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## New findings on the significance of Jebel Moya in the eastern Sahel

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**ABSTRACT** This paper presents new excavation data and new radiometric dates for Jebel Moya, south-central Sudan. These data suggest revisions to previous chronological understandings of the site. New excavations, initiated in 2017, show a longer, more continuous occupation of the site than has been previously recognised. Archaeozoological and archaeobotanical analyses provide evidence for domesticated taxa. Archaeobotanical evidence is dominated by domesticated sorghum (*Sorghum bicolor*), radiocarbon dated to *c.* 2550–2210 BC. Faunal remains include cattle and goat/sheep. A late third-millennium BC date on the human skeleton excavated in the 2017 season also shows that mortuary activity began early in the site's history, contemporary with domesticated faunal and botanical remains. These initial results indicate the long-term association of the site with pastoralism and agriculture and with environmental change. Jebel Moya's continued potential to serve as a chronological and cultural reference point for future studies in south-central Sudan and the eastern Sahel is reinforced.

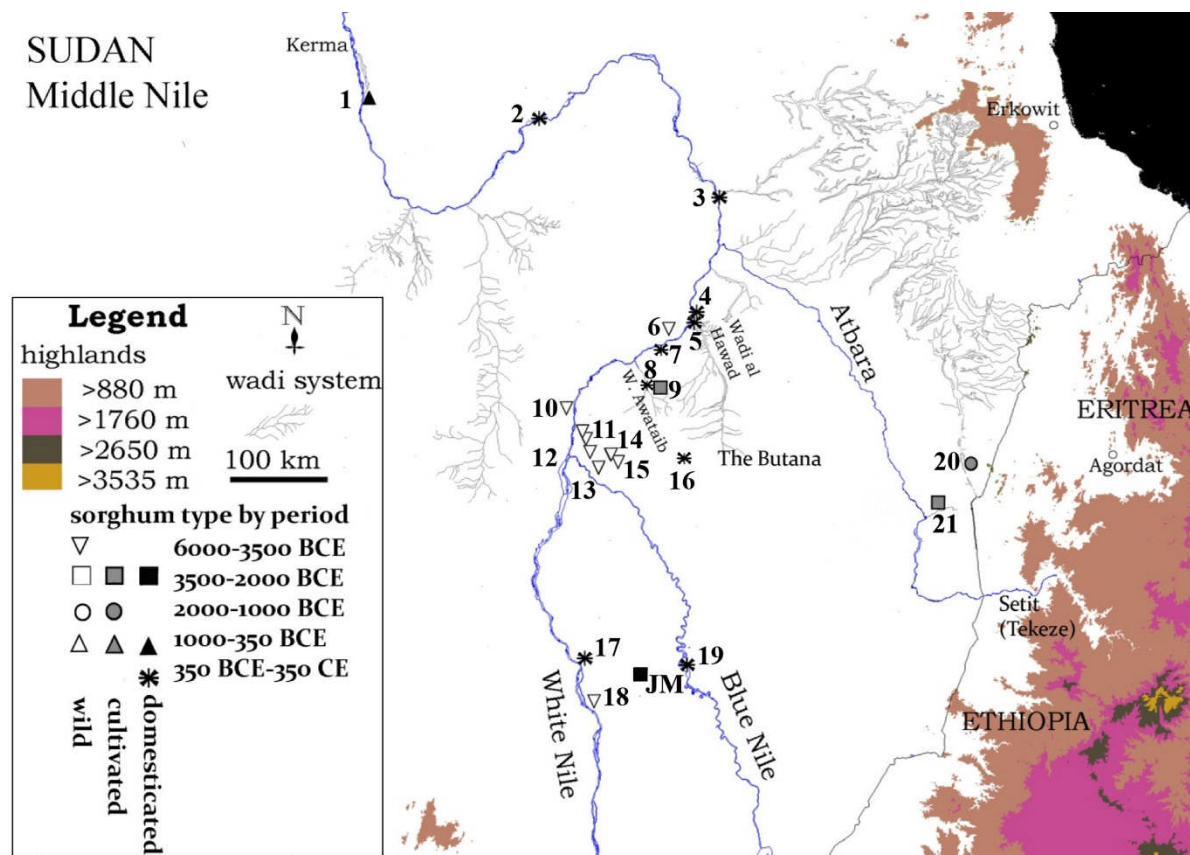
**KEYWORDS** Jebel Moya; cemeteries; sorghum; Sudan; agro-pastoralism

### Background

The establishment of mixed agropastoral economies and their dispersal across Africa is still poorly known especially true in the eastern Sahel and savanna (Sudan), despite this region having long been regarded as central to the origins of sorghum agriculture (Harlan *et al.* 1992; Clark 1984; Edwards 2004). Sorghum is the most important traditional cereal in Africa, but its domestication is less well documented archaeologically than other global cereals such as barley, maize, rice and wheat. Recently, studies of sorghum chaff imprints in ceramics and other clay artefacts have pushed back domestication processes to 3500–3000 BC at KG23 near the Atbara River (eastern Sudan) (Winchell *et al.* 2017, 2018; Fuller and Stevens 2018), with somewhat later evidence for probable mixed cultivation of sorghum and pearl millet by *c.* 1850 BC from K1 (Kassala, Sudan) (Beldados *et al.* 2018). Notably, there is no associated domesticated fauna at KG23. The mixture of savanna pastoralism and sorghum cultivation, previously more widely associated from the second millennium BC (Sadr 1991; Linseele 2010), formed the foundation of the later Meroitic state's economy (*c.* 350 BC – AD 350) until the present (Fuller 2014). Now, new archaeological fieldwork at Jebel Moya (south-central Sudan) has produced empirical data that confirms integrated sorghum cultivation, but not pearl millet, with pastoralism south of Khartoum by the mid-third millennium BC.

Jebel Moya is the largest massif in the southern Gezira Plain, approximately 250 km south of Khartoum (Figure 1). The 10.4 ha valley excavated by Henry Wellcome from 1911 to 1914 is

in the northeast corner of the massif (Figure 2). To date, 3136 human burials have been excavated. The University College London – University of Khartoum – NCAM Expedition to the South Gezira (Sudan), jointly directed by Michael Brass and Ahmed Adam, initiated new excavations at the site in October 2017. A key aim of this project is the application of new approaches and collaborations to enrich our understanding of health, identity, mobility and economic pathways in arid and semi-arid environments.



**Figure 1.** Map with location of Jebel Moya (JM) in relation to other sites with archaeological evidence of sorghum (wild, cultivated, and fully domesticated), numbered: (1) Kawa; (2) Umm-Muri; (3) Dangeil; (4) Meroe City; (5) Hamadab; (6) El Kadada; (7) Muweis; (8) Naqa (art) (9) Shaqadud; (10) Shaheinab; (11) El Zakiab and Kadero; (12) Umm Direiwa; (13) Sheikh Mustafa; (14) El Mahalab; (15) Sheikh el Amin; (16) Jebel Qeili (art); (17) Jebel Tomat; (18) Rabak; (19) Abu Geili; (20) Kasala K1 (21) Kasm el Girbha 23. Updated from Winchell et al 2017; Fuller and Stevens 2018.



**Figure 2.** Google Earth view of the Jebel Moya massif. The arrow is north and the excavated valley is in the north-east corner.

This paper presents the results from the 2017 field season, which produced important botanical, faunal and human skeletal data. We also report radiometric dating and isotopic results on some of these remains. Additionally, earlier OSL dates (Brass and Schwenniger 2013) have been slightly revised based on new soil sampling to recalculate the dose rate received by the quartz

mineral grains in pottery. Combined, these new radiometric dates provide improved chronological sequences and understanding of temporal context. The isotopic, faunal and floral data shed light on diet and broader environmental conditions. These results are subsequently integrated into an overview of the wider central Sudan setting and the implications for future research are detailed.

### Previous research

The archaeological data from Wellcome's expedition were originally analysed and published by Frank Addison (1949), who initially placed Jebel Moya in an uninterrupted sequence from 1000–400 BC. He later modified his dating to between the last centuries BC until the third century AD, contemporary with the Meroitic state to the north (Addison 1956, contra Arkell's 1955 ascription of it to the Napatan period, *c.* 750–350 BC). In 1973, Desmond Clark's team's brief visit yielded two radiocarbon dates on charcoal from the site dating from the first half of the third millennium BC (Table 1; Clark 1984).

Provenience	Material	Lab number	Uncalibrated bp	Calibrated BC
Test pit: Western perimeter	Charcoal	UCLA1874D	4200 ± 80	3009–2500
Test pit: Western perimeter	Charcoal	UCLA1874E	4200 ± 80	3009–2500

**Table 1.** J.D. Clark's C<sup>14</sup> dates for Jebel Moya. Adapted from Clark and Stemler (1975: Table 1) with a new calibration using OxCal 4.3 (IntCal13, Sigma 2 (95.4%) confidence interval).

In 1983, Randi Haaland and Ali el Mahi (el Mahi and Haaland 1984; Haaland 1984) conducted an archaeological survey between Jebel et Tomat and Rabak. The latter is situated about 70 km west of Jebel Moya and yielded Jebel Moya-like (Assemblage 2) pottery in Levels 2 and 3 (el Mahi and Haaland 1984: 30; Haaland 1987). The radiocarbon date on shell from Level 2 was 4490 ± 100 BP (T-5132, 3378–2909 cal. BC) and unpublished cattle remains were also stated to have been present in the upper layers (Haaland 1984). The association between the dated shell and the pottery is unknown, due to the lack of discernible stratigraphy for the cross-site correlation of cultural layers. Furthermore, no correction was made to account for any potential freshwater reservoir effect, which would have yielded too early a date as a result of 'hard water' with dissolved old carbonates (Brass 2016: 56).

In 1991, Isabelle Caneva recognised a previously unidentified Mesolithic component to the Jebel Moya pottery collection at the British Museum, attributed to the late sixth/early fifth millennia BC. Finally, Rudolf Gerharz (1994) revisited the issue of chronology, but relied exclusively upon Addison's dataset, Caneva's study and the conclusions reached by Haaland (1987) and Clark (Clark and Stemler 1975) over erroneous similarities with pottery wares from the Butana area to the east of the Blue Nile. Gerharz's first mortuary phase spanned the period *c.* 3000–1000 BC, with burials in random fashion outside whichever area of the valley was not being used by grass huts at the time. His second phase spanned *c.* 800–100 BC, with the burials occurring in the east and northeast sectors of the valley.

More recently, Brass (2016) utilised Wellcome's archives in the United Kingdom, which provided a statistically rigorous definition of the pottery assemblages curated at the British Museum, as well as the first absolute dates for the second and third assemblages (Table 2) (Brass and Schwenniger 2013): Assemblage 1 (Late Mesolithic, late sixth millennium BC

based on ceramic parallels (Caneva 1991; Salvatori, 2012), Assemblage 2 (*c.* 1700–700 BC) and Assemblage 3 (*c.* 100 BC – mid-first millennium AD). Assemblage 3 pottery was found at the agro-pastoral settlement of Abu Geili, approximately 30 km to the east of Jebel Moya on the banks of the Blue Nile (Addison 1950; Crawford and Addison, 1951). A lump of charred sorghum grains and spikelets from Abu Geili in the University College’s Institute of Archaeology’s collections was AMS dated to  $1790 \pm 40$  BP (BETA 194245) (calibrated: AD 127– 344) (Fuller 2014: 169). The vast majority, if not all, of the 3135 human burials at Jebel Moya were assigned by Brass (2016) to the third phase, contemporary with the flourishing and end of the Nilotic Meroitic state to the north (Brass 2015, 2016). The occupational lifestyle of the inhabitants in the third phase was regarded as pastoral by Brass based upon burials including cattle remains, the presence of cattle figurines and Rachel Hutton MacDonald’s (1999) work on human dental caries showing results consistent with the inhabitants of the final phase being pastoralists.

Laboratory code	Brass’ Assemblage attribution	Previous OSL age estimate (years before 2012)	Revised OSL age estimate (years before 2019)	Revised calibrated dates
X5291	3	$1760 \pm 295$	$1880 \pm 300$	161 BC – AD 439
X5292	2	$3245 \pm 755$	$3510 \pm 795$	2286–696 BC
X5293	3	$1490 \pm 270$	$1620 \pm 295$	AD 104–694
X5294	2	$3435 \pm 260$	$3720 \pm 205$	1906–1496 BC
X5295	2	$3250 \pm 445$	$3480 \pm 435$	1896–1026 BC
X5296	3	$1545 \pm 535$	$1680 \pm 575$	236 BC – AD 914

**Table 2.** Summary of the previous (2012) and revised (2019) OSL dating results on Jebel Moya sherds curated at the British Museum by the Research Laboratory for Archaeology and the History of Art (Oxford University).

### The 2017 field season

Occurring in October 2017, new material unearthed by the project team is opening up new avenues of research (Figures 3a-e).

#### *New insights into chronology*

A gully examined by us next to Trench 2 confirmed the geological strata and its order as described by Wellcome’s excavators: Stratum A is a darker brown-grey, Stratum B is lighter and grey, while Strata C and D are different shades of black/dark grey. The relative association of the pottery assemblages suggested and described by Brass (2016) was also confirmed by scraping into the exposed gully strata: Assemblage 1 was present in Stratum D, Assemblage 2 predominantly in Stratum C and Assemblage 3 in Strata A and B. Friable bone is also visible in the gully’s stratigraphy. In future field seasons, Trench 2 will be taken down to bedrock and also expanded to encompass the gully.

A total of seven AMS-radiocarbon dates have been derived from sampling *in situ* remains (Tables 3-5): one from Spit 2 in Trench 1; four from Spits 5, 12 and 14 in Trench 2; one on dental enamel from Trench 3’s human skeleton; and one from Spit 9 in Trench 4.

Trench 1 spits	Geological strata and dates	Trench 2 spits	Geological strata and dates	Trench 3 spits	Geological strata and dates	Trench 4 spits	Geological strata and dates
1	A	1	A	N/A	C (2470–2210 BC)	1	A
2	A (2558–2300 BC)	2	A			2	A
3	B	3	A			3	A
4	B	4	A & B			4	B
5	B	5	B (766–509 BC)			5	B
6	B	6	B			6	B
7	B	7	B			7	B
8	B	8	B			8	B
9	B	9	B			9	C (2465–2211 BC)
		10	B			10	C
		11	B				
		12	B (1613–1502 BC)				
		13	C				
		14	C (2575–2350 BC; 2866–2579 BC)				
		15	C				

**Table 3.** The excavated trenches with the number of spits, assigned geological strata and calibrated radiocarbon dates.

Material	Context	Lab number	Age <sup>14</sup> C (bp)	Calibrated age	δ <sup>13</sup> C ‰ VPDB
<b>Sorghum grain</b>	Trench 1, Spit 2	Beta-501555	3930 ± 30	2558– 2300 BC	-14.7
<b>Capra/Ovis maxillary molar</b>	Trench 2, Spit 5	OxA-X-3000-40	2473 ± 21	766–509 BC	-5.31 (carbonate)
<b>Bos maxillary premolar</b>	Trench 2, Spit 12	OxA-X-3000-39	3269 ± 22	1613–1502 BC	-0.25 (carbonate)

<b>Sorghum husks</b>	Trench 2, Spit 14	Beta-501557	3970 ± 30	2575–2350 BC	-9.8
<b>Ziziphus sp. endocarp</b>	Trench 2, Spit 14	Beta-501556	4120 ± 30	2866–2579 BC	-20.9
<b>Sorghum husks</b>	Trench 4, Spit 9	Beta-501554	3870 ± 30	2465–2211 BC	-9.6

**Table 4.** AMS dates on botanical and faunal remains from trenches 1, 2 and 4. Dating was done by Beta Analytic and the Research Laboratory for Archaeology and the History of Art (Oxford University). Calibration: OxCal 4.3.2, Intcal13, Sigma 2 (95.4%).

<b>Material</b>	<b>Context</b>	<b>Lab number</b>	<b>Age <sup>14</sup>C (bp)</b>	<b>Calibrated age</b>
Molar dental enamel	Trench 3	GdA-5760	3880 ± 40	2470–2210 BC

**Table 5.** AMS date for the human skeleton from Trench 3, by the Radiocarbon Laboratory, Institute of Physics – Centre for Science and Education, Silesian University of Technology. Calibration: OxCal 4.3.2, Intcal13, Sigma 2 (95.4%).

Trench 2, with the most dates, has a coherent chronological and stratigraphic order. The dates from the lower part of Trench 4 and the human skeleton of Trench 3 are contemporary with the lower part of Trench 2, i.e. *c.* 2550–2210 BC. This suggests both widespread occupation of the site during the later third millennium BC and some stratigraphically intact depositions and sequences. The odd date out is the third-millennium date on sorghum from Trench 1's Spit 2, as this comes so high up in the sequence and is associated with Stratum A and with Assemblage 3 ceramics. This dated sorghum material would appear to be out of phase and residual with respect to its position and ceramic association. This trench is the closest to the location where Wellcome's workmen had their camp. Given the soil disturbance and possible transference during the course of Wellcome's excavation, there is a possibility that the Trench 1 sample was reworked from deeper dug up sediment. A future dating programme will need to encompass the faunal remains from the other strata in Trench 1 to arrive at a resolution of this discrepancy.

Supplementing these new AMS dates are revised OSL dates (Table 2). A soil sample from Trench 2's Spit 14 was sent to the Research Laboratory for Archaeology and the History of Art at Oxford University. The internal and external dose rates were recalculated and revised dates produced for the original six British Museum pottery samples. The OSL dates should not be ignored given that a new soil sample has resulted in a small but noticeable shift to older age calculations and that their uppermost range is consistent with the AMS dates for the Neolithic and the archaeological evidence for the end of the main phase of burial activity 2000 years ago. However, further soil samples from Jebel Moya need to be obtained via light-proofed containers and new OSL dates done on newly excavated, *in situ* pottery.





**Figure 3a.** View towards the South-East indicating the locations of Trenches 1 and 2. Photo: CS.



**Figure 3b.** Taken from the same position as Figure 1, but facing eastwards. The positions of trenches 3 and 4 are indicated. Photo: CS.



**Figure 3c.** Profile of Trench 1. Photo: CS.



**Figure 3d.** Profile of Trench 2. Photo: CS.



**Figure 3e.** Profile of Trench 4. Photo: CS.

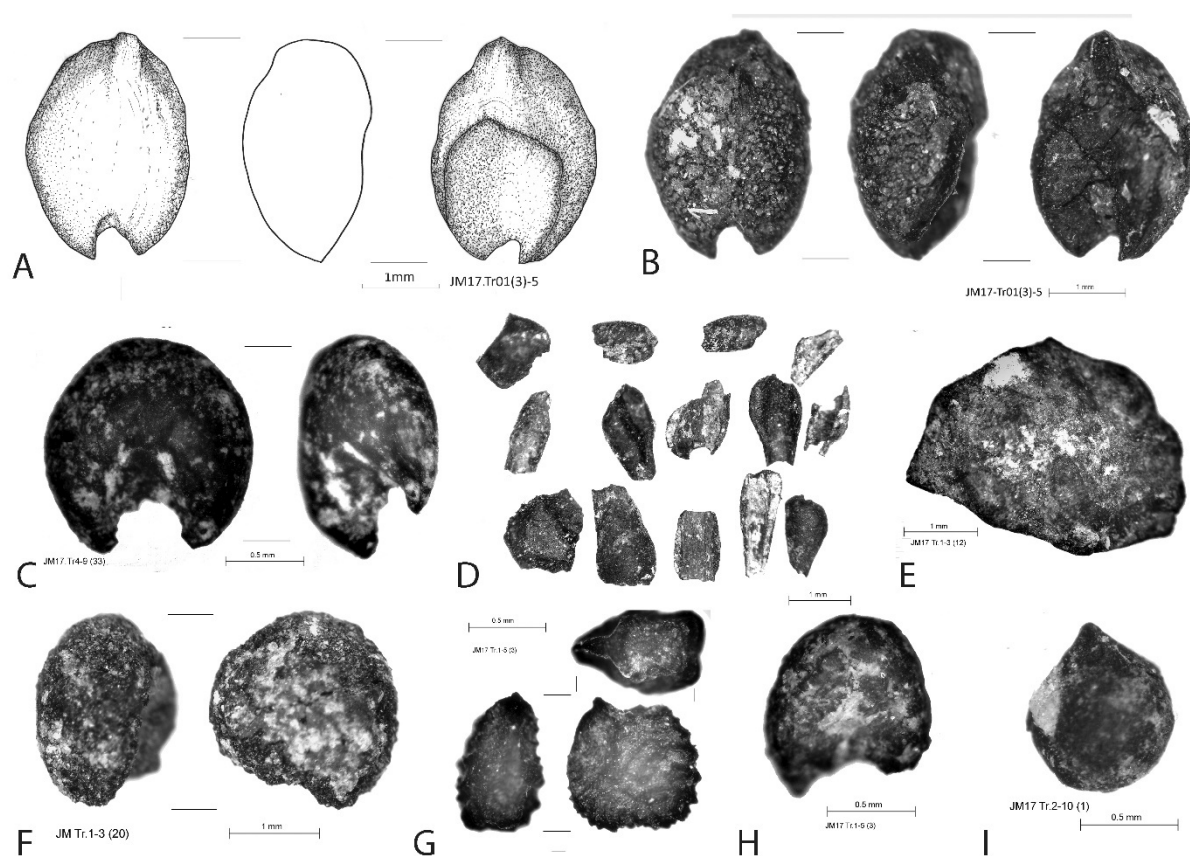
### *Archaeobotanical evidence from flotation*

Excluding the uppermost topsoil in each trench, sediment from each sampled spit throughout Trenches 1, 2 and 4 was collected for recovery through flotation. Each sample consisted of 20 litres of bulk sediment and two such samples were taken from each sampled spit. In total ~1720 litres were floated using simple washover bucket flotation (Pearsall 2000; Fuller 2008) at a reservoir (*hafir*) at the base of the massif. Flots were caught on a 250 micron mesh and bagged after being dried. Heavy fractions were wet sieved and 2 mm screens were used to check for small artefacts, bones and any obvious large/heavy plant remains that had been missed. In total, 43 flotation samples were collected.

Flotation samples were sorted in London by Stevens with identifications made by him and Fuller; use was made of the UCL Institute of Archaeology's reference collection. Preservation was by charring; a few uncharred remains were inferred to represent modern intrusive material. Wood charcoal was not studied, but 626 non-wood remains, mainly seeds/fruits/chaff or fragments thereof, were recovered (Supplementary Online Material Table 1). Charred plant remains were generally found in higher quantity and density in the lower deposits in each of the three trenches. This suggests that more intensive/sedentary occupation, and the routine processing of plant resources like crops, was more associated with the lower deposits than with the uppermost ones. In light of the dating and the identifiable plant remains, this suggests a more agricultural occupation is associated with the later third millennium BC.

Sorghum remains were by far the most common, including fragments of chaff (lemma/palea) and grains (Figure 4a-d, f). Identifiable sorghum items totalled 536, accounting for 85.6% of

all remains. These occurred across 63% of the samples. They are predominantly composed of charred chaff fragments (lemma/palea), but some grains and grain fragments were also found in each trench. The only other definite food plant is represented by fruit stones from *Ziziphus* sp. (Figure 4e) (jujube), a savanna shrub. Other fragments of possible nutshell and parenchyma tissue that could be from tubers hint at the use of additional wild plant resources. Other identifiable seeds include several grasses, including Panicoid grasses (e.g. *Echinochloa* sp.: Figure 4, H) that also could have been used as food, as they constitute a similar range to those known in Neolithic African grain assemblages (e.g. Stemler 1990; Wasylikowa and Dahlberg 2001). Some small legumes, *Chenopodiaceae*, the goosefoot grass (*Dactyloctenium* sp.) and *Lamiaceae* (Figure 4g, i) suggest that additional weedy taxa that were used as fuel; some could derive from the burning of animal dung. The presence of these assemblages highlights the need for more extensive archaeobotanical sampling, while further reference material is necessary to improve identification of the wild taxa. The dominance of sorghum remains suggests a likely dietary staple.



**Figure 4.** A. Line drawing of sorghum bicolor race bicolor grain (Tr. 1-Context 5, Flot#3, drawn by DQF). B. Photos of sorghum grain: ventral, lateral and dorsal views (Tr. 1-Context 5, Flot#3). C. Sorghum grain: dorsal and lateral views (Tr.4-Context 9, Flot#33); D. Sorghum husks (Tr.1-Context 3, Flot #20); E. *Ziziphus* endocarp fragment (Tr.1 Context 3, Flot#12); F. Sorghum grain: lateral and dorsal views (Tr.1-Context 3, Flot #20); G. *Dactyloctenium* cf. *aegyptium*: dorsal, lateral and basal views (Tr.1-Context 5, Flot #3); H. *Echinochloa* sp.: dorsal view (Tr.1-Context 5, Flot #3); I. *Lamiaceae* (Tr. 2-context 10, Flot#1). All photos: CS.

The sorghum grains and chaff both indicate the dominance of domesticated morphotypes of sorghum. Domestication in sorghum is indicated by changes in chaff and grain shape. In terms of chaff, the domestication process selected for non-shattering spikelets, which are usually

characterised by a torn rachilla and less frequently by a rip scar by which the bottom of the spikelet is torn (Winchell *et al.* 2017; Beldados *et al.* 2018; Fuller and Stevens 2018). Unfortunately, in charred chaff like that recovered here, these basal features are often not evident due to fragments coming from further up the spikelet or from damage (Figure 4d). Indeed, identification criteria for working with fragmentary charred spikelet bases in sorghum require further comparative study and more detailed documentation. Nevertheless, among the chaff remains there are some that show clear remnants of the torn rachilla, indicating the presence of the domesticated type.

The grains, although often fragmented and poorly preserved, appear to be broadly ovate in shape (e.g. Figure 4a-c, f). Wild sorghum grains are narrowly ovate, with an average length/width ratio of ~1.7, represented, for example, by charred archaeobotanical examples from early Holocene Nabta Playa (Wasylikowa and Dahlberg 2001) or Neolithic wild sorghum impressions studied by Stemler (1990) that have length/width ratios of between 1.6 and 2.7. In contrast, domesticated grains are larger and especially plumper, paralleling evolution in other cereals (Fuller *et al.* 2014, 2017). This is represented, for example, among archaeobotanical examples from the Meroitic period at Jebel Tomat, Abu Geili or Hamadab (Fuller 2014: Figure 14:4; Fuller and Stevens 2018: Figure 3), with length/width ratios of ~1.17 to ~1.28. Post-Meroitic desiccated grains from the Qasr Ibrim cemetery in Lower Nubia had a mean length/width ratio of 1.22 (Steele and Bunting 1982). Some data on archaeological charred sorghum grains from India suggest a range of length/width ratios of between 1 and 1.5 (cf. Kajale 1977; Saraswat 1986, 1993, 1997; Pokharia and Saraswat 1999). The well-preserved complete grains from Jebel Moya are even slightly more plump than this with a length/width ratio of ~1.33. We therefore conclude that the sorghum remains found in the 2017 field season appear to be predominantly domesticated.

### ***Preliminary archaeozoological analysis***

Analysis of the faunal remains by MacDonald is ongoing, but preliminary results on diagnostic elements are available. Bones of cattle (*Bos sp.*), goats (*Capra hircus*), and probably sheep (*Ovis aries*) are present in Trenches 1, 2 and 4 and throughout the sampled stratigraphic sequences (Table 6). Interestingly, kob (*Kobus kob*) and waterbuck (*Kobus ellipsiprymnus*), both present in Trench 1 Spit 4, are highly territorial and associated with the local presence of permanent water sources. Neither of these animals have been recorded in the area during recent history or in the present. There is one small permanent water source on the outskirts of the modern Jebel Moya village at the base of the excavated valley, but no other surface water source is currently found in the immediate vicinity. The lower part of Trench 4 also produced an elephant (*Loxodonta africana*) molar.

The ecological requirements, particularly daily water, for kob and waterbuck (Spit 4, Trench 1; Stratum B) attest to wetter conditions than present with grassy savanna plains and some gallery forest before the first millennium BC. The ecology of dorcas gazelle (*Gazella dorcas*) in Spit 4 of Trench 2 suggests the presence of the current Sahelian semi-arid grasslands by the mid-first millennium BC.

<b>Trench</b>	<b>Spit</b>	<b>Identification</b>	<b>Body part</b>
1	3	<i>Canis</i> sp. (Dog or jackal)	Vertebra
	3	<i>Bos</i> (cattle)	Carpal (Lunate)

	4	<i>Kobus kob</i> (Kob)	Phalanges (first x 2), phalanx (third)
	4	<i>Homo sapiens</i> (humans)	Vertebral fragment
	4	<i>Numida/Gallus</i> (Guineafowl or chicken)	Tibiotarsus (distal)
	4	<i>Capra/Ovis</i> (goat/sheep)	Humerus (distal)
	4	<i>Bos</i> (cattle)	Maxillary molar (fragment), mandibular third molar, first phalanx (two fragments)
	4	<i>Kobus ellipsiprymnus</i> (Waterbuck)	Phalanx (third)
	4	<i>Alcephinae</i> (Hartebeest or Topi)	Phalanx (second)
2	4	<i>Gazella dorcas</i> (Dorcas Gazelle)	Phalanx (first, fragmentary)
	4	<i>Bos</i> (cattle)	Phalanx (first, fragmentary)
	4	<i>Capra/Ovis</i> (goat/sheep)	Metacarpal (distal)
	5	<i>Gazella dorcas</i> (Dorcas Gazelle)	Phalanx (first)
	5	<i>Capra/Ovis</i> (goat/sheep)	Astragalus, radius (proximal), maxillary molar
	5	<i>Capra hircus</i> (goat)	Horncore
	7	<i>Bos</i> (cattle)	Tibia/Fibula (distal)
	8	<i>Capra/Ovis</i> (goat/sheep)	Phalanx (first, proximal)
	8	<i>Bos</i> (cattle)	Mandibular third molar
	9	<i>Bos</i> (cattle)	Premolar (maxillary)
	9	<i>Capra/Ovis</i> (goat/sheep)	Metacarpal (distal)
	10	<i>Capra/Ovis</i> (goat/sheep)	Mandible (immature), ulna, scapula
	10	<i>Bos</i> (cattle)	Premolar (maxillary)
	12	<i>Bos</i> (cattle)	Premolar (maxillary x2), molar (second maxillary), phalanx (second)
	13	<i>Capra/Ovis</i> (goat/sheep)	Mandible (immature)
	13	<i>Bos</i> (cattle)	Premolar (maxillary)
	14	<i>Bos</i> (cattle)	Patella, phalanx (third), premolar (maxillary), mandible (distal part, no dentition), tooth row (maxillary), dentition (mandibular x 3)

	14	<i>Capra/Ovis</i> (goat/sheep)	Dentition (mandibular x 3)
4	6	<i>Bos</i> (cattle)	Metatarsal (proximal)
	6	<i>Capra/Ovis</i> (goat/sheep)	Phalanx (second), radius/ulna (shaft)
	6	<i>Loxodonta</i> (elephant)	Molar

**Table 6.** Important diagnostic faunal remains.

### ***The Trench 3 human skeleton***

The partially exposed skeletal remains were examined macroscopically by Kozieradzka-Ogunmakin to assess their state of preservation and completeness, estimate the sex and age-at-death of the individual and assess his/her physical health at the time of death. The skeletal recording was conducted in accordance with the British Association for Biological Anthropology and Osteoarchaeology's 2004 *Guidelines to the Standards of Recording Human Remains*.

The overall completeness of the skeleton was approximately 60–75% (Figure 5). The orientation was northwest. Its burial position was supine, with the head turned to the left, the arms extended and the hands placed below the pubis. The skeleton consisted of a fragmented cranium with partially preserved right maxilla and fragmented mandible, fragmented and incomplete left and right bones of the shoulder girdle and arms with wrist and hand bones, the vertebrae (C1-2, C6-7 and T12 not being present) and fragmented sacrum, extremely fragmented ribs, a fragmented right innominate and fragments of the left innominate, the right femur without its distal end and small fragments of the remaining long bones of the lower extremities.



**Figure 5.** Trench 3 skeletal remains *in situ*. Photo: MB

Sex and age-at-death estimations were based on current standards (Miles 1962; Brothwell 1981; Buikstra and Ubelaker 1994; Schwartz 2006; Cunningham *et al.* 2016). Visual assessment of observable morphological features of the cranium (mastoid process), the

mandible (mental protuberance and ramus) and the right innominate (sciatic notch, ischial tuberosity, acetabulum) allowed the individual's sex to be estimated as possible female. This was further supported by the overall gracility of the skeleton and metrical data (the right femoral head diameter = 38.4mm; <45mm = female, after Steele and Bramblett (1988).

The individual was a young adult at the time of death, based on the presence of third molars, minimal wear and the absence of marked changes in morphology of the auricular surface of the pelvis. Considering the incomplete fusion of the medial flake in the left clavicle and retained space between the first and second sacral elements, which are expected to be fused by the age of 27–30 years (Cunningham *et al.* 2016), the individual was likely aged 24–27 years at the time of death. Skeletal incompleteness and bone fragmentation precluded estimation of the individual's stature.

Visual examination revealed no abnormalities or pathological changes. Dental assessment confirmed the presence of nearly all the permanent teeth. The only teeth missing were the two lower central incisors, which were lost ante-mortem, most likely due to deliberate dental extraction or ablation (Figure 6). Similar patterns of dental extraction were also noted in the Jebel Moya skeletal collection housed at the Duckworth Laboratory (Hutton MacDonald 1999) and have been observed in the human remains at the northern Gezira site of Al Khiday (Jakob 2010). Dental attrition was minimal and largely restricted to the molar cusps, presenting a flat wear plane typically observed in hunter-gatherers and produced through the mastication of tough and fibrous foods (Smith 1984); this differs from the wear pattern observed in Jebel Moya individuals curated at the Duckworth Laboratory (University of Cambridge), who exhibited oblique wear angles observed in pastoralists and agriculturalists (Hutton MacDonald 1999). Furthermore, the maxillary incisors demonstrated advanced attrition with well-defined polished areas on their lingual aspect (Figure 7), with no equivalent wear on the corresponding mandibular dentition. The lingual surface attrition of the maxillary anterior teeth (LSAMAT) has been attributed to subsistence or occupational activities, or a mixture of the two, for example in shredding or peeling organic materials for consumption or utilitarian production (e.g. Irish and Turner 1987). Slight calculus deposits were noted predominantly on the lingual aspect of the premolars and molars. Caries lesions, associated with a high-carbohydrate diet, were recorded on the interproximal aspects of the right maxillary canine and first premolar.





**Figure 6.** Mandible showing healed alveolar sockets (arrow) following ante-mortem extraction of central incisors; note horizontal occlusal wear in molars. Photo: IK-O.



**Figure 7.** Lingual surface attrition of the maxillary anterior teeth (LSAMAT). Photo: IK-O.

Selected teeth (canine, first and third molars) and bone samples (rib and femur fragments) were collected for radiocarbon dating and stable isotopes analyses. Poor preservation and degradation of the collagen in bone tissue due to the semi-arid conditions meant that tooth enamel was used to obtain the carbon, oxygen and strontium isotopes data to shed light on the individual's diet and environmental conditions (Table 7).

Sample	Sex	Tooth	$\delta^{13}\text{C}_{\text{ca}}$ ‰ VPDB	$\delta^{18}\text{O}_{\text{ca}}$ ‰ VPDB	$\delta^{18}\text{O}_{\text{ca}}$ ‰ VSMOW	$^{87}\text{Sr}/^{86}\text{Sr}$
JM 003	?F	M3	-5.04	1.31	32.27	-
JM 003	?F	M1	-	-	-	0.707202
Botanical (modern)	-	-	-	-	-	0.706653

**Table 7.**  $\delta^{13}\text{C}_{\text{ca}}$ ,  $\delta^{18}\text{O}_{\text{ca}}$  and  $^{87}\text{Sr}/^{86}\text{Sr}$  values for the Jebel Moya individual and modern botanical sample. The carbon and oxygen stable isotopes analysis was performed at the Stable Isotope Laboratory, Centre for Arctic Gas Hydrate, Environment and Climate, the Arctic University of Norway in Trømsø. The instrument used was Thermo Scientific MAT253 IRMS + Gasbench II; standard deviation  $\leq 0.1\text{‰}$ . The strontium stable isotope analysis was performed at the Isotope Laboratory, Adam Mickiewicz University in Poznan; error  $\pm 0,000010$ .

### Isotopic data: contextualising ways of life in the Gezira Plain

The native grasses and sedges of the south-central Sudan use the  $\text{C}_4$  photosynthetic pathway. The average  $\delta^{13}\text{C}$  value of  $\text{C}_3$  plants is  $-28\text{‰}$  to  $-26.5\text{‰}$ , whereas  $\text{C}_4$  plants average  $-14\text{‰}$  to  $-12.5\text{‰}$  (van der Merwe 1982). However, no isotope studies have yet been undertaken on the modern plants in and around Jebel Moya. Sorghum and millet are  $\text{C}_4$  cereals. At Jebel Moya, the sorghum  $\delta^{13}\text{C}$  values are  $-14.7\text{‰}$ ,  $-9.8\text{‰}$  and  $-9.6\text{‰}$  (Table 4). The  $\delta^{13}\text{C}_{\text{carbonate}}$  value of  $-5.04\text{‰}$  for the human skeleton obtained from dental enamel is low.

The  $\delta^{13}\text{C}$  values from collagen and apatite should not be equated as they represent different parts of the diet. Collagen reflects largely the protein portion ( $\sim 70\%$ ) and apatite the entire diet inclusive of the energy component. The offset to get the value of the diet when apatite is used is approximately  $-12\text{‰}$  (Lee-Thorp 2008). When offsetting the JM 003 value of  $-5.04\text{‰}$ , the dietary value of approximately  $-17.04\text{‰}$  indicates a probable diet of 67%  $\text{C}_4$  and 33%  $\text{C}_3$ . Dated around 350 years earlier than JM003 is the  $\text{C}_3$  *Ziziphus* sp. endocast with a reading of  $-20.9\text{‰}$ , while caprines are present in contemporary levels from Trench 2 (Table 6). The later radiocarbon-dated *Capra/Ovis* maxillary molar's carbonate value of  $-5.39\text{‰}$  (offset: ca.  $-17.39\text{‰}$ ), and the *Bos* value of  $-0.25\text{‰}$  (offset: ca.  $-12.25\text{‰}$ ) is unsurprising in this context: cattle would have been general grazers, while goats would have consumed food leftovers, as well as leaves from bushes, shrubs and lower branches of trees, including fruits. Goats are also a valuable source of meat.

There is one comparative isotopic faunal dataset for the south-central Sudan: Al Khiday, just south of Khartoum along the White Nile, where  $\delta^{13}\text{C}_{\text{apatite}}$  values from human rib bones have been calculated for three phases (Iacumin *et al.* 2016). Only the Pre-Mesolithic populace had a majority  $\text{C}_4$  component ( $\sim 60\%$ ) in its diet. The median values are  $-14.3\text{‰}$  (Pre-Mesolithic),  $-18.4\text{‰}$  (Neolithic) and  $-18.5\text{‰}$  (Meroitic). The Pre-Mesolithic value is attributed to the consumption of  $\text{C}_4$  cereals, tubers and meat from animals grazing on  $\text{C}_4$  grasses and sedges. The lower values for the subsequent periods are attributed to a mixed agro-pastoral economy

inclusive of domesticated Near Eastern C<sub>3</sub> cereals (Buckley *et al.* 2014: 5; Madella *et al.* 2014; Iacumin *et al.* 2016; Out *et al.* 2016).

Iacumin *et al.* (2016: Table 3) also calculated  $\delta^{13}\text{C}_{\text{Carbonate}}$  for bovids and fish as follows: Modern (-7.2‰ bovid and -7.4‰ fish mean), Neolithic (-9.3‰ bovid, -2.3‰ fish mean), Late Mesolithic (-1.2‰ bovid, -2.8‰ fish mean), Middle Mesolithic (-1.1‰ bovid, -1.1‰ fish mean) and Early Mesolithic (-0.6‰ bovid, -2.5‰ fish mean). The unenriched values for Neolithic and modern bovids are stated by Iacumin *et al.* (2016) to be due to a higher C<sub>3</sub> component in their diet. If the bovid  $\delta^{13}\text{C}_{\text{Carbonate}}$  values are offset to  $\delta^{13}\text{C}_{\text{Diet}}$ , there is a question to be raised over whether the  $\delta^{13}\text{C}_{\text{Diet}}$  values for Al Khiday's Neolithic human remains could be partially due to consumption of C<sub>3</sub> browsers, including goats.

The JM 003 oxygen isotope values fall near the median range for the Al Khiday Neolithic bovids (31.9) and fish (28.8) (Iacumin *et al.* 2016). A dry environment during the Neolithic for Jebel Moya, although one wetter than at present as hypothesised by the White Nile's temperature being an average of 13°C lower than today (Iacumin *et al.* 2016), is also supported by the presence of *Kobus kob*.

## Discussion and conclusions

It is apparent that different ways of life were followed in different parts of the Sudan and the eastern Sahelian belt during later prehistory. In the Nilotic Nubian Neolithic (4500–3000 BC), people fished (hooks), herded livestock (cattle, goat, sheep) and utilised wild sorghum and millet (little or no cultivation) (Winchell *et al.* 2018). They were more mobile than during the preceding Mesolithic. Emmer and barley (winter crops originally domesticated in the Near East) were adopted and were present as far south as Al Khiday (Out *et al.* 2016).

In the Southern Atbai's Butana Group phase (3800–2800 BC), wild fauna were hunted. There was no livestock and little fishing. However, there are stone picks (for cultivation?) and some sickle-gloss chaff-tempered pottery. About 90% of the impressions on the pottery were of sorghum, of which approximately 50% are of domesticated sorghum (Winchell *et al.* 2017). In the succeeding Gash Group (2800–1700 BC) there was more site differentiation with ongoing domestication of sorghum and the start of the integration of livestock (Winchell *et al.* 2018).

The antiquity of Jebel Moya has been confirmed by direct AMS radiocarbon dating. AMS dates were taken on one *Ziziphus* sp. (jujube) stone endocast, one sorghum grain and two assemblages of multiple sorghum husks, as well as on the human skeleton and two animal bones (of domestic cattle and goat/sheep respectively). Thus far, the following periods can be discerned at Jebel Moya subject to ongoing investigation in future field seasons: (1) Late Mesolithic, late sixth millennium BC; (2) c. 2750–2250 BC; (3) mid-second millennium BC; and (4) c. 700 BC to 2000 years ago. The age gap between Spits 12 and 14 (c. 2650/2550–1550 BC) in Trench 2 indicates that there must have been erosional activity occurring, but micro-sedimentological analysis is required to assess this further.

It is now apparent that domesticated sorghum was present as early as 2500 BC at Jebel Moya, making this the second oldest domesticated sorghum assemblage yet found, after the KG23 impressions (Winchell *et al.* 2017). In future field seasons, we shall excavate Trench 2 and other trenches down through Strata C and D to bedrock. The relationship between the 'Neolithic' and previously attested basal 'Mesolithic' strata will be highly interesting, particularly with regard to subsistence, as animal bones are present in the basal stratum in the

nearby gully to Trench 2. Environmental data also require further disentangling: the isotope and faunal data point towards dry conditions with permanent water bodies nearby for the third millennium BC, turning to semi-arid by or during the first millennium BC.

The AMS date from the skeleton is the first demonstrable evidence that burial activity started at Jebel Moya earlier than the first millennium BC. Future field seasons will also focus on excavating more skeletal remains to determine the extent, nature and changing chronology of the burials. The caprine date from Trench 2 Spit 5 and the upper range of the revised OSL dates for Assemblage 3 show that occupational activity occurred during the mid- to late first millennium BC perhaps down to 2000 years ago. Our current working model is that, while there was earlier burial activity at the site, the majority of burials occurred in the second half of the first millennium BC, ending arguably at the turn of 2000 years ago.

The site provides extraordinary scope to examine how communities with a mobile pastoral component (see Hackner (2017) on mobility and tibia morphology at Jebel Moya) incorporated more sedentary agricultural activities in their subsistence system, and how (during the time of pottery Assemblage 3) the community was part of the trade networks feeding into the Meroitic state to the north. Such a focus moves beyond straitjacket narratives of whether a society was agricultural or pastoral. Modern Nuer pastoralists schedule cultivation of domesticated sorghum in their seasonal rounds. Fundamentally, it is now known that the integration of savanna herding and cultivation of domesticated sorghum was present by the mid-third millennium BC in the eastern Sahel.

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<i>Vicia</i> type										1
<i>Fabaceae</i> (small)										
<i>Lamiaceae</i> e (cf. <i>Hyptis</i> type)										
Cf. <i>Lamiaceae</i>										
Small indet	1						1			
Indet tuber/stem										
<i>Parenchyma</i>				3	1					















Table A1. Continued

Trench	4	4
Context	10	10
Flot	28	36
Liters	20	20
Modern	+	++
Charcoal	+	+
<i>Sorghum bicolor</i> husks	50	37
<i>Sorghum bicolor</i> grain	1	
cf. wild Sorghum		
<i>Ziziphus</i> cf. <i>spina-</i> <i>crusti</i> endocarp	1	1
Large nut shell		
Nutlet fragments		
<i>Dactyloctenium</i> <i>aegyptium</i>		
Indet <i>Poaceae</i> grain		
Indet <i>Poaceae</i> , large (>2mm)		
Indet <i>Panicoid</i> grains		1
<i>Setaria</i> type		
<i>Echinochloa</i> sp.		
<i>Chenopodiaceae</i>	1	
small legume		
<i>Vicia</i> type		2
<i>Fabaceae</i> (small)		
<i>Lamiaceae</i> (cf. <i>Hyptis</i> type)	1	
Cf. <i>Lamiaceae</i>		
Small indet	3	
Indet tuber/stem		
<i>Parenchyma</i>		

