state that:

> … remnants of beach deposits along the scarp indicate that some of these basins may have coalesced into larger lakes in early Holocene time sometime near 9000 BP [c. 8250 BC]. Playa mulls intermixed with aeolian sand make up the floor and in places, as at Nabta playa, are underlain by Pleistocene dunes believed to be overlying bedrock shale. Thus, with the onset of pluvial conditions, rainwater saturated the dunes and collected on the clay floor as sediments washed into the basin. With the return of arid conditions, the surface water evaporated and the lacustrine deposits suffered deflation until limited by the shallow ground water. Subsequent return to pluvial conditions would, via dune windows in the wind-scoured floor of the playa, recharge the local water table until a new lake had formed. (Haynes and Haas 1980, p. 712)

An annual precipitation of c. 100 mm would have been sufficient to have this effect (Haynes and Haas 1980), which challenges the notion that insufficient water was available to support more than small game animals. Today, acacia semi-desert scrub predominates on sand between the present-day 50 and 250 mm isohyets in the Sudan (Halwagy 1961). A dense cover of grasses and herbs grows after the first consequential rains (July) and is complete at the end of the season (September). *Panicum turgidum* dominates the grasses and is particularly prevalent in the lower rainfall zones on sandy dunes which it stabilises (Wickens 1982, p. 35). The Bayuda Desert, which is presently situated at the 100 mm isohyet that moved northwards to the vicinity of Nabta Playa, is dominated by acacia. The brief seasonal showers provide forage particularly along wadis for Bayuda pastoralists' light herds consisting mainly of sheep and goats and limited numbers of cattle. A little further north, acacia scrub is present in southwestern Wadi Halfa, while *Acacia*, *Capparis decidua* and *Tamarix* depend on groundwater in the interconnected Laqiya Valley, Wadi Shaw and Wadi Sahal, which received an annual rainfall of 5–10 mm (Neumann 1989). The presence of multiple plant species within modern-day semi-desert environments leaves open a possibility that the early archaeobotanical record from the Nabta Playa—Bir Kiseiba region may have been influenced by deliberate human selective activities.

At Nabta Playa, signs of huts and remnants of hearths and numerous lithics were recently located on a phytogenic dune at Site E-06-1 and dated to as early as c. 8400 BC (Jórdeczka et al. 2013). Despite the onset of more humid conditions, the El Adam and subsequent El Ghorab phases still saw some eolian sand and phytogenic dune activity (Wendorf et al. 1984, 2001). E-06-1 and E-77-7 (at the neighbouring El Gebal El Beid Playa, radiocarbon-dated to 8424–7735 BC) are the two El Adam period sites that have yielded viable botanical samples. At E-06-1, the samples are from different plants with overlapping rainfall tolerances: *Tamarix* (75–500 mm); *Citrullus colocynthis* (perennial desert gourd which tolerates 250–1500 mm and irregular precipitation due to its long roots which can tap underground reserves of water); *Echinochloa colona* (400–1000 mm); and *Poaceae* grass (Jórdeczka et al. 2013). The nearby site of E-77-7 yielded 625 charcoal samples in which *Tamarix* was the only identified plant, which may potentially indicate that it was a preferred

source of wood (if *Tamarix nilotica*), but it can also grow in monotype stands if the water table is no less than 8 m below the surface. *Leguminosae* (50–1800 mm) and *Panicum turgidum* (200–250 mm) seeds were also found. In addition, El Hadidi (1980) identified *Salsola baryosma*, *Phragmites australis* (an aquatic or subaquatic reed) and fibrous grass roots in the Lower Level at E-77-7.

Acacia and other tree or large bush species are not present in the very limited floral remains from E-06-1. Sahelian flora though is present in early Holocene levels to the south in northern Sudan at El Atrun, Oyo and Selima (Haynes et al. 1989), which may indicate an incomplete botanical record from the El Adam phase at Nabta Playa. *Acacia* and *Tamarisk* are both able to survive in (semi-) arid conditions. Although there are modern oases in southwestern Egypt with only *Tamarix*, *Acacia–Panicum* and *Tamarix–Stipagrostis* were present along with denser herbaceous vegetation in wadis from the Acacus mountains during the middle Holocene of the Central Sahara (Cremaschi et al. 2014; Mercuri 2008; Wasylikowa and van der Veen 2004, p. 216). The *tamarix* monotypic stands in the oases are dependent on groundwater. This argument, combined with the presence of *Phragmites australis* at E-77-7 and geomorphological data from the Bir Kiseiba playas has implications not only for reconstruction of the early Holocene environment but also for the availability of water and vegetation at certain times of the year to support both humans and semi-arid adapted antelopes with similar or lesser water needs. For the early independent African domestication model, the absence of hartebeest remains is particularly puzzling. Hartebeest are grazers surviving on grasses and legumes who inhabit dry savannahs, semi-arid grassland and wooded grasslands (Capellini and Gosling 2007). In areas with water scarcity, they derive moisture from melons, tubers and roots for days or months. In other words, based on water resources and the availability of adequate pasture, hartebeest, which co-existed with aurochs in the Nile Valley, and other bovids such as oryx could have survived in the same ecological environment as the hypothetically domesticated *Bos* in the early cattle domestication model, although their remains (bar possible oryx in the wetter Ru'at El Ghanam Middle Neolithic) are not present in the recovered faunal assemblages.

The question of seasonal migration by the early occupants of the Nabta Playa—Bir Kiseiba area has most recently been addressed by Donatella Usai (2005, 2008). Usai (2008) has proposed seasonal movement between Nabta Playa—Bir Kiseiba and the Second Cataract region of the Nile Valley. She points out the technological similarities between the El Ghorab and El Nabta industries and the Shamarkian group, and that the site of 11-I-13 in Wadi Karagan (Nile Valley) is strikingly similar to the El Ghorab. There are no domesticated cattle remains at Wadi Karagan. Despite the claim by Wendorf and Schild (2001) that there is no El Nabta/Al Jerar-like complex in the Nile Valley, Usai (2005) suggests that sites 626 and 628 to the west of the Nile were intermediary camps for hunter-forager peoples moving out of the Nile Valley during flood season, before they moved into the desert after the summer rains in an integrated cultural and ecological system. Based on these combined re-analyses, there is no ecological or Nile Valley archaeological evidence for the early Holocene inhabitants of Bir Kiseiba—Nabta Playa having incorporated habitually domesticated cattle into their socio-economy.

The El Nabta/Al Jerar Maximum and the Ecology of Nabta Playa

The Afro-Asian monsoon grew stronger around the beginning of the El Nabta/Al Jerar Maximum. This resulted in an increase in the ground and surface water in the southern Western Desert (Nicoll 1998, 2004). Maximum lacustrine conditions were reached more broadly across the Sahara up to 25°N at c. 6500 BC (Hély et al. 2014).

Botanical samples from this period are available from eight sites (Table 2): seven from Nabta Playa and one (E-77-7) from El Gebel El Beid Playa. At E-77-7, *Acacia ehrenbergiana*, *Hyphaene thebaica*, *Medicago* sp., *Salsola baryostna*, *Tamarix* sp. and fibrous grass roots were recovered from the Middle Layer (ascribed to the El Nabta phase) (El Hadidi 1980). The Nabta Playa site E-75-6 yielded fruit and seed remains, together with wood charcoal, in greater quantity than at any of the other sites (Table 3): c. 460 samples, including 371 bulk soil samples, collected in the 1990–1992 seasons, of which c. 439 were analysed. The site is described as

Table 2 Select ^{14}C dates for the Nabta Playa and El Gebal El Beid Playa (E-77-7) sites which have had botanical remains analysed. No ^{14}C dates are available for sites E-94-1 and E-94-2. Derived from Wendorf, Schild and Associates (2001, Table 3.1)

Site	Uncalibrated bp	Calibrated BC	Period	Lab number
E-77-7	8875 ± 75	8246–7755	El Adam	ETH-8583
E-75-6	9360 ± 70	8808–8350	El Adam	SMU-200
E-75-6	8290 ± 80	7521–7084	El Ghorab	SMU-257
E-75-6	8260 ± 100	7516–7069	El Nabta	Gd-6260
E-75-6	8130 ± 60	7338–6848		SMU-255
E-75-6	8120 ± 100	7452–6714		SMU-199
E-75-6	8080 ± 90	7321–6701		SMU-252
E-75-6	7970 ± 70	7061–6661		SMU-240
E-75-6	7910 ± 110	7073–6509		Gd-6500
E-75-6	7610 ± 120	6742–6219	Al Jerar	Gd-6507
E-75-6	7480 ± 110	6561–6081		Gd-6509
E-91-1	8180 ± 100	7496–6833	El Nabta	Gd-12186
	7740 ± 115	7027–6399	Al Jerar	DRI-3526
	7700 ± 170	7040–6243	Al Jerar	DRI-3599
	7536 ± 110	6631–6113	Al Jerar	SMU-2738
E-75-8	7120 ± 150	6352–5715	Ru'at El Ghanam Middle Neolithic	SMU-242
	6570 ± 70	5632–5379		SMU-452
E-92-7	7760 ± 240	7321–6108	Al Jerar	Gd-9307
	7250 ± 110	6381–5913	Al Jerar	Gd-10112
	7040 ± 80	6050–5748	Al Jerar	Gd-10112
E-94-1	NOT IN ^{14}C TABLE			
E-94-2	NOT IN ^{14}C TABLE			
E-94-3	6550 ± 60	5621–5379	Ru'at El Baqar Late Neolithic	CAMS-16590
	5970 ± 90	5205–4614		DRI-2827

Table 3 List of botanical species from Site E-75-6 with their associated rainfall tolerance intervals. Derived from Wasylikowa (2001)

Archaeobotanical remains	Modern environment	Range of annual rainfall
Abutilon type	Genus includes perennial herbs, shrubs and trees, often but not always hardy. Scrubland. High drought tolerance	150–650 mm
Acacia sp.	Wooded grassland on sandy soils	50–2200 mm
Acacia ehrenbergiana	Tall shrub or small tree, one of the most drought-resistant of the genus	50–400 mm
Acacia nilotica	Tall shrub or tree in well-drained seasonally flooded and riverine habitats	300–2200 mm
Acacia tortilis	Tall shrub or tree. Drought-resistant and tolerant of seasonal waterlogging, it grows in sand dunes and other well-drained soils such as sandy loam and rocky soils	75–700 mm, optimal 300–700 mm
Alisnui type	Water plant along shores which survives seasonal inundation	
Arnebia hispidissima	Large plant growing in wind-blown sandy, dry or stony conditions. Persists between growing seasons	100–350 mm
Astragalus type	Annual scrubland herb, along forest margins and water sources	
cf. *Astragalus vogelii*	Annual scrubland herb in very dry conditions along water sources	
Boerhavia sp.	Desert herb growing in rocky or sandy spots near water sources	20–50 mm of rainfall to germinate
Capparis sp.	Shrubs or lianas	300–500 mm
Capparis decidua	Tall shrub or low tree, drought-resistant and widely distributed in arid and semi-arid conditions in shallow soils or on stabilised sand dunes	100–750 mm
Compositae A type	Herbaceous. Common in open and dry ecologies	25–500 mm
Compositae B type	Common in open and dry ecologies	25–500 mm
Compositae C type	Common in open and dry ecologies	25–500 mm
Coronilla scorpioides	Annual herb. Light sandy, well-drained soils. Prefers moist soils	25–500 mm
Cucurbitaceae indet.	Gourd family, species unknown	
Cyperaceae A type	Sedge. Wet ecologies, including lakeshores	
Cyperaceae B type	Sedge. Wet ecologies, including lakeshores	
Cyperaceae C type	Sedge. Wet ecologies, including lakeshores	
Cyperaceae D type	Sedge. Wet ecologies, including lakeshores	
Cyperaceae E type	Sedge. Wet ecologies, including lakeshores	

Table 3 continued

Archaeobotanical remains	Modern environment	Range of annual rainfall
Cyperaceae F type	Sedge. Wet ecologies, including lakeshores	
Cyperaceae NP-21 type	Sedge. Wet ecologies, including lakeshores	
Cyperus cf. *rotundus*	Perennial tuber. Wet ecologies, including shores, wet salt marshes and reed swamps	
Digitaria type	Very drought-tolerant annual grasses. Requires less moisture than rhizomes and tubers due to presence on higher-lying sandy soils	300–1300 mm
Echinochloa colona	Wild ancestor of sawa millet (*E. frumentacea*). Requires less moisture than rhizomes and tubers due to presence on higher-lying sandy soils	400–1000 mm
Fuirena type	Sedge. Moist soils and swamp-like conditions	
Gramineae indet.	Grasses. Around permanent and semi-permanent ponds	
Grewia sp.	Highly drought-resistant shrub in semi-desert scrub at desert margins	100–600 mm
Heliotropium sp.	Perennial herbaceous. Dry or arid areas	100–300 mm
Hyoscyamus cf. *muticus*	Perennial herb. Favours sandy soil, though found in gravelly sand, sandy limestone and loam, and sandy clay	100–400 mm
Hyphaene thebaica	Palm tree. Requires groundwater. In riverine areas, wadis and oases	50–600 mm
Indigofera type	Mostly shrubs but some small trees and annual or perennial herbs. Not particular about soil type	400–1800 mm
Labiatae/ Boraginaceae type	Herb (or also shrubs or trees if Boraginaceae). Moist soils	180–3000 mm
Leguminosae indet.	Family includes *Astralagus*, *Acacia* and *Indigofera* genera	50–1800 mm
Leguminosae NP-9 type	Species could not be identified	
Leguminosae NP-13 type	Species could not be identified	
Leguminosae NP-19 type	Species could not be identified	
Leguminosae NP-24 type	Species could not be identified	
Leguminosae NP-30 type	Species could not be identified	
Maerua crassifolia	Small tree. Sandy soils in dry savannah and semi-desert scrubland	75–700 mm, optimal 300–700 mm
Medicago sp.	Annual or perennial legumes, rarely shrubs. Moist, sandy soils	300–400 mm
Nymphaea sp.	Aquatic. Body of water	

Table 3 continued

Archaeobotanical remains	Modern environment	Range of annual rainfall
Paniceae A type	Grasses. Drought- and salt-tolerant. Deserts and semi-deserts, dunes and rock outcrops with sandy sections	200–250 mm
Paniceae B type	Grasses. Drought- and salt-tolerant. Deserts and semi-deserts, dunes and rock outcrops with sandy sections	200–250 mm
Paniceae indet.	Grasses. Drought- and salt-tolerant. Deserts and semi-deserts, dunes and rock outcrops with sandy sections	200–250 mm
Panicum turgidum	Perennial bunchgrass bush. Drought- and salt-tolerant. Deserts and semi-deserts, dunes and rock outcrops with sandy sections	200–250 mm
Phragmites australis	Reed. Aquatic or subaquatic	
Pteridophyta indet.	Still used to informally refer to ferns	
Rumex sp.	Annual, biennial and perennial herbs. Dry or moist, well-drained sandy or loamy soils or in rocky areas catching water run-off	50–200 mm
Salsola baryosma	Shrub. Dry wadis and disturbed areas	20–500 mm
Salvadora persica	Evergreen shrub or tree. Requires readily available groundwater: around waterholes, seasonally wet areas, drainage lines in arid conditions or river banks	
Salvia/Stachys type	Includes annuals, herbaceous perennials and shrubs	
Schouwia purpurea	Annual herb. Desert plains and water catchments (e.g. in wadis)	
Scirpus sp.	Aquatic grass-like species	
Scirpus maritimus	Perennial aquatic species. Found in wetland areas	
Senna alexandrina	Drought-resistant. Herb. Semi-desert scrub and grassland	50–500 mm
Setaria type	Hardy grasses	300–400 mm
Sida sp.	Annual or perennial herbaceous species. Semi-arid	100–700 mm
Solanum cf. *nigrum*	Annual herbaceous plant or small shrub. Temperate, sub-tropical, tropical and semi-arid environments	500–1200 mm
Sorghum bicolor	Semi-arid	300–800 mm
Tamarix sp.	Deciduous shrubs or trees with long roots to tap underground water reserves up to 8 m. Semi-arid, riparian and oasis environments	75–500 mm
Trifolieae tribe	Legumes, annual	100–1200 mm
Typha sp.	Perennial freshwater aquatic herb	
Urochloa sp.	Annual or perennial grasses. Waterholes, swamps, semi-arid, savannah and shady forests	300–600 mm
Ziziphus sp.	Spiny shrubs and small trees. Semi-arid to subtropical	100–500 mm

composed of three levels (Wasylikowa 2001, p. 544): Upper, Middle and Lower. The single charcoal date of 9360 ± 70 bp from the Lower Level falls within the defined El Adam cultural entity and is listed by Wendorf and Schild (2001, Table 3.1) as 'entity questionable'. However, the first study of plant remains (El Hadidi 1980) lists three types deriving from the Lower Level (El Adam phase). The majority of the plant remains derive from the Middle Level (El Nabta), while the remainder are from the Upper Level (Al Jerar). The site consists of the remnants of huts and pits covered by clays and silts. The remains were recovered both from three pits and from four hut floors where they were likely charred in or near hearths.

In total, 15 families with 65 taxa were identified from E-75-6, of which grasses, legumes and sedges predominated. Wasylikowa (2001, p. 548) measured the abundance, density and frequency of occurrence of the seeds to determine their significance in reconstructing the ecology and potential use by the inhabitants. Human selective action was strong. Economic requirements (food and fuel) appear to have been the dominant reason for the presence of most of the specimens, while medicinal purposes and accidental inclusion from dung and hut construction cannot be ruled out. Many of the sedge species, although edible, grow in wet conditions and could be taken as reflective of local ecology. More broadly, however, as Wasylikowa (2001, p. 549) noted, 'The numerical relations between diaspores of different species do not correspond to those between species in the [wider landscape's flora]. Any reconstruction of the former vegetation and paleoecological conditions is, therefore, strongly restricted by the origin of the material.' It appears though to broadly reflect the diverse ecological conditions of adequate bodies of freshwater, grasses stabilising dunes, plenty of moisture, scrubland and aquatic species bordering shores that rose and fell with seasonal rains averaging 200 mm.

This phase saw the appearance of plant storage pits (Wendorf et al. 2001, p. 658), which represent a shift to intensive harvesting and storage as part of a delayed-return economy. At E-75-6, there are c. 20 huts, more than 30 pits and a walk-in well dug to facilitate access to the underground water table, which argues for semi-sedentary occupations. Whereas the preceding El Adam and El Ghorab occupations occurred during summer, the more abundant El Nabta/Al Jerar semi-sedentary settlements are stated by the excavators to have spanned autumn to the onset of the summer rainfall (Wendorf et al. 2001, p. 658). However, there are no unequivocal signs of intensive social differentiation, although it appears that broad-spectrum economic exploitation and delayed return occurred, which may have entailed socially-mediated and negotiated resource acquisition, laying the socio-ideological foundations for the inhabitants to be receptive to incorporating new forms of animal exploitation in the succeeding phases.

The Archaeofaunal Remains from the CPE Expeditions

It is against these ecological and social backdrops that the faunal data from the Combined Prehistoric Expedition's excavations can be placed. The published faunal remains, by Gautier (2001), from Bir Kiseiba, El Gebel El Beid, El Kortein and Nabta Playa are from the field seasons in the 1970s, the year 1980, and the 1990s. Gautier did not participate in the 1991, 1992 and 1994 seasons, which affected the

sample size and restricted the rigour of the subsequent classificatory process, while identifications were made on site in 1990. Despite this, Gautier was confident that the archaeozoological trends are consistent in nature. Tables 4 and 5 detail the known published numbers of individual animals by phase, with Table 4 focusing specifically on cattle and caprines.

Not included in Table 5 or in Gautier's corresponding Table 23.1 are elephant remnants, as Gautier (2001, p. 623) believes that their biochemical markings are indicative of a Middle Palaeolithic origin. Regardless, elephants are known from modern semi-arid and arid deserts such as the Namib Desert in Namibia. While

Table 4 The occurrence of *Bos* and ovicaprid remains in the different phases at Nabta Playa and Bir Kiseiba. The ^{14}C dates are calibrated using IntCal13, 95.4% confidence interval. From Gautier et al. (2001, Table 23.1)

Period	Site	Cattle	caprines	^{14}C range	Calibrated BC
El Adam Humid Interphase	E-75-9	2	0	8750 ± 70	8183–7597
	E-77-3	1	0	8840 ± 90	8244–7675
	E-77-4	1	0	N/A	N/A
	E-77-7	2	0	8875 ± 75	8246–7755
	E-79-8	10	0	8920 ± 130	8325–7611
	E-80-4	6	0	9220 ± 120	8764–8237
El Ghorab Humid Interphase	E-75-6	1	0	8290 ± 80	7521–7084
	E-79-4	1	0	8190 ± 120	7521–6827
El Nabta	E-80-1	2	0	8020 ± 90	7181–6652
El Nabta/Al Jerar	E-75-6	3	0	8080 ± 110	7355–6679
Al Jerar	E75-6	1	0	7480 ± 110	6561–6081
	E-77-1	9	3?	7480 ± 80	6476–6116
	E-77-5	1	0	7530 ± 180	6811–6015
	E-79-2	1	0	7780 ± 130	7037–6433
	E-90-3	5	0	N/A	N/A
	E-91-1	9	10 (5?)	7850 ± 75	7030–6513
	E-98-1	1		N/A	N/A
Ru'at El Ghanam Middle Neolithic	E-75-8	32	120	7220 ± 75	6236–5928
				6690 ± 100	5787–5472
	E-79-6	3	0	7170 ± 80	6221–5898
Middle/Late Neolithic	E-75-8	11	41	6650 ± 120	5781–5365
	E-97-17	2	1	N/A	N/A
Ru'at El Baqar Late Neolithic Humid Interphase	E-75-8	75	176	6550 ± 80	5633–5362
	E-79-5	3	0	N/A	N/A
	E-94-1	0	3	6470 ± 270	5972–4805
	E-96-1	5	3	N/A	N/A

Table 5 The occurrence and percentages of the documented faunal remains in the different phases at Nabta Playa and Bir Kiseiba. The ^{14}C dates are calibrated using IntCal13, 95.4% confidence interval. From Gautier (2001, Table 23.1)

Species	El Adam Humid Interphase	El Ghorab Humid Interphase	El Nabta	Al Jerar	Ru'at El Ghanam Middle Neolithic	Middle/Late Neolithic	Ru'at El Baqar Late Neolithic Humid Interphase
Smaller birds	6 (1.02%)	2 (1.29%)	5 (1.72%)	9 (0.67%)	47 (4.85%)	2 (1.14%)	29 (3.62%)
Desert hedgehog	0 (0%)	0 (0%)	1 (0.34%)	9 (0.67%)	10 (1.03%)	0 (0%)	3 (0.37%)
Hare	17 (2.88%)	16 (10.32%)	53 (18.28%)	554 (41.5%)	296 (30.55%)	35 (19.89%)	176 (21.95%)
Ground squirrel	0 (0%)	0 (0%)	4 (1.38%)	1 (0.07%)	1 (0.1%)	0 (0%)	0 (0%)
Field rat	1 (0.17%)	1 (0.65%)	3 (1.03%)	36 (2.7%)	66 (6.81%)	7 (3.98%)	42 (5.24%)
Porcupine	1 (0.17%)	10 (6.45%)	0 (0%)	6 (0.45%)	9 (0.93%)	2 (1.14%)	8 (1%)
Jackal	8 (1.36%)	0 (0%)	1 (0.34%)	16 (1.2%)	29 (2.99%)	1 (0.57%)	13 (1.62%)
Striped hyena	0 (0%)	0 (0%)	5 (1.72%)	3 (0.22%)	0 (0%)	0 (0%)	0 (0%)
Wild cat	1 (0.17%)	1 (0.65%)	3 (1.03%)	14 (1.05%)	8 (0.83%)	0 (0%)	0 (0%)
Small carnivores	0 (0%)	0 (0%)	0 (0%)	2 (0.15%)	9 (0.93%)	0 (0%)	0 (0%)
Dama gazelle	82 (13.9%)	1 (0.65%)	14 (4.83%)	23 (1.72%)	45 (4.64%)	10 (5.68%)	45 (5.61%)
Dorcas gazelle	452 (76.61%)	122 (78.71%)	199 (68.62%)	621 (46.52%)	286 (29.51%)	63 (35.8%)	202 (25.19%)
Barbary sheep	0 (0%)	0 (0%)	0 (0%)	1 (0.07%)	4 (0.41%)	1 (0.57%)	2 (0.25%)
Ovicaprids	0 (0%)	0 (0%)	0 (0%)	13 (0.97%)	120 (12.38%)	42 (23.86%)	182 (22.69%)
Cattle	22 (3.73%)	2 (1.29%)	2 (0.69%)	27 (2.02%)	35 (3.61%)	13 (7.39%)	83 (10.35%)
Dog	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (0.41%)	0 (0%)	17 (2.12%)
Total	590	155	290	1335	969	176	802

areas in the Western Desert such as Abu Ballas, Gilf Kebir and the Selima Sandsheet, plus Wadi Howar and Wadi Shaw in the Sudan, have yielded remains of giraffe, giraffes are only present in the Late Neolithic faunal record at Nabta Playa, when there was greater aridification (Gautier 2001, p. 622). However, no numbers are provided by Gautier. There is no ecological rationale for either species not to have been present during the early Neolithic, unless they were not being hunted to any great extent and their meat not brought back to the encampments along the playas.

Three fragments (omitted from Table 5 and Gautier's Table 23.1), including one distal metacarpal moiety from E-75-8, are identified as oryx; two of these fragments may also be addax (Gautier 1984, 2001). The latter two are from a mixed Ru'at El Ghanam or Ru'at El Baqar Humid Interphase and Late Neolithic deposit, while the other was found on the playa's surface. Addax and oryx have similar distribution patterns. Both can live in arid and semi-arid ecologies, and oryx are frequently found in association with gazelle. At Tin Ouaffadene (Niger), oyrx are also found together with elephant remains (Roset et al. 1990). Oryx drink water where it is present and derive sustenance from acacia fruits and leaves, grasses and shrubs, and moisture from succulent bulbs and wild melons (Gautier 2001, p. 622).

Therefore, addax or oryx, or both, were present at E-75-8 at a time when the environment was slightly wetter than in the early Holocene, but worse than during the Al Jerar Humid Interphase. Their remains have not been described from the faunal records of earlier phases. They should have been more abundant in the earlier faunal record if the full range of faunal diversity was represented, especially with the presence of water for a significant portion of the year, even more so as they are a companion to gazelle, with old males associating with dama gazelle herds (Roset et al. 1990; Van Neer and Uerpmann 1989). What this indicates is that the addax/oryx was either not hunted very often or it was hunted away from the camps and any remnants brought back to camp were not preserved, which further renders the faunal records unrepresentative of the diversity in the broader landscape.

Thirteen 'domesticated' caprines are assigned to the Al Jerar (Table 5), but Gautier believes that these are more likely to be remains of Barbary sheep, while domesticated caprines are present from the Ru'at El Ghanam onwards. The caprine remains are very fragmentary or incomplete. For the Ru'at El Ghanam, the caprines are detailed from the excavated dune section of site E-75-8. Gautier's Table 23.1 assigns them to site E-75-8 A (layers 1–3), subsurface and spits 5–9. Spit 9 is the oldest (Table 6), but there is no indication from Gautier of which spits contained caprine remains. However, information in this regard is provided by Close:

> Re-excavation of E-75-8 has confirmed the presence of domesticated sheep/goat in El Ghanam Middle Neolithic, specifically in the three upper spits, 5–7. Unfortunately, the state of preservation of the bones precluded their being dated directly; this is not uncommon in extremely arid environments. Thus, strictly speaking, the possibility remains that the sheep/goat are intrusive from the overlying El Baqar Late Neolithic, but their distribution within the Middle Neolithic makes this possibility remote. If they were intrusive from above, then they would be most numerous in Spit 5 and would

Table 6 Breakdown of the spits at Site E-75-8 as excavated in 1990 and described by Close (2001)

Spit	Period	Description
1–4	Late Neolithic	A ^{14}C date, from Spit 4, of 5633–5362 BC marks its start
5	Ru'at El Ghanam	60–75 cm below surface. Not rich in archaeological remains
6	Ru'at El Ghanam	75–90 cm below. Archaeological material more common than in spits above
7	Ru'at El Ghanam	90–110 cm. Richest
8	Ru'at El Ghanam	>110 cm. Artifacts but at a lesser density than in Spit 7
9	Ru'at El Ghanam	Unstated depth. Hearth in Spit 9, the earliest El Ghanam Middle Neolithic deposits, dated to 6236–5928 BC

rapidly decrease in frequency below that. However, although the overall frequencies of bones in Spits 5 and 6 are essentially the same, the absolute number of sheep/goat remains in Spit 6 is twice that of Spit 5. We may, therefore, be confident that the domesticated sheep/goat really do date from El Ghanam Middle Neolithic. (Close 2001, p. 383)

At E-75-8, caprines are absent from Spits 8 and 9. They are present in Spit 7, which has the most cultural materials but in smaller numbers than in Spit 6. Disappointingly, the caprine numbers are not broken down by spit and Gautier's table lumps Spits 5–9 together.

Cattle appear later than the caprines. Remains from the 1977 excavation's designated Unit 2 at E-75-8 are broadly bracketed to around c. 5600–5480 BC (after Wendorf and Schild [1980, fig. 3.19]), while pre-1990s excavation units 4 and 5 are part of the Late Neolithic (see Close [2001, fig. 10.2] with its numbers). The cattle remains collected during and after the 1990 excavations are—for the Middle Neolithic—found on the boundary between the Ru'at El Ghanam Middle Neolithic and the Late Neolithic and in Spit 5. An instance for Spit 7 is labelled 'one doubtful subadult sesamoid' by Gautier (2001, p. 627).

At E-94-1N, at the northern end of the Nabta basin, lies a cluster of tumuli, nine of which have been excavated and contain articulated cattle remains (Applegate et al. 2001). The earliest is the famous articulated cow tumulus of Site E-94-1N, with its burial pit and hypothesised wooden roof. Regularly cited as being dated to c. 5400 BC, its radiocarbon date of 6480 ± 270 bp has a wide one sigma error range of 5976–4835 cal BC. Potential animal tumuli also exist at Bir Murr 1 (110 km northwest of Nabta Playa), where three stone structures have been located (Connor 1984). The structures reportedly have similarities to the Nabta Playa tumuli and are dated to c. 5250 BC (Applegate et al. 2001).

In addition, Gautier's (2001, Table 23.25) published analysis clusters the fragmentary early Neolithic *Bos* within the size range of small aurochs. Most of the highly fragmentary and poorly preserved *Bos* remains assigned to the El Adam, with the notable exception of two molars, are fragments of an adult phalanx and a cannon bone's distal condyle from Site E-80-4, surface finds. This raises questions of their stratigraphical provenance beyond a generalised time period, due to the practice of excavating in artificial spits. Measurements for just five individuals

attributed to the Ru'at El Ghanam show a shift for four to the lowest end of aurochs and within the uppermost range of domesticated cattle; the other measurement is firmly within the range of most of the measurements provided by Gautier (2001, fig. 23.2, Table 23.5) for small wild aurochs from the early Neolithic, which could be read as hypothetical evidence for the presence of aurochs in this part of the Western Desert at this time. The later period measurements show a clear shift to domesticated cattle.

Gautier's analysis produces similar results to Smith's (1984) analysis. Figure 2a, b show Smith's comparative metrical analysis, using the standard animal method, of aurochs samples from the Maghreb, *Bos primigenius* from Europe and Kom Ombo (Nile Valley), and domesticated *Bos* from Arlit (Sahara), the Maghreb and Europe, as well as modern zebu cattle from the Tilemsi Valley in Mali. Unfortunately, Gautier (2001) does not provide a breakdown of the distal condylar width of the humeri and the distal width of the metapodials by site or by period, and therefore most of the data behind Gautier's analysis could not be overlaid on Smith's for a like-for-like comparison. However, five cattle bones described in Gautier (1980) with comparative measurements were able to be included by Smith (1984) and are also included in Fig. 3a, b. Unfortunately, there are no good published images of the bones. The two El Nabta/Al Jerar specimens fall within the range of *Bos primigenius* while the Ru'at el Ghanam specimen is within the range of domesticated cattle for the metapodial widths, and likewise for the one El Nabta/Al Jerar and one Ru'at el Ghanam specimens respectively.

Grigson (2000) used the standard animal method but does not provide her measurements in mm, which precludes overlapping the data in her figures with Smith's. Grigson also does not break down her measurements by period to look at temporal variances. However, it is important to note that some of Grigson's (2000) measurements fall within the range of aurochs (of unspecified date) from the Nile Valley. While Grigson and Smith's analyses have been criticised on the basis that a limited sample size from the Nabta Playa—Bir Kiseiba region could have skewed the results, due to inter-population size variability, it is noteworthy that all three analyses show that at least the earlier Holocene cattle from the area fall within the range of aurochs but not domestic cattle. Two analyses (Gautier 2001; Smith 1984) show that cattle remains from the middle Neolithic onwards are predominantly within the range of domesticated cattle.

Gautier (1987, p. 180), however, previously advanced a counter-argument against the use of size criteria to judge the domestic or non-domestic status of early Saharan cattle remains: 'The early cattle of Nabta Playa and Bir Kiseiba are also large, but if we are dealing with an early phase of domestication, then the decline in size in response to poor ecological conditions may not yet have begun.' Gautier (2001, p. 628) repeats this argument. However, Linseele noted:

> While the Pleistocene African aurochs was as at least as large as its Holocene Danish cousin, the Holocene African aurochs was clearly smaller and would have reached only the size of the Pleistocene African females. The size decline recorded during the Holocene from northwestern to southeastern Europe and from there to the Near East appears to have continued down to Africa. Within

Fig. 3 a Comparative metapodial distal condylar width measurements (mm) of aurochs and ▶ domesticated cattle. The figures are derived from Smith (1984) with permission and incorporate the temporal period assignments for the Nabta Playa–Bir Kiseiba region's sites from Wendorf et al. (2001). **b** Comparative humeri distal condylar width measurements (mm) of aurochs and domesticated cattle. The figures are derived from Smith (1984) with permission and incorporate the temporal period assignments for the Nabta Playa–Bir Kiseiba region's sites from Wendorf et al. (2001)

northern Africa, aurochs size was variable. The available measurements point to a Pleistocene African aurochs that was at least as robust as its Holocene northern European relatives, although its successors from the Holocene may have been more slender. (Linseele 2004, p. 182)

Linseele (2004, p. 183) also concluded that although the size of African Holocene aurochs was also more uniform than that of their Pleistocene counterparts, there is a slight overlap in size between large male domestic cattle from the modern Nile Valley and African Holocene aurochs. Linseele's fig. 12 shows that the overlap is small, which correlates with the trend shown by Gautier (2001, Table 23.25) and Smith (1984) (Fig. 3a, b), while Grigson's (2000, fig. 4.7b) analysis would be compatible with sexual dimorphic differences with large males and smaller females for middle and late Holocene domesticated cattle from Nabta Playa—Bir Kiseiba.

Furthermore, the dates of the first appearance of cattle remains during the Ru'at El Ghanam Middle Neolithic place the decrease in size of domesticated cattle towards and at the end of the period, c. 5600–5400 BC, after the first appearance of caprines. Taken together at face value, these measurements and dates mark the Post-Al Jerar Arid Phase as a juncture after which first small numbers of caprines and subsequently morphologically domesticated cattle become visible in the archaeological record in this region of the Western Desert.
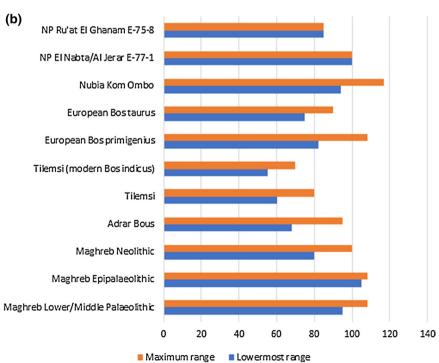
Signatures of Domestication, and Their Timing in the Adjacent Near East

According to Zeder (2008, 2009), the harvesting age profiles and the corresponding degree of sexual dimorphism are more relevant than previously traditional measurements in marking the onset of animal domestication. Male goats and sheep were targeted between the ages of two and three, which is a strategy reliant upon conserving the females and the presence of enough young males in surrounding wild herds to fill the vacancies. Later, as herding takes hold, females past their prime reproductive years are killed. Young males not required for reproductive activities are also disposed of, but their more friable bones are less likely to survive in the archaeological record, and this may be particularly true under the harsh preservation conditions in the Western Desert of Egypt.

Zeder's analyses show clear profiles useful for distinguishing between hunting, management and domestication. Differential targeting creates the effect of an apparent overall reduction in anatomical body size, which could be mistaken for a sign of morphological domestication (involving genetic manipulation through selective breeding), when instead focus on sex is the primary factor. Unfortunately, evaluation of the sex of the Nabta Playa—Bir Kiseiba cattle remains has not been possible due to their fragmentary nature. Therefore, the herd composition and

(a)

(b)

culling or hunting strategies cannot be determined. Recently, in Europe, decreasing size of *Bos* has been attributed to possible sub-adult breeding, where newborns were smaller due to birthing constraints (Manning et al. 2015).

Caprines and cattle have behavioural attributes conducive to domestication, notably a dominance hierarchy which could be co-opted and subsequently manipulated in favour of individuals with less aggressive tendencies. In southeastern Anatolia, herd management of sheep was in place around 8500 BC (Zeder 2009, p. 36). At Ganj Dareh (northern Iran), for goats, the demographic markers appear c. 7900 BC, while managed goats appear c. 8200 in southeastern Anatolia, and at Abu Hureyra (Syria) c. 7600 BC (Barich 2016; Zeder 2008). The earliest Near Eastern sites showing signs of aurochs domestication are located in the Middle Euphrates Valley. Djade el Mughara (northern Iraq) was occupied c. 8650–8250 BC (Early Pre-Pottery Neolithic) (Helmer et al. 2005) and a sample yielded the earliest securely archaeologically dated T3 haplotype that is common to later *Bos taurus* (Edwards et al. 2007, p. 1384). To the west, morphologically wild cattle first appear in Cyprus, where they are not native, from 8250 to 8150 BC onwards (Vigne et al. 2000; Vigne 2013), while morphologically domesticated cattle are present in central Anatolia after 6000 BC (Zeder 2008).

In the Arabian Peninsula, Drechsler (2007) has suggested that caprines and domesticated cattle appear between 6800 and 6200 BC in the margins to the east and south. There is an ongoing debate over whether this represents the arrival of Levantine herders or the adaptation and integration of low numbers of domesticated stock into hunter-gatherer economies, or a mixture of both in different areas of the Peninsula (Boivin and Fuller 2009; Crassard and Drechsler 2013; Drechsler 2007; Magee 2014; McCorriston and Martin 2009). Regardless, the rock art of Shuwaymis in northwestern Saudi Arabia (Ha'il Province) has been taken to indicate the adoption of cattle into formerly hunter-gatherer economies, with the possible addition of peoples with livestock from the eastern Jordan steppe during Pre-Pottery Neolithic B (c. 6800–4900 BC). A recent paper mentions the presence of possible domesticated cattle between 5200 and 5070 BC at Jebel Oraf 2 (northern Saudi Arabia) (Guagnin et al. 2017). Together, these data support the plausibility of Close's (2002) hypothesis of an initial southern route for the arrival of caprines in Northeast Africa via the Red Sea.

At c. 6200 BC, there was a cold period lasting two to four centuries in the Near East and North Africa (Cremaschi et al. 2010; Goodfriend 1991; Migowski et al. 2006; Wendorf et al. 2001). In North Africa, this resulted in drier conditions, while west Asia experienced c. 300 years of aridification and cooling. Shortly afterwards, as discussed below, low numbers of caprines are detected in North Africa, followed by domesticated cattle and indications of cultivation activities of Near Eastern domesticated cereals from the mid sixth millennium BC.

Implications of Haplotype Diversity for the Origins of Domesticated Cattle

The pioneering mtDNA study of modern cattle by Bradley et al. (1996) looked at the short segments of the control region, the main non-coding DNA area of the

mtDNA genome. It showed a deep time depth for the divergence for African taurines from European and Asian taurines, but it has since been shown that there was admixture between the latter two taurines due to intentional exportation of European cattle (Decker et al. 2014). Decker et al. (2014) also hypothesised that African taurines were less divergent than their European and Asian counterparts when introgression from African aurochs was modelled, which would not be expected if there was an independent centre for domesticated cattle in North Africa from which African *Bos taurus* are descended. The degree of introgression is currently unknowable as no North African aurochs DNA has yet been extracted (Stock and Gifford-Gonzalez 2013), although it has been estimated to reach a high of 26% (Decker et al. 2014). Genetic introgressions are known from other species and these results are also stated by Decker et al. (2014, p. 5) to be consistent with linkage disequilibrium patterns showing a larger than expected ancestral population for African taurines.

Within the T1 haplogroup are haplotypes that appear to be unique to and diverse within Africa; there are also microsatellite variations which are suggestive of both indigenous origins and of gene flow from the Middle East being predominantly male (Bradley and Magee 2006; Hanotte et al. 2002; Perez-Pardal et al. 2010). In addition, there appears to have been a Y2 multilocus microsatellite introgression from African *Bos primigenius* into later African *Bos taurus* (Perez-Pardal et al. 2010), which would be in line with introgressions detected between European *Bos primigenius* and *Bos taurus* (Upadhyay et al. 2017). Introgression has previously been postulated for the early cattle domestication model to be responsible for delays in the onset of a decrease in size (Marshall and Weissbrod 2011), but quite how it would work over a span of nearly 3000 years until the early–mid sixth millennium BC in the Nabta Playa—Bir Kiseiba region has not been made explicit. However, introgressive capture, whereby animals domesticated in one area have picked up genetic diversity from local wild populations, has been a recurrent process in animal dispersal (Larson and Fuller 2014). It appears, therefore, that there may have been a period or periods of cross-fertilisation between African aurochs and incoming domesticated cattle (Bradley and Magee 2006; Hanotte et al. 2002; Perez-Pardal et al. 2010), although this remains to be proven (Caramelli 2006).

While multiple Near Eastern centres of management of sheep and goats have been postulated, aurochs were much larger and behaviourally more dangerous, and it has been estimated that *Bos taurus* is descended from a small group of c. 80 female individuals (or 23–452 for a 95% confidence interval) (Bollongino et al. 2012). Sequencing data has shown the existence of two clades which both arose in the Near East: T1′2′3, with the former T4 subsumed within T3, and T5. As noted by Bonfiglio et al. (2012, p. 2), T1 is 'two control region mutations away (16050, 16113) from the node T1′2′3″, with a coalescence range of 13–10 kya. Achilli et al. (2010) argue that the T1 haplogroup from African samples differs from the T1′2′3 ancestor by one mutation and two mutations from the T3 ancestor. These and other studies (Ajmone-Marsan et al. 2010, Beja-Pereira et al. 2006) show that the T1 haplogroup found in African *Bos taurus* originates in the Fertile Crescent.

Olivieri et al. (2015) undertook Bayesian and phylogenetic analyses on 31 mitogenomes from the Domiatry and Menofi cattle breeds in the Nile Delta. High

haplotype and haplogroup affiliation diversity were detected. They report the presence of T2 and T3 in high frequency, which is in contrast to the breeds in most of the rest of the African continent, as well as haplogroup Q1. Significantly, they state that 'their "randomly collected" samples are also characterised by an extremely high haplotype diversity, with each mitogenome harbouring a different haplotype. Furthermore, almost all haplotypes depart directly from the respective haplogroup root, with a star-like topology and a rather similar average number of nucleotide differences within each haplogroup' (Olivieri et al. 2015, p. 6) The reconstructed coalescence dates for especially T1 and Q1 pre-date the 11–10 ka range given by Zeder and Helmer et al. for initial domestication of cattle by 4–5 ka, indicative of sequence diversity in the ancestral aurochs populations in the Middle Euphrates Valley. Their analysis also demonstrates that there was movement of domesticated cattle from the Levant but not southern Egypt into the Delta region.

The Wider Egyptian Desert Context

The earliest archaeologically-known occurrence of domesticated caprines in North East Africa is at Sodmein Cave on the Red Sea coast, where a sheep or goat phalanx was unearthed below a feature dated to 6218–6034 BC (Vermeersch et al. 2015, p. 487). Overall, Vermeersch et al. (2015, p. 486) state that as few as ten bones of caprines are present in the mid-Holocene layers, while a further 12 specimens could be either domesticated caprines, Barbary sheep or ibex. The lithics are typical of hunter-collectors and have similarities with the Egyptian Western Desert bifacial technocomplex characterised by large points, including Djara and possibly Bashendi A facially retouched points.

   In the Fayum, the earliest sheep appear at Qasr El-Sagha XI/81 (c. 5400 BC), while there are cattle, goat and sheep at IX/8 around 5200 BC (Linseele et al. 2014, p. 9). In Level 1 at Merimde Beni Salama, both Near Eastern cereal domesticates and animals are present from 4850–4650 BC onwards. However, these dates for the Fayum and the Nile Delta may eventually be pushed back. Shirai (2010, p. 312) has argued that similarities between bifacial sickle blade technologies from Caton-Thompson's excavations and surface collections in the Fayum and the Lodian culture in the Levant (c. 5850–5500 BC), and Neolithic bifacial axes and small bifacial projectile points, suggest cultural diffusion of technologies outside of the Delta. However, an earlier date for the Fayum may be problematic as Kom W is currently dated to the mid fifth millennium BC, and the earliest dates on cereals from Merimde and Sias in the Nile Delta are in the range c. 4800–4400 BC (Merimde) and by the start of the sixth millennium BC (Sias) (Barich 2016, p. 15; Linseele et al. 2014; Rowland and Bertini 2016; Wilson et al. 2014).

   Elsewhere, outside of the Nile Valley in the Western Desert at Farafra Oasis, goat and sheep were first present between c. 5900 and 5500 BC (Barich and Lucarini 2008; Barich et al. 2014). They occurred alongside cultivated wild cereals in a mixed delayed-return economy. To the southeast of Farafra Oasis, Dakhleh Oasis had favourable geological conditions, being protected from northerly winds by an escarpment. As at Bir Kiseiba and most likely Nabta Playa, groundwater was close to the surface. Early and middle-Holocene faunal assemblages from the

Epipalaeolithic (Masara, c. 8300–6500 BC) and early Neolithic (Bashendi A, c. 6400–5650 BC) phases of Dakhleh Oasis have certain characteristics in common, namely medium-sized bovids such as hartebeest (further highlighting its absence from the Nabta Playa—Bir Kiseiba area) and gazelle, and small animals such as hares (Churcher 1983; McDonald 1998, 2009, 2016). There are no wild or domesticated cattle remains in its Bashendi A faunal assemblage. The communities were mobile foragers, with increased sedentism arising in late Bashendi A (c. 6000–5650 BC) at Locality 270 and the Farafra Oasis sites of Hidden Valley and Sheik el Obeiyid, with numerous stone slab features. At Nabta Playa during the El Nabta/Al Jerar Maximum there is evidence for increased sedentism, such as hand-dug wells, but there were no slab structures. It is during the Late Bashendi A, c. 5900 BC, that goats appear at Dakhleh Oasis Site 270. Most of the succeeding Bashendi B faunal remains derive from pits, and they include mature and juvenile cattle, goat, gazelle and hartebeest. The best samples of domestic cattle come from the pits of Site 271, where the earliest date of 6360 ± 120 bp has a calibrated one-sigma range of 5551–5037 BC (McDonald 2001).

It is speculated that there was a bimodal rainfall pattern (two rainy seasons) during the time of Late Bashendi A at Dakhleh Oasis, which resulted in an increased supply of readily available water. Numerous sites were occupied across the Western Desert at this time (Kuper and Kröpelin 2006). Manning and Timpson (2014) also reconstruct fluctuating demographic trends during the Holocene, and a significant decline after 5600 BC following a lengthy period of steady growth, increased pasture and available plant resources. As McDonald has argued:

> Intensification may also have been driven by (or have promoted) increased social complexity … Socioeconomic differentiation may have been emerging in Late Bashendi A times, the main categories of evidence being site structure (site size plus the distribution on site of cultural material, and the presence of 'prestige technologies'. Briefly, the size of 270 and the distribution within it of artefacts, structures and features (including large possible fire pits), plus the settlement pattern elsewhere in southeastern Dakhleh, suggest a large population (minimally, of several hundred) broken down into social groups of various composition, and engaged in diverse activities at various times of the year. Such circumstances might have required an entity to play managerial and mediating roles. (McDonald 2009, p. 27)

Increased sedentism raises the possibility of socio-ideological changes rendering the communities more receptive to incorporating—at first—small numbers of domesticates. Delayed return and exploitative surpluses incorporate notions of ownership, which is partially evidenced at Dakhleh Oasis and Nabta Playa by the mid Holocene by the number of sites and structures. The El Nabta/Al Jerar Maximum produced an ecological backdrop against which a potentially multi-faceted return exploitative economy arose at Nabta Playa. Stone bracelets have been interpreted as markers of emerging, transient elites by Kevin MacDonald (1998), and they are present during Bashendi B at Dakhleh Oasis. This is earlier than my previous hypothesis of the first convincing cultural markers of incipient social complexity in ethnically and culturally mixed populations in North Africa arising c.

4000 BC through mobile elites (Brass 2007). Such multi-layered social systems would be expressed through continually negotiated relationships and socially mediated redistribution of resources, which may have predisposed the socio-economic and ideological outlook of communities in the Western Desert to incorporate small numbers of domesticates arriving as the result of 'leakages' from the Levant and Sinai.

The trend toward increased sedentism, with attendant material manifestations of potential social elites (McDonald 2009, p. 27), is reversed in Bashendi B (c. 5400–3800 BC) with forager-herders and open air sites. The lithic assemblage, which include grinding stones, headstones and tentative sickles, and also retains portable tools such as small arrowheads, supports a reconstruction of a mobile society exploiting a broad spectrum of resources, including small numbers of domestic livestock (McDonald 2009, p. 10).

More generally, Riemer (2007) has looked at the relationship between people and objects of mobility, using the portable material refuse traditionally associated with pastoralism as a proxy for human mobility in detailed contextual analysis. He concluded that there is little archaeological data to support an early independent African centre of cattle domestication and a spread of domesticated cattle from a core Nabta Playa–Bir Kiseiba region. His data showed that, across the Sahara, there are no sites with unambiguously domesticated cattle found outside of the Nabta Playa—Bir Kiseiba area prior to the sixth millennium BC. In addition to the aforementioned sites, a goat or sheep molar dating to c. 4900 BC has been found at Djara (phase B), while limited numbers of sheep dating to 5900–4900 BC are found at Glass Area 81/61 (Willmann's Camp). At Kharga Oasis, c. 200 km to the west of the Nile Valley with which it maintained contact, pastoralists inhabited KS43 (4800–4400 BC) during the winter season (Lesur et al. 2011). Its faunal remains include caprines and cattle.

Further evidence of trade links to the Red Sea is provided by the presence of cowrie beads in the Western Desert. Sites south of 25.5°N are, by contrast, placed in a different facies characterised by microlithic arrowheads (Riemer 2007). Riemer also concluded that there is an orientation towards the northern bifacial tradition from 5400 BC onwards, which may be connected with a wider adoption of domesticates, including cattle, between neighbours or with the movement of peoples as the aridification of the Western Desert continued. Manning and Timpson (2014) modelled a population decline starting shortly beforehand, at c. 5600 BC, which is around the time of Bashendi B and shortly before domesticated cattle appear at Dakhleh Oasis. Prior small-scale movement of domesticates from the Near East would have provided the apprenticeship (as well as the T1 haplotype) needed for North Africans to learn about animal husbandry. Handling large-bodied domesticates like cattle would have been very difficult without prior experience of dealing with small stock (Smith 1986). Julius Caesar (1869) described aurochs thus:

> Their strength and speed are extraordinary; they spare neither man nor wild beast which they have espied. These the Germans take with much pains in pits and kill them. The young men harden themselves with this exercise, and practice themselves in this kind of hunting, and those who have slain the

greatest number of them, having produced the horns in public, to serve as evidence, receive great praise. But not even when taken very young can they be rendered familiar to men and tamed (Gallic War, 6.28).

Discussion

At Nabta Playa—Bir Kiseiba, the sites represent a palimpsest of occupations which, considering that most of the excavations proceeded by spits rather than stratigraphic layers (compare Close [2001] with Nelson [2001]), makes it difficult to discern discrete occupational events. It also raises issues of contemporaneity between botanical, faunal and material culture assemblages and dated materials. The Combined Prehistoric Expedition has not succeeded in obtaining direct dates on the fragments of cattle remains. Neither are there published descriptions with full measurements of all specimens permitting independent, complete verification of the faunal assemblages. However, this re-analysis of the little-discussed geomorphic data from Bir Kiseiba provides a different perspective on the hydroclimatic conditions there during the early Holocene. It, together with revisiting the botanical data, strongly indicates that the early Holocene ecology at Nabta Playa—Bir Kiseiba was capable of supporting both small game animals such as hares, medium-sized bovids beyond gazelles such as hartebeest and wild *Bos*, and other semi-arid adapted animals. The lithic assemblages too are similar to hunter-collector toolkits, possessing no significant distinguishing features indicative of herding (Kuper and Kröpelin 2006; Riemer 2007). Together with the botanical and fragmentary faunal data and the presence of arid-adapted addax/oryx in the later wetter mid Holocene, and *Bos primigenius* depicted in undated rock art elsewhere in the Sahara, there is no conclusive evidence for the presence of habitually or morphologically domesticated cattle in the early Holocene of Northeast Africa.

It is only later during the El Nabta/Al Jerar Maximum and Late Bashendi A phases at Nabta Playa and Dakhleh Oasis, and the near contemporary sites at Farafra Oasis, that semi-sedentism and storage indicative of delayed-return economies emerged. The change laid the ideological foundations for the subsequent integration of at first low numbers of caprines and later cattle into the broad-spectrum economies of the Western Desert at different times. The spread was made possible and facilitated by trade links stretching from the Western Desert to the Red Sea, evidenced by the appearance of cowrie beads.

In the southern Levant, domesticated cattle appear by 6500 BC (Conolly et al. 2011; Zeder 2008), which is contemporary with the period of 6800–6200 BC bracketed for the eastern and southern margins of the Arabian Peninsula. However, only low numbers of domesticated caprines have been found at Sodmein Cave on the Red Sea coast, which is the earliest known appearance on the African continent. Arguably, through the choices they made, the local inhabitants adopted and modified the range of domesticated animals used by their Near Eastern counterparts to their specific socio-economic requirements. By 5900 BC, caprines are likely present at Nabta Playa, while the earliest verifiable occurrence of domesticated cattle there is c. 5600 BC, but both are dated later at other Western Desert sites: e.g.

Dakhleh Oasis (goats c. 5900 BC, cattle c. 5551–5037 BC); Farafra Oasis (caprines 5900–5500 BC); Fayum (Qasr El-Sagha caprines c. 5400 BC, cattle c. 5200 BC); and Djara (phase B, caprines c. 4900 BC).

Cattle have previously been stated to appear in the central Sahara from the mid sixth millennium BC onwards (Di Lernia 2006; Di Lernia and Manzi 2002; Paris 1995, 1997; Smith 2004), but the early dates have wide error margins and their appearance after 5500 BC falls within the spectrum of dates for the spread of cattle east to west across the Sahara. More recently, new dates for Takarkori show that the pastoral period begins from c. 6300 BC for the Acacus Mountains (Libyan Sahara) (Biagetti and di Lernia 2013). However, the dung present in the earliest two pastoral sub-phases of Takarkori's Early Pastoral period (c. 6300–5750 and c. 5750–5350 BC) has not been conclusively identified as deriving from both Barbary sheep and cattle together, which is pertinent as dung in the preceding Late Acacus period (c. 8100–6300 BC) is from Barbary sheep (Di Lernia 2001), and for the time being this leaves open the question of the composition of pastoral herds at the onset of pastoralism in the central Sahara.

Further south, in the Sudan, there is evidence for domestic cattle at el-Barga (near Kerma) around 5750 BC (Honegger 2005; Linseele 2013), and the presence of domestic wheat and barley, from the second half of the sixth millennium BC, and at least throughout the fifth millennium BC, at R12, Ghaba (Madella et al. 2014; Out et al. 2016; Ryan et al. 2016) and Kadruka 1 (Reinold 2000), which are all upstream south of Kerma. This date from el-Barga, together with the data from the Acacus Mountains in the central Sahara, indicates that there was possibly a southern dispersal of (limited?) numbers of domesticated cattle along a southern route at or close to the time caprines were first introduced into Northeast Africa.

The adoption of elements from Near Eastern economies at different times masks the variable nature of subsistence strategies practised by the inhabitants of the Western Desert, and indeed the Fayum (Linseele et al. 2014; Phillipps et al. 2016; Riemer 2007; Shirai 2013). Possibly a key driver in the eventual adoption of cattle into already mixed economies was its use as a source of fat (Smith 1986), requiring well-fed cattle which would also have been necessary for milk production, as the aridification of the desert continued from the middle of the sixth millennium BC onwards and population numbers declined, culminating in the emergence of mobile herder groups.

As McDonald and others have noted (Barich 2016; Barich and Lucarini 2008; McDonald 2016), Western Desert lithic technologies evolved locally, and plant exploitation and cultivation activities did not include Near Eastern summer rainfall crops. However, population movement from the Levant into the Nile Delta via the land barrier, or using small sea-going craft, with diffusion from the Delta into the Western Desert, as well as an earlier and possibly also contemporary route across the Red Sea, meant that there was cultural contact with all its attendant possibilities of exchange of animals and indeed maybe apprenticeships on controlling and herding those animals. Anthropologically, it is very difficult for hunters to become herders (Ingold 1980), but if there were small-scale exchanges through trade and migration between North Africa and the Levant and the Arabian Peninsula, similar to what has been proposed for the spread of domesticates into southern Africa

(Smith 2016), then there is the apprenticeship (as well as the T1 haplotype) needed for communities in Northeast Africa to encounter animal husbandry.

This is where the progression from small stock (goats and sheep) in the Levantine region to the incorporation of domesticated cattle seems to be the most likely trajectory and argues against a reverse trajectory in Northeast Africa, where there would be a two-thousand-year gap between the earliest habitually domesticated cattle and the first caprines according to the early independent African centre of domestication model.

What is clear from the growing body of data on *Bos taurus* DNA is that its domestication happened outside of North Africa in the Middle Euphrates Valley. The first generation of genetic results (Bradley et al. 1996) tended to interpret signatures of introgressive capture for multiple domestication centres. The results from modern DNA analyses, coupled with (a) this re-examination of the ecological underpinnings of the early African cattle domestication model and (b) the dates of the appearances of caprine and cattle domesticates in a minimum of two diffusionist waves via different land and sea routes from a current bracketed date of c. 6300 BC onwards, show that the time has come to abandon the long-standing hypothesis of an early Holocene independent centre of cattle domestication in Northeast Africa.

References

Achilli, A., Olivieri, A., Pellecchia, M., Uboldi, C., Colli, L., Al-Zahery, N., et al. (2010). Mitochondrial genomes of extinct aurochs survive in domestic cattle. *Current Biology, 18,* R157–R158.

Ajmone-Marsan, P., Garcia, J., Lenstra, J., & Consortium, G. (2010). On the origin of cattle: How aurochs became cattle and colonized the world. *Evolutionary Anthropology, 19,* 148–157.

Applegate, A., Gautier, A., & Duncan, S. (2001). The north tumuli of the Nabta Late Neolithic ceremonial complex. In F. Wendorf, R. Schild et al. (Eds.), *Holocene settlement of the Egyptian Sahara (volume 1): The archaeology of Nabta Playa* (pp. 468–488). London: Kluwer Academic/Plenum Publishers.

Barich, B. (2016). The introduction of Neolithic resources to North Africa: A discussion in light of the Holocene research between Egypt and Libya. *Quaternary International, 410,* 198–216.

Barich, B., & Lucarini, G. (2008). The Nile Valley seen from the Oases: The contribution of Farafra. In B. Midant-Reynes & Y. Tristant (Eds.), *Egypt at its origins 2* (pp. 569–584). Leuven: Peeters Publishers.

Barich, B., Lucarini, G., Hamdan, M., & Hassan, F. (Eds.). (2014). *From lake to sand: The archaeology of Farafra Oasis, Western Desert, Egypt*. Firenze: All'Insegna del Giglio.

Beja-Pereira, A., Caramelli, D., Lalueza-Fox, C., Vernesi, C., Ferrand, N., Casoli, A., et al. (2006). The origin of European cattle: Evidence from modern and ancient DNA. *PNASI, 103,* 8113–8118.

Biagetti, S., & di Lernia, S. (2013). Holocene deposits of Saharan rock shelters: The case of Takarkori and other sites from the Tadrart Acacus mountains (Southwest Libya). *African Archaeological Review, 30,* 305–338.

Boivin, N., & Fuller, D. (2009). Shell middens, ships and seeds: Exploring coastal subsistence, maritime trade and the dispersal of domesticates in and around the ancient Arabian Peninsula. *Journal of World Prehistory, 22,* 113–180.

Bollongino, R., Burger, J., Powell, A., Mashkour, M., Vigne, J.-D., & Thomas, M. (2012). Modern taurine cattle descended from small number of Near-Eastern founders. *Molecular Biology and Evolution, 29,* 2101–2104.

Bonfiglio, S., Ginja, C., De Gaetano, A., Achilli, A., Olivieri, A., Colli, L., et al. (2012). Origin and spread of *Bos taurus*: New clues from mitochondrial genomes belonging to Haplogroup T1. *PLoS ONE, 7,* e38601.

Bradley, D., MacHugh, D., Cunningham, P., & Loftus, R. (1996). Mitochondrial diversity and the origins of African and European Cattle. *PNAS, 93,* 1531–1535.

Bradley, D., & Magee, D. (2006). Genetics and origins of domestic cattle. In M. Zeder, D. Bradley, E. Emshwiller, & B. Smith (Eds.), *Documenting domestication: New genetic and archaeological paradigms* (pp. 317–328). Berkeley: University of California Press.

Brass, M. (2003). Tracing the origins of the Ancient Egyptian cattle cult. In A. Eyma & C. Bennett (Eds.), *A delta-man in Yebu: Occasional volume of the Egyptologists' Electronic Forum* (Vol. 1, pp. 101–110). Parkland: Universal Publishers.

Brass, M. (2007). Reconsidering the emergence of social complexity in early Saharan pastoral societies, 5000–2500 BC. *Sahara, 18,* 1–16.

Brass, M. (2013). Revisiting a hoary chestnut: The nature of early cattle domestication in Northeast Africa. *Sahara, 24,* 7–12.

Brooks, N. (2005). The environment–society nexus in the Sahara from prehistoric times to the present day. *The Journal of North African Studies, 304,* 253–292.

Caesar, J. (1869). *Caesar's Gallic War* (1st Ed.) (Trans. W. A. McDevitte, W. S. Bohn). Harper's New Classical Library. New York: Harper & Brothers.

Capellini, I., & Gosling, L. M. (2007). Habitat primary production and the evolution of body size within the hartebeest clade. *Biological Journal of the Linnean Society, 92,* 431–440.

Caramelli, D. (2006). The origins of domesticated cattle. *Human Evolution, 21,* 107–122.

Churcher, C. (1983). Dakhleh oasis project—Palaeontology: Interim report on the 1982 field season. *Journal Society for the Study of Egyptian Antiquities, 8,* 178–187.

Close, A. (2001). Site E-75-8: Additional excavation of the seventh millennium site at Nabta Playa. In F. Wendorf, R. Schild, & Associates. (Eds.), *Holocene settlement of the Egyptian Sahara (Volume 1): The archaeology of Nabta Playa* (pp. 352–385). New York: Kluwer Academic/Plenum Publishers.

Close, A. (2002). Sinai, Sahara, Sahel: The introduction of domestic caprines to Africa. In Jennerstrasse 8 (Ed.), *Tides of the desert: Contributions to the archaeology and environmental history of Africa in honour of Rudolph Kuper* (pp. 459–469). Köln: Heinrich Barth Institut.

Clutton-Brock, J. (1993). The spread of domestic animals in Africa. In T. Shaw, P. Sinclair, B. Andah, & A. Okpoko (Eds.), *The archaeology of Africa: Food, metals and towns* (pp. 61–70). London: Routledge.

Connor, D. (1984). The Kiseiba Plateau and Bir Murr Playa. In F. Wendorf, R. Schild, & A. Close (Eds.), *Cattle-keepers of the Eastern Sahara: The Neolithic of Bir Kiseiba* (pp. 350–403). Dallas: Department of Anthropology, Institute for the Study of Earth and Man, Southern Methodist University.

Conolly, J., Colledge, S., Dobney, K., Vigne, J.-D., Peters, J., Stopp, B., et al. (2011). Meta-analysis of zooarchaeological data from SW Asia and SE Europe provides insight into the origins and spread of animal husbandry. *Journal of Archaeological Science, 38,* 538–545.

Crassard, R., & Drechsler, P. (2013). Towards new paradigms: Multiple pathways for the Arabian Neolithic. *Arabian Archaeology and Epigraphy, 24,* 3–8.

Cremaschi, M., Zerboni, A., Mercuri, A., Olmi, L., Biagetti, S., & Di Lernia, S. (2014). Takarkori rock shelter (SW Libya): An archive of Holocene climate and environmental changes in the central Sahara. *Quaternary Science Reviews, 101,* 36–60.

Cremaschi, M., Zerboni, A., Spöti, C., & Felletti, F. (2010). The calcareous tufa in the Tadrat Acacus Mt. (SW Fezzan, Libya): An early Holocene palaeoclimate archive in the central Sahara. *Palaeogeography, Palaeoclimatology, Palaeoecology, 287,* 81–94.

Decker, J., McKay, S., Rolf, M., Kim, J., Alcala, A., Sonstegard, T., et al. (2014). Worldwide patterns of ancestry, divergence, and admixture in domesticated cattle. *PLoS Genetics, 10,* 1–14.

Di Lernia, S. (1999). Discussing pastoralism: The case of the Acacus and surroundings (Libyan Sahara). *Sahara, 11,* 7–20.

Di Lernia, S. (2001). Dismantling dung: Delayed use of food resources among Early Holocene foragers of the Libyan Sahara. *Journal of Anthropological Archaeology, 20,* 408–441.

Di Lernia, S. (2004). Book review: 'Holocene settlement of the Egyptian Sahara. Volume 1: The archaeology of Nabta Playa'. *African Archaeological Review, 21,* 49–57.

Di Lernia, S. (2006). Building monuments, creating identity: Cattle cult as a social response to rapid environmental changes in the Holocene Sahara. *Quaternary International, 151,* 50–62.

Di Lernia, S. (2013). The emergence and spread of herding in Northern Africa: A critical reappraisal. In P. Mitchell & P. Lane (Eds.), *Oxford handbook of African archaeology* (pp. 523–536). Oxford: Oxford University Press.

Di Lernia, S., & Manzi, G. (2002). *Sand, stones, and bones: The archaeology of death in the Wadi Tanezzuft Valley (5000–2000 BP).* Firenze: All'insegna del giglio.

Drake, N., Blench, R., Armitage, S., Bristow, C., & White, K. (2011). Ancient watercourses and biogeography of the Sahara explain the peopling of the desert. *PNAS, 108,* 458–462.

Drechsler, P. (2007) *The dispersal of the Neolithic over the Arabian Peninsula.* BAR International Series 1969. Oxford: Archaeopress.

Edwards, C., Bollongino, R., Scheu, A., Chamberlain, A., Tresset, A., Vigne, J.-D., et al. (2007). Mitochondrial DNA analysis shows a Near Eastern Neolithic origin for domestic cattle and no indication of domestication of European aurochs. *Proceedings of the Royal Society B, 274,* 1377–1385.

Ehret, C. (1993). Nilo-Saharans and the Saharo-Sudanese Neolithic. In T. Shaw, P. Sinclair, B. Andah, & A. Okpoko (Eds.), *The archaeology of Africa: Food, metals and towns* (pp. 104–125). London: Routledge.

El Hadidi, M. (1980). Vegetation of the Nubian Desert (Nabta region). In F. Wendorf & R. Schild (Eds.), *Prehistory of the Eastern Sahara* (pp. 345–351). London: Academic Press.

Gautier, A. (1980). Appendix 4. Contributions to the archaeozoology of Egypt. In F. Wendorf & R. Schild (Eds.), *Prehistory of the Eastern Sahara* (pp. 317–337). London: Academic Press.

Gautier, A. (1984). Archaeozoology of the Bir Kiseiba region, Eastern Sahara. In F. Wendorf, R. A. Schild, & A. E. E. Close (Eds.), *Cattle-keepers of the Eastern Sahara: The Neolithic of Bir Kiseiba* (pp. 49–72). Dallas: Southern Methodist University.

Gautier, A. (1987). Prehistoric men and cattle in North Africa: A dearth of data and a surfeit of models. In A. Close (Ed.), *Prehistory of arid North Africa: Essays in honor of Fred Wendorf* (pp. 163–187). Dallas: Southern Methodist University Press.

Gautier, A., Wendorf, F., Schild, R., & Associates. (2001). The Early to Late Neolithic archeofaunas from Nabta Playa and Bir Kiseiba. In F. Wendorf & R. Schild (Eds.), *Holocene settlement of the Egyptian Sahara (Volume 1): The archaeology of Nabta Playa* (pp. 609–635). New York: Kluwer Academic/ Plenum Publishers.

Goodfriend, G. (1991). Holocene trands in ^{18}O in land snail shells from the Negev Desert and their implications for changes in rainfall source areas. *Quaternary Research, 35,* 417–426.

Grigson, C. (2000). *Bos africanus* (Brehm)? Notes on the archaeozoology of the native cattle of Africa. In R. Blench & K. MacDonald (Eds.), *The origins and development of African livestock: Archaeology, genetics, linguistics and ethnography* (pp. 38–60). London: UCL Press.

Guagnin, M., Shipton, C., Martin, L., & Petraglia, M. (In press). The Neolithic site of Jebel Oraf 2, northern Saudi Arabia: First report of a directly dated site with faunal remains. *Archaeological Research in Asia.*

Halwagy, R. (1961). The vegetation of the semi-desert north east of Khartoum, Sudan. *Oikos, 12,* 87–110.

Hanotte, O., Bradley, D., Ochieng, J., Verjee, Y., Hill, E., & Rege, J. (2002). African pastoralism: Genetic imprints of origins and migrations. *Science, 296,* 336–339.

Haynes, C. (2001). Geochronology and climate change of the Pleistocene-Holocene transition in the Darb el Arba'in Desert, Eastern Sahara. *Geoarchaeology, 16,* 119–141.

Haynes, C., Eyles, C., Pavlish, L., Richtie, J., & Rybak, M. (1989). Holocene palaeoecology of the eastern Sahara: Selima Oasis. *Quaternary Science Reviews, 8,* 109–136.

Haynes, C., & Haas, H. (1980). Radiocarbon evidence for Holocene recharge of groundwater, Western Desert, Egypt. *Radiocarbon, 22,* 705–717.

Helmer, D., Gourichon, L., Monchot, H., Peters, J., & Saña Segui, M. (2005). Identifying early domestic cattle from Pre-Pottery Neolithic sites on the middle Euphrates using sexual dimorphism. In J. Vigne, J. Peters, & D. Helmer (Eds.), *The first steps of animal domestication* (pp. 86–95). Oxford: Oxbow Books.

Hély, C., Lézine, A.-M., & Contributors A. (2014). Holocene changes in African vegetation: Tradeoff between climate and water availability. *Climate of the Past, 10,* 681–686.

Honegger, M. (2005). Kerma et les débuts du néolithique africain. In C. Bonnet & M. Honegger (Eds.), *Les fouilles archéologiques de Kerma (Soudan)*. Genava 53 (pp. 239–249). Geneva: Musée de Genève.

Ingold, T. (1980). *Hunters, pastoralists, and ranchers: Reindeer economics and their transformations*. Cambridge: Cambridge University Press.

Issawi, B., & el Hinnawi, M. (1984). Contributions to the study of the playas in the southeastern part of the Western Desert of Egypt. In F. Wendorf, R. A. Schild, & A. E. E. Close (Eds.), *Cattle-keepers of the Eastern Sahara: The Neolithic of Bir Kiseiba* (pp. 41–48). Dallas: Southern Methodist University.

Jórdeczka, M., Królik, H., Masojć, M., & Schild, R. (2011). Early Holocene pottery in the Western Desert of Egypt: New data from Nabta Playa. *Antiquity, 85,* 99–115.

Jórdeczka, M., Królik, H., Masojć, M., & Schild, R. (2013). Hunter–gatherer cattle-keepers of Early Neolithic El Adam type from Nabta Playa: Latest discoveries from Site E–06–1. *African Archaeological Review, 30,* 253–284.

Kuper, R., & Kröpelin, S. (2006). Climate-controlled Holocene occupation of the Sahara: Motor of Africa's evolution. *Science, 313,* 803–807.

Larson, G., & Fuller, D. (2014). The evolution of animal domestication. *Annual Review of Ecology Evolution and Systematics, 45,* 115–136.

Lesur, J., Briois, F., Midant-Reynes, B., & Wuttman, M. (2011). Domesticates and wild game in the Egyptian Western Desert at the end of the 5th millennium BC: The fauna from KS 43, Kharga Oasis. In H. Jousse & J. Lesur (Eds.), *People and animals in Holocene Africa Recent advances in archaeozoology* (pp. 59–74). Frankfurt-am-Main: Africa Magna Verlag.

Linseele, V. (2004). Size and size change of the African aurochs. *Journal of African Archaeology, 2,* 165–185.

Linseele, V. (2013). Early stock keeping in northeastern Africa: Near Eastern influences and local developments. In N. Shirai (Ed.), *Neolithisation of Northeastern Africa* (pp. 97–108). Berlin: Ex Oriente.

Linseele, V., Van Neer, W., Thys, S., Phillipps, R., Cappers, R., Wendrich, W., et al. (2014). New archaeozoological data from the Fayum 'Neolithic' with a critical assessment of the evidence for early stock keeping in Egypt. *PLoS ONE, 9,* e108517.

MacDonald, K. (1998). Before the empire of Ghana: Pastoralism and the origins of cultural complexity in the Sahel. In G. Connah (Ed.), *Transformations in Africa: Essays on Africa's later past* (pp. 71–103). London: Leicester University Press.

MacDonald, K. (2000). The origins of African livestock: Indigenous or imported? In R. Blench & K. MacDonald (Eds.), *The origins and development of African livestock: Archaeology, genetics, linguistics and ethnography* (pp. 2–17). London: UCL Press.

Madella, M., García-Granero, J., Out, W., Ryan, P., & Usai, D. (2014). Microbotanical evidence of domestic cereals in Africa 7000 years ago. *PNAS, 9,* e110177.

Magee, P. (2014). *The archaeology of prehistoric Arabia: Adaptation and social formation from the Neolithic to the Iron Age*. Cambridge: Cambridge University Press.

Manning, K., & Timpson, A. (2014). The demographic response to Holocene climate change in the Sahara. *Quaternary Science Reviews, 101,* 28–35.

Manning, K., Timpson, A., Shennan, S., & Crema, E. (2015). Size reduction in early European domestic cattle relates to intensification of Neolithic herding strategies. *PLoS ONE, 10,* e0141873.

Marshall, F., & Hildebrand, E. (2002). Cattle before crops: The beginnings of food production in Africa. *Journal of World Prehistory, 16,* 99–143.

Marshall, F., & Weissbrod, L. (2011). Domestication processes and morphological change: Through the lens of the donkey and African pastoralism. *Current Anthropology, 52,* S397–S413.

McCorriston, J., & Martin, L. (2009). Southern Arabia's early pastoral population history: Some recent evidence. In M. Petraglia & J. Rose (Eds.), *The evolution of human populations in Arabia: Palaeoenvironments, prehistory and genetics* (pp. 237–250). London: Springer.

McDonald, M. (1998). Early African pastoralism: View from Dakhleh Oasis (south central Egypt). *Journal of Anthropological Archaeology, 17,* 124–142.

McDonald, M. (2001). The late prehistoric radiocarbon chronology for Dakhleh Oasis within the wider environmental setting of the Egyptian Western Desert. In C. Marlow & A. Mills (Eds.), *The Oasis Papers 1: The proceedings of the First International Conference of the Dakhleh Oasis Project* (pp. 26–42). Oxford: Oxbow Books.

McDonald, M. (2009). Increased sedentism in the central oases of the Egyptian Western Desert in the early to mid-Holocene: Evidence from the peripheries. *African Archaeological Review, 26,* 3–43.

McDonald, M. (2016). The pattern of Neolithization in Dakhleh Oasis in the Eastern Sahara. *Quaternary International, 410,* 181–197.

Mercuri, A. (2008). Human influence, plant landscape evolution and climate inferences from the archaeobotanical records of the Wadi Teshuinat area (Libyan Sahara). *Journal of Arid Environments, 72,* 1950–1967.

Migowski, C., Stein, M., Prasad, S., Negendank, J., & Agnon, A. (2006). Holocene climate variability and cultural evolution in the Near East from the Dead Sea sedimentary record. *Quaternary Research, 66,* 421–431.

Nelson, K. (2001). Site E-75-8: A slice through time. In F. Wendorf, R. Schild, & Associates. (Eds.), *Holocene settlement of the Egyptian Sahara. Volume 1: The archaeology of Nabta Playa* (pp. 386–411). New York: Kluwer Academic/Plenum Publishers.

Neumann, K. (1989). Holocene vegetation of the eastern Sahara: Charcoal from prehistoric sites. *African Archaeological Review, 7,* 97–116.

Nicoll, K. (1998) *Holocene playas as sedimentary evidence for recent climate change in the presently hyperarid Western Desert, Egypt.* University of Arizona, Unpublished Ph.D thesis

Nicoll, K. (2001). Radiocarbon chronologies for prehistoric human occupation and hydroclimatic change in Egypt and northern Sudan. *Geoarchaeology, 16,* 47–64.

Nicoll, K. (2004). Records of recent environmental change and prehistoric human activity in Egypt and northern Sudan. *Quaternary Science Reviews, 23,* 561–580.

Olivieri, A., Gandini, F., Achilli, A., Fichera, A., Rizzi, E., Bonfiglio, S., et al. (2015). Mitogenomes from Egyptian cattle breeds: New clues on the origin of Haplogroup Q and the early spread of *Bos taurus* from the Near East. *PLoS ONE, 10,* e0141170.

Out, W., Ryan, P., García-Granero, J., Barastegui, J., Maritan, L., Madella, M., et al. (2016). Plant exploitation in Neolithic Sudan: A review in the light of new data from the cemeteries R12 and Ghaba. *Quaternary International, 412,* 36–53.

Paris, F. (1995). Essai de classification des monuments funéraires sahariens. *Bulletin de la Société Préhistorique Française, 92,* 549–553.

Paris, F. (1997). Burials and the peopling of the Adrar Bous region. In B. Barich & M. Gatto (Eds.), *Dynamics of populations, movements and responses to climatic change in Africa* (pp. 49–61). Rome: Bonsignori.

Perez-Pardal, L., Royo, L. J., Beja-Pereira, A., Chen, S., Cantet, R. J. C., Traore, A., et al. (2010). Multiple paternal origins of domestic cattle revealed by Y-specific interspersed multilocus microsatellites. *Heredity, 105,* 1–9.

Phillipps, R., Holdaway, S., Emmitt, J., & Wendrich, W. (2016). Variability in the Neolithic settlement patterns of the Egyptian Nile Valley. *African Archaeological Review, 33,* 277–295.

Reinold, J. (2000). *Archéologie au Soudan: Les civilisations de Nubie.* Paris: Éditions Errance.

Riemer, H. (2007) When hunters started herding: Pastro-foragers and the complexity of Holocene economic change in the Western Desert of Egypt. In Bollig, M., Bubenzer, O., Vogelsang, R., & Wotzka, H.-P. (Eds.) *Aridity, change and conflict in Africa* (pp. 105–144). Proceedings of an International ACACIA Conference held at Königswinter, Germany October 1–3, 2003. Köln: Heinrich Barth Institut.

Ritchie, J., & Haynes, C. (1987). Holocene vegetation zonation in the eastern Sahara. *Nature, 330,* 645–647.

Roset, J.-P., de Broin, F., Faure, M., Gayet, M., Guerin, C., & Mouchet, F. (1990). La faune de Tin Ouaffadene et d'Adrar Bous 10, deux gisements archéologiques de l'Holocène ancien au Niger nord-oriental. *Géodynamique, 5,* 67–89.

Rowland, J., & Bertini, L. (2016). The Neolithic within the context of northern Egypt: New results and perspectives from Merimde Beni Salama. *Quaternary International, 410*(Part A), 160–172.

Ryan, P., Out, W., García-Granero, J., Madella, M., & Usai, D. (2016). Plant microremains from the white deposits and dental calculus from Ghaba and R12 cemeteries. Identification and implications.

In S. Salvatori, D. Usai, & Y. Lecointe (Eds.), *Ghaba: An early Neolithic cemetery in Central Sudan* (pp. 109–120). Frankfurt-am-Main: Africa Magna Verlag.

Shirai, N. (2010). *The archaeology of the first farmer-herders in Egypt. New insights into the Fayum Epipalaeolithic and Neolithic*. Leiden: Leiden University Press.

Shirai, N. (Ed.) (2013). *Neolithisation of northeastern Africa*. Studies in early Near Eastern production, subsistence, and environment 16. Berlin: Ex Oriente.

Smith, A. (1984). The origins of food production in Northeast Africa. *Palaeoecology of Africa and the Surrounding Islands, 16,* 317–324.

Smith, A. (1986). Cattle domestication in North Africa. *African Archaeological Review, 4,* 197–203.

Smith, A. (1992). Origins and spread of pastoralism in Africa. *Annual Review of Anthropology, 21,* 125–141.

Smith, A. (2004). A prehistory of modern Saharan pastoralists. *Sahara, 15,* 43–58.

Smith, A. (2005). *African herders: Emergence of pastoral traditions*. Walnut Creek: AltaMira Press.

Smith, A. (2013). An appraisal of the terms 'Neolithic' and 'Neolithisation' for use in North Africa in the 21st century. In N. Shirai (Ed.), *Neolithisation of Northeastern Africa* (pp. 5–22). Berlin: Ex Oriente.

Smith, A. (2016). More thoughts on Khoekhoe origins. *The Digging Stick, 33,* 15–16.

Stock, F., & Gifford-Gonzalez, D. (2013). Genetics and African cattle domestication. *African Archaeological Review, 30,* 51–72.

Upadhyay, M., Chen, W., Lenstra, J., Goderie, C., MacHugh, D., Park, S., et al. (2017). Genetic origin, admixture and population history of aurochs (*Bos primigenius*) and primitive European cattle. *Heredity, 118,* 169–176.

Usai, D. (1997). Problemi di transizione culturale nell'Africa Nord-orientale durante l'Olocene Antico e Medio: misura della variabilità sincronica dei litocomplessi. Unpublished Ph.D. Dissertation. Napoli, Istituto Universitario Orientale.

Usai, D. (2005). Early Holocene seasonal movements between the desert and the Nile Valley: Details from the lithic industry of some Khartoum Variant and some Nabta/Kiseiba Sites. *Journal of African Archaeology, 3,* 103–115.

Usai, D. (2008). Tracing the movements of the Western Desert dwellers: Site 11-I-13 in Wadi Karagan, Sudanese Nubia, closely akin to El Ghorab or El Nabta. *Journal of African Archaeology, 6,* 219–233.

Van Neer, W., & Uerpmann, H. 1989. Palaeoecological significance of the Holocene faunal remains of the B.O.S. Missions. In Kuper, R. (Ed.), *Forschungen zur Umweltgeschichte der Ostsahara*. Africa Praehistorica 2 (pp. 307–341). Cologne: Heinrich Barth Institut.

Vermeersch, P., Linseele, V., Marinova, E., Van Neer, W., Moeyersons, J., & Rethemeyer, J. (2015). Early and Middle Holocene human occupation of the Egyptian Eastern Desert: Sodmein Cave. *African Archaeological Review, 32,* 465–503.

Vigne, J.-D. (2013). Domestication process and domestic ungulates: New observations from Cyprus. In S. College, J. Conolly, K. Manning, & S. Shennan (Eds.), *The origins and spread of domestic animals in Southwest Asia and Europe* (pp. 115–128). Walnut Creek: Left Coast Press.

Vigne, J.-D., Carrére, I., Saliéége, J., Person, A., Bocherens, H., Guilaine, J., et al. (2000). Predomestic cattle, sheep, goat, and pig during the late 9th and the 8th millennium cal BC on Cyprus: Preliminary results of Shillourokambos (Parekklisha, Limassol). In M. Mashkour, A. Choyke, H. Buitenhuis, & F. Poplin (Eds.), *Archaeozoology of the Near East, IV. ARC Publications No. 32* (pp. 83–106). Groningen: ARC.

Wasylikowa, K. (2001). Site E-75-6: Vegetation and subsistence of the Early Neolithic at Nabta Playa, Egypt, reconstructed from charred plant remains. In F. Wendorf, R. Schild, & Associates. (Eds.), *Holocene settlement of the Egyptian Sahara (Volume 1): The archaeology of Nabta Playa* (pp. 544–591). New York: Kluwer Academic/Plenum Publishers.

Wasylikowa, K., & van der Veen, M. (2004). An archaeobotanical contribution to the history of watermelon, *Citrullus lanatus* (Thunb.) Matsum. & Nakai (syn. *C. vulgaris* Schrad.). *Vegetation History and Archaeobotany, 13,* 213–217.

Wendorf, F., & Schild, R. (1980). *Prehistory of the Eastern Sahara*. London: Academic Press.

Wendorf, F., & Schild, R. (1994). Are the Early Holocene cattle in the Eastern Sahara domestic or wild? *Evolutionary Anthropology, 3,* 118–128.

Wendorf, F., & Schild, R. (1998). Nabta Playa and its role in northeastern African prehistory. *Journal of Anthropological Archaeology, 17,* 97–123.

Wendorf, F., Schild, R., & Associates. (2001). *Holocene settlement of the Egyptian Sahara (Volume 1): The archaeology of Nabta Playa*. New York: Kluwer Academic/Plenum Publishers.

Wendorf, F., Schild, R., & Close, A. (1984). *Cattle-keepers of the Eastern Sahara: The Neolithic of Bir Kiseiba*. Dallas: Southern Methodist University.

Wickens, G. (1982). Palaeobotanical speculations and Quaternary environments in the Sudan. In M. Williams & D. Adamson (Eds.), *A land between two Niles: Quaternary geology and biology of the Central Sudan* (pp. 23–50). Rotterdam: A. A. Balkema.

Wilson, P., Gilbert, G., & Tassie, G. (2014). *Sais 2: The prehistoric period*. London: Egypt Exploration Society.

Zeder, M. (2008). Domestication and early agriculture in the Mediterranean Basin: Origins, diffusion, and impact. *PNAS, 105,* 11597–11604.

Zeder, M. (2009). The Neolithic macro-(r)evolution: Macroevolutionary theory and the study of culture change. *Journal of Archaeological Research, 17,* 1–63.