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1 The site of Nataruk

The site of Nataruk was investigated as part of the IN-AFRICA Project (ERC 295907; http://in-africa.org) in 2012. It was discovered by Mr Pedro Ebeya, a field assistant working with Mirazón Lahr and Foley since 2009, who noticed fragmentary human remains in the area, as well as the exposed portion of a buried cranium. Very fragmentary human remains were found on the surface of two areas of the site, while portions of another five skeletons were visible as these had been exposed through deflation (see Extended Data Fig. 2). The excavation of the latter led to the exposure of several more human skeletons located in the immediate proximity.

Nataruk is one of several palaeontological and archaeological localities in the area dating to the Late Pleistocene and Early Holocene, when the edge of Lake Turkana extended ~30 kilometres southwest of its current margin (Extended Data Figure 1). Most of these localities do not represent living sites, but rather areas where aeolian and fluvio/lacustrian erosion have exposed sediments that are rich in fossil remains and archaeological artefacts associated with the exploitation of the lake palaeo-shores. Only at one site, Kalakoel 4, the nature of the remains (including dense pottery scatters) suggests a temporary encampment. The lake palaeo-shores are clearly visible throughout the landscape in the form of beach shell beds that also include the remains of aquatic animals. Differently from most of the other Late Pleistocene/Early Holocene sites investigated in the area, Nataruk was probably a few kilometres away from the lake shore at the time, near the edge of a small lagoon.

Nataruk is located on a flat landscape, at the end of a plain denuded of vegetation or other features. The plain abuts a set of small dunes to the south, the latter the result of recent aeolian action. The plain is part of a structural basin that was drained by the distributaries of lagoonal streams, draining an arid landscape into the palaeo Turkana lake basin. The basin slopes gently to the north, with extensive gullies to the north/northeast. These gullies are permanently dry as precipitation in the area is minimal (the weather station in Lodwar from the Meteorologisk Institute records an average of nineteen days of precipitation per year - http://www.yr.no/place/Kenya/Turkana/Lodwar/statistics.html). There is a small geological fault approximately 400 m to the east of the site, running north-south and exposed for *c.* 1 km; the fault shapes the drainage system. The surface of the plain is covered with patinated gravel of small to medium size and Middle Stone Age artefacts (the southern extension of the Kalakoel 3 open-air Middle Stone Age site 2 km to the north). Amongst the gravel on the deflated surface, there are rare fragments of Middle Pleistocene fossil remains.

The late Pleistocene/early Holocene human remains from Nataruk were found on the deflated surface/edge of a gravel bar ridge that runs *c.* 200 m east-west parallel to the dunes, as well as on the surface/edge of a small mound *c.* 70 m to the northeast of the ridge. Both the ridge and the mound are ~1 m above the surface of the plain. They are covered by a thin layer of recent sands overlying lake carbonates, which sits unconformably on older sediments. The human remains were found embedded in the lake carbonates, surrounded by small bivalve and gastropod shells.

2 The human remains from Nataruk

The skeletal remains of a minimum of 27 individuals were found at the site of Nataruk. Fifteen of these had been exposed and were found as dispersed surface fragments from which neither the position of the body nor major injuries could be inferred or observed. Twelve skeletons were found *in situ* in variable states of preservation. The position and orientation of the bodies varied randomly, including individuals lying extended on their side, their back, prone, flexed or in a sitting position (see Figs. 1 and 2). Some of the skeletons were embedded in the lake carbonates, suggesting the bodies had either fallen in the shallow water of the lagoon, or been covered by it soon after death. One of the skeletons, found in a reclining/sitting position, had a cranium of a Nile Perch and other fish remains next to it, again suggesting the covering of the bodies by the lagoon’s water. Finally, it should be noted that, in contrast to the Qadan graveyard at Jebel Sahaba, where individuals were buried and stone slabs were used to cover the graves in a number of cases[20], the people of Nataruk were not buried. Thus, there are no grave structures that could collapse and fracture the skeletons after death, nor are there boulders or rocks anywhere on site.

2.1 Ageing of the juvenile remains from Nataruk

Among the 27 individuals from Nataruk there were 6 juveniles and 21 adults. Age at death of juvenile remains was assessed through the chronology of dental eruption, developmental fusion of osteological elements and overall size of individual bones[30-32]. Of the six juveniles identified at Nataruk, two (KNM-WT 71252 and KNM-WT 71273) had a partially preserved dentition as well as post-cranial bone fragments, while the other four (KNM-WT 71254, KNM-WT 71270, KNM-WT 71271, KNM-WT 71272) were identified from a small number of post-cranial elements. It should be noted that age estimation of juvenile osteological remains relies on reference samples that, for the most part, represent European, European descent and/or African American populations who are not only genetically different from the population of Nataruk, but also experienced different socio-economic conditions during growth. Since ethnicity, health and nutrition can affect a child's growth and development, a disassociation between chronological and biological age can occur[89,90], although tooth development and dental eruption are considered reliable estimates of age at death in most cases[32,91,92]. Nevertheless, estimating the age of an archaeological juvenile skeleton on the basis of another population's relationship between chronological and biological age may lead to inaccuracies, particularly in terms of the size of individual elements[93]. In that context, there is no precise reference population to age the juvenile skeletons of fisher-foragers from early Holocene Turkana with certainty, and a potential error of up to 2 years could exist in some cases (forensic methodological studies reviewed in[94]). Information on the preservation of juvenile remains at Nataruk and the basis for the estimated ages is found in Supplementary Table 1.

A 28th individual at the site is represented by the remains of a very young child found within the abdominal cavity of KNM-WT 71255. This includes a left *partes lateralis* from the occipital bone, preserving the developing hypoglossal canal, and a fragment of alveolar bone, consistent with a near-term foetus[32:95]. Also found amongst the matrix adhering to the ribs of the adult individual were primary centres of ossification associated with the calcaneus and talus, and possible fragmentary pedal elements.

2.2 Ageing of the adult remains from Nataruk

Adult remains were identified cranially by the presence of the third molar in occlusion and/or the fusion of the spheno-occipital synchondrosis, and post-cranially by the fusion of epiphyses and size[33,34:21-38]. While the osteological identification of an individual as adult on the basis of growth cessation (end of dental eruption, fusion of the spheno-occipital synchondrosis, and epiphyseal fusion of post-cranial elements) can be made with confidence in complete skeletons, in fragmentary and incomplete remains this is not always the case. Among the 21 remains from Nataruk identified as adult, 9 individuals (KNM-WT 71261, 71262, 71266, 71267, 71268, 71274, 71275, 71276, 71277) preserve ≤10% of the skeleton. Among these, three (KNM-WT 71268, 71275, 71276) preserve aspects of the dentition: KNM-WT 71268 a 3rd molar in occlusion, and in the case of KNM-WT 71275 and KNM-WT 71276, teeth with advanced stages of dental wear. Dental wear accrues throughout the occlusional history of teeth through the progressive loss of tooth enamel and dentine caused by the rubbing of the upper and lower dentition during mastication, accelerated by the toughness of the food, the presence of intrinsic or extrinsic abrasive elements in the food, and the paramasticatory use of the teeth[36,95-97]. As the latter are population-specific, dental wear is a very imprecise method of assessing adult age-at-death, allowing only consideration of broad categories[36,97,98]. Accordingly, the stage of dental wear observed in KNM-WT 71275 and KNM-WT 71276 is only sufficient to estimate that these individuals were not young adults[36:71-2]. Three of the very fragmentary remains preserve post-cranial elements that, besides their size and development, show epiphyseal fusion consistent with an adult age (KNM-WT 71266, 71267, 71277). The fragmentary nature of the last three poorly preserved individuals (KNM-WT 71261, 71262 and 71274) only allows attribution of the fragments to an adult on the basis of the size and thickness of the bones, the degree of development of muscular attachments and the extent of wear of the few articular surfaces preserved. While these latter wear-and-tear indicators of age are not precise and, similarly to the case of dental wear, are reflective of population-specific activities and lifestyle, they provide a measure of the ageing process[90,99-102]. In these latter six cases, no attempt was made to estimate the age of the individuals with greater precision.

The remaining 12 adult individuals found at the site were sufficiently complete to allow further assessment of age by combining information from different aspects and elements of an ageing skeleton. Thus, these individuals were grouped into young adults, middle-aged and old adults depending on a combination of developmental and ageing indicators, such as whether any epiphyses remained unfused, the degree of dental wear, degree of cranial suture obliteration, presence of degenerative joint disease, and any other indications of age-related change (including those that, because of poor preservation, could only occasionally be observed for the pubic symphyses, auricular surfaces and sternal rib end morphology)[35-38,90,100-104]. Through these means, 5 individuals from Nataruk were identified as young adults at the time at death (KNM-WT 71253, 71255, 71256, 71257, 71265), 5 as middle aged/older adults (KNM-WT 71254, 71258, 71259, 71260, 71263, 71264), and 1 as an older adult (KNM-WT 71251). Information on the preservation of adult remains at Nataruk and the basis for the estimated ages is found in Supplementary Table 1.

2.3 Sex distribution

Among the adults found at the site there were 7 men (and a possible 8th), 4 women (and other possibly 4), and 5 individuals of unknown sex. Sex was determined from pelvic and cranial features following standard practice[34:16-20], supplemented by metrical assessment[33]. The age and sex distribution of the sample, as well as information on the degree of completeness of each skeleton is given in Supplementary Table 1.

Supplementary Table 1 – Demographic profile and state of preservation of the human remains from Nataruk.

Individual	Field #	Sex	Age	Basic information	State of preservation		
					Cranium	Mandible	Post-cranium
WT 71251	SK1	♂	A	Older adult, with extremely worn teeth; robust cranium. Male pelvis and cranium.	√	√	~ 60%
WT 71252	SK2J		J	12-15 yrs; M3s not erupted, no trace of occlusal wear on LP3 and LP4. Bones are extremely small.	FFFF	FFF	~ 25%
WT 71253	SK3	♂	A	Young adult; scapula acromial epiphysis not fully fused; medial clavicle epiphysis unfused; no wear remaining dentition. Male pelvis and cranium.	FF	√	~ 60%
WT 71254	SK4	♀ ?	A	Middle-aged adult; mild wear on mandibular M3s, extensive on other molars. Female pelvis.	√	√F	~ 60%
WT 71255	SK5	♀	A	Young adult, > 23 yrs, based on complete fusion of iliac, femoral and ulnar epiphyses. Foetus in abdominal cavity. Female pelvis.	FFFF	√F	~ 40%
WT 71256	SK6	♀	A	Young adult; slight wear on preserved dentition; some closure of mid-coronal and sagittal sutures; some DJD of hands. Female pelvis and cranium.	√F	√F	~ 70%
WT 71257	SK7	♂	A	Young adult; M3s unworn, slight wear on the rest of the dentition; no closure of sutures. Male pelvis and cranium.	√	√	~ 70%
WT 71258	SK8	♂	A	Middle-aged/older adult? RUM3 only preserved, which is extremely worn; femoral head fully fused. Large and robust skeleton, male pelvic fragments.	FFF	FF	~ 20%
WT 71259	SK9	♀	A	Middle-aged/older adult? LLM2 only preserved, which is extremely worn; proximal epiphyses of pedal phalanges all fused; DJD of R foot and hands. Female pelvis, gracile skeleton.	FFFF	√FF	~ 40%
WT 71260	SK10	♂	A	Middle-aged/older adult; extensive wear on all teeth, with dentine exposure. Large and very robust skeleton, male pelvis.	FFF	FFF	~ 25%
WT 71261	SK11		A	Fragments of size, muscular attachments and articular wear consistent with adult age.	-	-	~ 5%
WT 71262	SK12		A	Fragments of size, muscular attachments and articular wear consistent with adult age.	-	-	~ 5%

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Supplementary Table 1 (cont.)

Individual	Field #	Sex	Age	Basic information	State of preservation		
					Cranium	Mandible	Post-cranium
WT 71263	SK13	♂	A	Middle-aged/older adult; extensive wear on all teeth. Male pelvis.	√F	√	~ 55%
WT 71264	SK14	♂	A	Middle-aged adult; extensive wear on all teeth; some closure of sagittal suture; some DJD in hands. Male pelvis and cranium.	√	√	~ 70%
WT 71265	SK15	♀	A	Young adult; medium to extensive wear on extant teeth; no closure of sutures. Female cranium, gracile skeleton.	FFF	FF	~ 25%
WT 71266	SK18	♀ ?	A	Adult; complete fusion of metacarpal and metatarsal epiphyses; if mandibular fragment found on the surface above the skeleton is part of this individual, then middle-aged/older adult based on the substantial, sloping wear on a LLP4. Very gracile skeleton.	-	?FFF	~ 3%
WT 71267	SK21	♀ ?	A	Adult, at least >17-20 yrs based on fusion of proximal and distal epiphyses of R humerus. Very gracile skeleton.	FFFF	-	~ 10%
WT 71268	SK2A		A	Adult; M3 in occlusion	FFFF	-	~ 10%
WT 71269	SK4J		J	3-6 yrs – only 2 fragments of juvenile vertebral neural arches unfused to centrum, juvenile R mandibular condyle and L mastoid process preserved.	FFFF	FFFF	< 1 %
WT 71270	SK3-6J		J	4-5 yrs – only R mandibular fragment preserved, with LLM1 in crypt.	-	FFFF	-
WT 71271	SK12J		J	< 6 yrs – small post-cranial fragments	-	FFFF	< 1 %
WT 71272	SK15J		J	< 3 yrs – only 4 fragments of unfused vertebral neural arches preserved – left and right unfused arches of C1, and two lateral aspects of thoracic neural arches.	-	-	< 1%
WT 71273	SK17J		J	5-6 yrs – only fragments of the temporal bone, 3 fragments of mandible (with unerupted anterior dentition), L 4th metacarpal fragment, and intermediate 3rd pedal phalanx preserved.	FFFF	FFFF	< 1%
WT 71274	SK16		A	Fragments of size, muscular attachments and articular wear consistent with adult age.	-	-	~ 5%
WT 71275	SK17	♀ ?	A	Middle-aged/older adult; LUM1 extremely worn. Very gracile skeletal elements.	FFFF	FFFF	~ 5%
WT 71276	SK19	♂ ?	A	Middle-aged/older adult based on dental wear. Robust skeletal elements.	FFFF	FFFF	~ 5%
WT 71277	SK22		A	Adult, at least >16 yrs based on fusion of proximal epiphysis of distal manual phalanx.	FFFF	-	~ 1%

Abbreviations: ♀: female; ♂: male; A: adult; J: juvenile; DJD: degenerative joint disease; F-FFFF: degrees of fragmentation; %: estimated percentage of preserved post-cranium.

The human remains were accessioned in the collections of the National Museums of Kenya with the numbers KNM-WT 71251 to KNM-WT 71277, and are curated at the Turkwell Station of the Turkana Basin Institute, Kenya. A 28th individual is represented by the foetal remains found within the abdominal cavity of one of the adult females, and is identified as KNM-WT 71255b.

3 Peri-mortem trauma in the skeletal remains from Nataruk

In skeletal remains, evidence of interpersonal trauma, inter-group conflict and warfare is recognised from three diagnostic features: (1) the presence of projectile points embedded in the bone or within the body cavity; (2) fractures resulting from blunt or sharp force trauma; and (3) cut-marks associated with dismembering and trophy-taking (such as scalping)[28,29,39,41-43,49,59,105-114]. Among the remains from Nataruk, both embedded projectiles/projectiles within the body cavity, and fractures resulting from blunt- and sharp-force trauma are observed; no evidence of cut-marks was found. Fractures require particular attention, so that injuries resulting from traumatic events at or near the time of death (peri-mortem) can be distinguished from injuries in the life of an individual (ante-mortem), or post-mortem breakage of the bones. There is a vast literature on the forensic and archaeological identification of peri-mortem violent trauma, as well as on the incidence, distribution and character of violent trauma in historic and prehistoric societies. Here, a few key points relevant for the assessment of the traumatic lesions at Nataruk are discussed.

3.1 Methodological considerations

Evidence of healing and/or periosteal reaction is considered diagnostic of an ante-mortem injury[28,44], and its absence as indicative of peri-mortem or post-mortem breakage of the bones. The healing process of a bone fracture begins almost immediately, but is not observable for one to two weeks after the injury[58,115]. This will always leave a window of time between the time of injury and evidence of healing, so that some traumatic lesions may be considered peri-mortem while, in fact, these could have occurred one or two weeks before the death of the individual. Although this possibility cannot be fully excluded, the context of the skeleton, the distribution and character of lesions, and the age and sex of the injured provide important secondary-level information for identifying a fracture as peri-mortem in the absence of healing.

The mortuary context of the Nataruk skeletons (absence of burial pits and grave structures, the unpatterned position of the bodies, absence of associated material culture), the demographic profile of those injured, and the location of lesions all provide secondary-level information that suggests they were victims of violence[29,116-118]. Furthermore, violent injuries are most often observed in ribs, scapulae, forearms and hands, and particularly in the head and neck[45-48] - the main distribution of lesions among the individuals from Nataruk.

Parry fractures in the forearms and hands can be indicative of accidents (axial load) or injuries incurred as a defence against blows intended for the head[99,117,119]. The most common aetiology for such fractures is accidents[120,121]; however, in the context of other evidence for violence in a skeletal population, a violent aetiology becomes more likely[117]. In the case of Nataruk, a female individual (KNM-WT 71256) displays fractures on two adjacent elements of the hand, possibly related to a singular event, which may have been sustained through blunt-force trauma or axial load (such as a fall). Another individual (KNM-WT 71254), also probably female, displays a fracture on the right trapezoid that may have similar aetiology.

Fractures to the knees can equally result from accidental falls (including a fall induced by blunt and/or sharp-force trauma elsewhere in the body) or direct trauma. In Nataruk, two individuals display knee fractures that are here considered as probably resulting from peri-mortem injuries. A male skeleton, KNM-WT 71251, has multiple injuries to the skull, including an embedded projectile on the left parietal bone; he lay prone amongst lake carbonates and gastropod shells, suggesting that he may have fallen face-down in the lagoon sediments following the traumatic lesions to the head. Both his left and right distal femora and proximal tibiae show depressed fractures on the anterior surface, including changes in the profile of the bones. As the individual lay prone, these injuries could not have been caused by soil overburden, but could have been incurred either as the result of the fall or blunt-force trauma. A second individual, a female who has no preserved cranium (KNM-WT 71259) also shows depressed fractures on the right knee. This individual lay in a very unusual position, partially reclined against a sand bank supported by her left elbow, and with fish remains in immediate proximity. The right femur and tibia, tightly flexed, display depressed fractures on the anterior surface, including the presence of adhering fragments. As is the case with KNM-WT 71251, the position of the injuries is inconsistent with a post-mortem origin of the injuries caused by soil overburden, since the latter would have damaged the lateral, not the anterior aspect of the elements. The left leg was bent back at the knee, with the left lower leg turned laterally so that the left foot was bent in an unnatural direction lying underneath the hands. Although the left knee articulation is too poorly preserved to inform on the presence or absence of lesions, the position of the foot described above suggests a possible traumatic injury to the left knee or ankle that would have prevented walking, while the presence of fish in direct association with the body, suggests the latter was covered by the waters of the lagoon soon after death. The recent report of a late Neolithic massacre in Central Europe[122], where intentional blunt- and sharp-force trauma to the lower limbs was observed in a large percentage of individuals, suggests that the two cases of possible violent trauma to the knees observed at Nataruk may not be so singular.

The record of prehistoric and historic trauma shows that cranial fractures are significantly more likely to have been caused by inter-personal violence than by accidents (accidental injuries to the head are mostly observed in either young (under 15 years) or old (over 50 years) individuals[123], as well as more likely to be the result of violence than post-cranial fractures, particularly among males[39,123,124]. Indeed, blunt force peri-mortem traumatic lesions in the head can be considered diagnostic of inter-group conflict in some contexts (for example[29,49-51,125] among others). Among the remains from Nataruk, there are 5, possibly 6, cases of sharp-force trauma and 5 cases of blunt-force trauma to the head.

These cranial lesions, as well as the post-cranial fractures observed at Nataruk are here interpreted as resulting from traumatic events at or near the time of death. Peri-mortem fractures are recognized from a set of diagnostic features associated with the natural elasticity of living (or “green”) bone – (1) presence of depressed adhering bone fragments, (2) secondary linear and/or concentric radiating fractures, (3) inner bevelling of the margins of the lesion, (4) irregular, sharp or splintered edges (instead of shattered), (5) flaking of the internal fracture surface, and (6) absence of discoloration (i.e. the colour of the borders of the lesion is consistent with the surrounding bone)[28,49,52,54-62,126-143], although not all these features will be observed in every case, and the nature of the lesions may differ in relation to whether the fracture was the result of projectile trauma, blunt force, sharp force or thermal stress. Perforating lesions have particular features – (a) the morphology of the lesion itself (having a linear, circular or ellipsoidal section); (b) well-defined edges and either smooth or serrated/splintered margins, which may be polished; (c) a V, semi-V or U shaped cross-section; (d) the presence of internal bevelling and/or parallel striations; and (e) anatomical position consistent with a projectile’s trajectory. In the case of the lesion being caused by a non-sharp projectile, such as a bone point or polished arrow shaft, the margin of the lesion is typically rounded or oval in shape, with rounded edges[63].

3.2 Traumatic lesions among the skeletons from Nataruk

Among the 12 individuals from Nataruk with more than 20% of the post-cranial skeleton preserved, 10 show lesions consistent with trauma (Supplementary Table 2). These are observed in the skull, mandible, vertebrae, ribs, hands and possibly knees. Thus, both the nature of the lesions (described in detail below) and their distribution are consistent with peri-mortem injuries resulting from violent trauma – two cases of projectiles in direct association with the remains, seven cases of blunt and/or sharp force trauma to the head, two cases of sharp force trauma to the neck, two cases of possible fractures to the knees, and two cases of fractures to the hands.

There are 2 individuals with no traumatic lesions in the preserved parts of the skeleton – KNM-WT 71255, the skeleton of a woman who was probably in the last stages of pregnancy at the time of death, and KNM-WT 71260, the very partially preserved post-cranial skeleton (~25%) of a middle-aged/older man, whose hands nevertheless may have been bound.

No cut-marks were observed among the skeletons from Nataruk, implying that the practice of dismemberment and trophy-taking was not part of the behavioural repertoire of these foraging communities. The lesions among the people from Nataruk are indicative of trauma caused by projectiles – supported by the presence of the actual lithic projectiles in two individuals and lesions to the neck and head consistent with sharp and non-sharp projectiles, by sharp force trauma to the face, head and hand, and by blunt force trauma to the head, thorax and possibly knees. Fractures on the hands and knees were observed on individuals who also had head (KNM-WT 71251, KNM-WT 71254), neck (KNM-WT 71256) or thoracic injuries (KNM-WT 71259), and may be part of the single events.

Supplementary Table 2 – Distribution of major or peri-mortem injuries among the twelve articulated skeletons found in situ at Nataruk.

	Sex	head		thorax		knees	hands	
		sharp-force trauma (projectile, cut)	blunt-force trauma	sharp-force trauma	blunt-force trauma	blunt-force trauma	trauma	bound
KNM-WT 71251	♂	multiple, including embedded projectile; perforating lesion on R parietal bone				Anterior depressed fractures that may be ante-mortem		
KNM-WT 71253	♂		depressed fractures, L temporal bone	Perforating lesions on cervical and 1st thoracic vertebrae				
KNM-WT 71257	♂		depressed fractures, L temporal bone					
KNM-WT 71258	♂			projectiles within thoracic cavity				probably
KNM-WT 71260	♂							probably
KNM-WT 71263	♂	linear perforating lesion on frontal bone						
KNM-WT 71264	♂		depressed fractures on L temporal and frontal bones					
KNM-WT 71254	♀ ?	perforating lesion on frontal bone; linear perforating lesion on mandible					Linear perforating lesion on R trapezoid	
KNM-WT 71255	♀							probably
KNM-WT 71256	♀			Perforating lesions on cervical vertebrae			multiple fractures on 2nd and 3rd R metacarpals	
KNM-WT 71259	♀				fractures on 3 ribs (2 consecutive)	Anterior depressed fractures that may be ante-mortem		probably
KNM-WT 71265	♀		depressed fractures on frontal bone					

Abbreviations: ♀ : female; ♂ : male.

3.3 Detailed description of individual lesions

3.3.1 KNM-WT 71251 (Extended Data Figure 4a)**:** Adult male, head ESE, found face down in an extended position, with the head deeper than the legs, embedded in the lacustrine sediments; the lower extremities were exposed and lost. Traumatic lesions are observed on the cranium (i, ii), and possibly on the left and right femora (iii, iv), and left and right tibiae (v, vi). The description of the lesions observed on the distal left and right femora and proximal left and right tibia of KNM-WT 71251 (iii-vi) could be consistent with peri-mortem trauma, as opposed to post-mortem damage, particularly if the position of the body is taken into account. The individual was lying prone; if soil overburden had been the source of damage to the elements, these fractures would be observed on the posterior, not the antero-lateral aspect. However, the weathered nature of the knee articulation precludes certainty about these injuries.

i. **Cranium:** A linear lesion is observed on the ectocranial surface of the left parietal bone, travelling diagonally for *c.* 11.6 cm from a point *c*. 2.3 cm antero-superior to the mid-point of the left lambdoid suture to meet the coronal suture above pterion. At its posterior end, the lesion is shallow, forming a groove of increasing depth, bound inferiorly by a smooth, partially polished surface, and superiorly by a rough edge that overhangs the inferior portion of the parietal bone to a depth of *c.* 0.4 cm. The lesion perforates the bone *c.* 3.6 cm posterior to the coronal suture, forming a bevelled inferior margin with sharp edges. The perforation has an asymmetrical tear-drop shape in a antero-posterior direction, wider at its posterior end. It measures 5.8 cm in maximum length, and *c.* 2 cm in maximum width. An obsidian bladelet, measuring 2.8 cm in length, was found *in situ*, embedded within the parietal bone, with the embedded tip displaying an impact scar. The projectile's trajectory terminated as it impacted against the cross-section of the parietal bone.

ii. **Cranium**: A perforating lesion is observed on the right parietal bone, associated with a major depressed fracture of the anterior portion of the right parietal bone, right aspect of the sphenoid and frontal bones, and right aspect of the superior facial bones, which have inferiorly displaced into the endocranial cavity. The left aspect of the skull, most of the occipital bone, basicranium, and the right temporomandibular joint and mandible have retained their natural shape. The perforating lesion is *c.* 7 cm superior to the right auditory meatus. The perforation has a circular section, missing the anterior portion, with a maximum diameter of *c.* 0.8 cm. The external margins are regular and sharp; a series of associated small depressed fractures are observed on the posterior margin of the lesion. The direction of impact appears to have been from a posterior direction.

iii. Right Femur: A series of fractures extends superiorly from the extant edge of the distal right femoral metaphysis onto the distal aspect of the diaphysis on the most lateral aspect of the element, covering an area 3.2 cm wide and 6 cm long. The centre of the lesion appears to be a depressed area *c.* 2 cm medial to the extant lateral edge of the metaphysis, and 1.1 cm superior to the extant distal edge, surrounded by a complex network of fractures. The margins are straight and smooth. The cortical bone has been depressed into the underlying trabeculae due to the placement of severe blunt force in a lateral-medial direction. The point of impact appears to be approximately 1.1 cm superior to the extant distal edge. The full distal extent of this fracture is not known as the metaphysis has been lost due to post-mortem damage. It is possible that this lesion communicates inferiorly with the fractures described for the proximal aspect of the right tibia.

iv. Left Femur: A series of fractures extends superiorly from the extant edge of the distal metaphysis onto the distal aspect of the diaphysis on the most medial aspect of the element, covering an area 4.6 cm wide and 7.2 cm long. The centre of the lesion appears to be a depressed area *c.* 4.0 cm superior to the extant central distal edge of the metaphysis, surrounded by a complex network of fractures; the margins are straight and smooth. The cortical bone has been depressed into the underlying trabeculae due to the placement of severe blunt force in a medial-lateral direction. The point of impact appears to be approximately 4.0 cm superior to the extant distal edge. The full distal extent of this fracture is not known as the metaphysis has been lost due to post-mortem damage. A diagonal fracture, with straight and smooth margins and *c.* 1.9 cm maximum length, is observed on the antero-medial aspect of the diaphysis, 5.6 cm superior to the extant distal medial edge, inclined superiorly towards the medial aspect of the element. A further radiating fracture, *c.* 6.9 cm maximum length, is observed extending distally from the diagonal fracture towards the metaphysis, on the anterior aspect of the element. The full extent of this fracture is not known as the metaphysis has been lost due to post-mortem damage. It is possible that this lesion communicates inferiorly with the fractures described for the proximal aspect of the left tibia.

v. Right Tibia: A series of fractures extends inferiorly from the extant edge of the proximal metaphysis onto the proximal aspect of the diaphysis on the most lateral aspect of the element, covering an area 2.7 cm wide and 4.2 cm long. The centre of the lesion appears to be a depressed area *c*. 1.5 cm lateral to the lateral, central edge of the tibial tuberosity, and 1.6 cm inferior to the extant proximal edge, surrounded by a complex network of fractures. The margins are straight and smooth. The cortical bone has been depressed into the underlying trabeculae due to the placement of severe blunt force in a lateral-medial direction. The point of impact appears to be approximately 1.6 cm inferior to the extant distal edge. The full proximal extent of this fracture is not known as the metaphysis has been lost due to the poor preservation of the articular aspects of the post-cranium. It is possible that this lesion communicates superiorly with the fractures described for the distal aspect of the right femur.

vi. Left Tibia: A series of fractures extends superiorly from the extant edge of the proximal metaphysis onto the proximal aspect of the diaphysis on the most medial aspect of the element, covering an area 3.9 cm wide and 2.5 cm long. The centre of the lesion appears to be a depressed area *c*. 2.0 cm inferior to the extant proximal edge of the metaphysis, *c*. 1.5 cm medial to the medial, central edge of the tibial tuberosity, surrounded by a complex network of fractures. The margins are straight and smooth. The cortical bone has been depressed into the underlying trabeculae due to the placement of severe blunt force in a lateral-medial direction. The point of impact appears to be approximately 2.0 cm inferior to the extant proximal edge. The full proximal extent of this fracture is not known as the metaphysis has been lost due to post-mortem damage. It is possible that this lesion communicates superiorly with the fractures described for the distal aspect of the left femur.

3.3.2 KNM-WT 71253 (Extended Data Figure 4b)**:** Partially preserved adult male skeleton in a semi-flexed position, head SSW, with the face down into the sediments. The skeleton was partially exposed through deflation, and fragments of the posterior aspects of the skull were found on the surface. Traumatic lesions are observed on the cranium (i), 3rd (?) cervical vertebra (ii), and 7th cervical vertebra (iii).

i. Cranium: A radiating fracture is observed on the ectocranial surface of the frontal bone, travelling horizontally from the left temporal line towards the midline for *c.* 4 cm. The fracture becomes shallower from left to right, ending in a V-shaped groove. The original lesion from which the radiating fractures emanate is not preserved, but it is considered to have been a blunt-force trauma to the left side of the head, similar to that observed in KNM-WT 71257 and KNM-WT 71264.

ii. 3rd (?) cervical vertebra: A deep channel is observed within the left superolateral aspect of the third (?) cervical vertebral body. The channel extends anteriorly from the vertebral foramen to the anterior rim of the vertebral body. The surface of the lesion is smooth and non-porotic, measuring a maximum 0.8 cm width, 0.4 cm depth and 1.5 cm in length. Posterior damage to the right edge of the body and base of the transverse arch can also be observed. The smooth and circular shape of the lesion is suggestive of sharp force trauma from a non-lithic implement (bone point or wooden shaft).

iii. 7th cervical vertebra: A perforation on the left lateral aspect of the lamina of the 7th cervical vertebra is observed. The lesion is roughly diamond-shaped, and is deepest at its central point, measuring a maximum 0.7 cm width, 0.3 cm length and 0.4 cm depth. There is a shallow groove extending laterally left of the deep central perforation (maximum 0.5 cm width, 0.1 cm length, 0.1cm depth). The edges of the lesion are straight and sharp, although a little rough in areas; it is suspected that this is due to post-mortem damage as the cortical surface of this element is slightly eroded. The perforation is diagonally, inferiorly inclined, and positioned 0.6 cm lateral to the spinous process crest, and 0.6 cm superior to the lamina base. This is a typical lesion from sharp projectile trauma, and comparative examples may be found elsewhere in the literature (for example, in Maiden Castle[144]).

3.3.3 KNM-WT 71254 (Extended Data Figure 5a)**:** Adult female, head S, face E. Relatively poorly preserved skeleton; the skull was recovered in fragments, many deeply patinated, indicating ancient post-mortem fragmentation. The sagittal suture shows bilateral compression. Traumatic lesions are observed on the cranium (i), the right mandibular ramus (ii), and the right hand (iii).

i. Cranium: A perforating lesion is observed on the frontal bone, *c.* 4 cm superior to the right orbital rim, and *c.* 0.4 cm to the right of the frontal bone midline. The lesion has an ellipsoidal section oriented coronally, with maximum internal dimensions of *c.* 0.8 cm length and 0.4 cm width. The internal margins are well-defined and sharp; external margins are larger, with bevelling of the inferior surface that slopes irregularly inwards towards the perforation. Two radiating fractures emanate from opposing lateral aspects of the perforation, one that travels diagonally from the supero-posterior aspect of the lesion terminating at the coronal suture, and another, extending horizontally from the left lateral aspect of the lesion, travelling horizontally for 0.8 cm, where it is broken. The full extent of this fracture is not known as the left portion of the cranium has been lost due to post-mortem damage.

ii. Mandible: A linear perforation is observed on the antero-lateral surface of the ascending ramus. The superior aspect of the lesion is located 2.9 cm inferior to the right coronoid process; the inferior aspect of the lesion is located 3.8 cm superior to the inferior border of the mandible. The lesion is oriented in a downwards-sloping, postero-anterior direction, and completely perforates the bone of the ramus. The most supero-posterior aspect of the lesion features a bevelled channel with very straight margins which extends for 0.3 cm. The margins of the remainder of the lesion are slightly rounded and slope inferiorly inwards towards the centre of the perforation. The rounding observed here may be taphonomic. The lesion measures 1.1 x 0.1 cm in maximum dimensions.

iii. Right trapezoid: A perforation of the cortical and trabecular bone is observed on the palmar process of the proximal aspect (site of articulation with capitate/scaphoid) of the right trapezoid, 0.5 cm inferior to the palmar surface. The lesion's orientation is approximately horizontal, and extends across the entire width of the proximal palmar surface of the bone (maximum dimensions: 0.8 cm length x 0.1 cm width). The margins of the lesion are sharp, and decline into the centre of the lesion in a V-shaped manner. The lesion is shallower (0.2 cm) at the medial aspect of the element, and deeper at the lateral aspect (0.4 cm), but in all areas maintains the V-shaped channel appearance. A small, additional fracture, *c*. 0.2 cm in length, emanates from the lateral aspect of the primary lesion at a depth of 0.2 cm from the proximal surface, although this may be post-mortem damage. The primary lesion may be a sharp-force trauma or a stress fracture due to axial load or bending stress.

3.3.4 KNM-WT 71255 (Extended Data Figure 5b)**:** Adult female, preserved in an upright sitting position, with the cervical vertebrae tilted posteriorly, indicating that the head was hyperextended, with the face superiorly oriented; the latter was exposed and broken away, although some fragments were found on the surface. The body is in an unusual position, being extremely flexed (with the knees exposed and broken), the feet crossed over each other at the level of the ankles, and the arms placed in extension between the legs, with the hands crossed over each other below the elbows to lie on top of the feet. No lesions were observed on the preserved post-cranial bones. Amongst the fragments recovered were five, possibly seven, foetal cranial and post-cranial bones (a left *partes lateralis* from the occipital bone preserving the developing hypoglossal canal, a fragment of alveolar bone, primary centres of ossification associated with the calcaneus and talus, and possible fragmentary pedal elements). All infant remains (accessioned as KNM-WT 71255b) are consistent with full-term foetal or perinatal age.

3.3.5 KNM-WT 71256 (Extended Data Figure 5c)**:** Adult female, head S, face up. Skeleton in an extended position within lake sediments, with the right hand over the pelvis, and the face and lower legs exposed and lost (except the right foot from the upwardly flexed right leg). Patination of the edge of the preserved cranial bones indicates that exposure occurred in antiquity. Traumatic lesions are observed on the neck (i), and the right hand (ii, iii). It is thought that the two hand fractures observed may have been related to a singular event, as they are on adjacent elements and appear to be consistent in nature and orientation. They may have been sustained through blunt-force trauma or axial load (such as a fall).

i. **6th cervical/1st thoracic vertebrae:** Perforating lesions are observed on the 6th cervical and 1st thoracic vertebrae. The cervical lesion is located on the right postero-lateral aspect of the lamina, commencing 0.6 cm lateral to the crest of the spinous process; it extends laterally for 1.4 cm to terminate at the lateral edge of the inferior articular process. The lesion presents as an arc-shaped defect. The margins are sharp and irregular, and there may have been some taphonomic damage to the area. The thoracic lesion is observed on the left posterior aspect of the superior edge of the vertebral body, on the border of the vertebral foramen. The lesion commences 0.3 cm medial to the left pedicle and extends for 0.4 cm medially towards the centre the superior aspect of the vertebral body (maximum dimensions *c.* 0.5 cm width, 0.7 cm length). The lesion presents as a circular-shaped perforation, which penetrates the cortical and trabecular bone in an infero-laterally inclined direction; the margins are sharp and smooth. There may have been some taphonomic damage to the area. It appears that the lesions described for the cervical and thoracic vertebra may have been sustained as part of a singular insult, as they directly align and communicate, likely as the result of a sharp-force (possibly projectile) injury which entered the body from a right posterior supero-lateral direction, with an inferior, diagonal orientation, penetrating the right posterior aspect of the 6th cervical lamina, travelling through the vertebral canal, perforating the left postero-lateral aspect of the 1st thoracic vertebral body and terminating in the left infero-lateral aspect of the vertebral body. When a bamboo skewer is placed within the parameters of the lesion it aligns perfectly.

ii: Right 2nd metacarpal: Two fractures are observed on the right second metacarpal (MC2). Lesion 1: a fracture commences on the palmar surface of the proximal metaphysis of the right MC2, on the extant edge of the articular surface, and continues in a superior direction for 1.3 cm before inclining in a supero-medial direction to twist around the diaphysis and reach its apex 2.9 cm superior to the central dorsal aspect of the proximal articular surface. The fracture then declines sharply in an infero-lateral direction for approximately 0.8 cm, creating a flake-like bone projection on the dorsal aspect of the diaphysis. The fracture margins are all sharp. Lesion 2: a fracture commences on the dorsal surface of the proximal metaphysis of the right MC2 at the approximate centre and continues in a supero-lateral direction for 1.6 cm, twisting around the diaphysis, and declining sharply in an infero-lateral direction for approximately 0.5 cm, creating a flake-like bone projection on the medial aspect of the diaphysis. The fracture then continues to decline in an infero-lateral direction for 0.8 cm, to meet the first fracture at its point of origin. The fracture margins are all sharp.

iii. Right 3rd metacarpal: Two fractures are observed on the right third metacarpal (MC3). Lesion 1: a fracture commences on the dorsal surface of the proximal metaphysis of the right MC3, at the approximate centre of the edge of the articular surface of the metaphysis and continues in a supero-medial direction for 1.4 cm, twisting around the diaphysis, before terminating on the palmar surface of the diaphysis, approximately 1.6 cm superior to the central palmar aspect of the proximal articular surface. The fracture margins are all sharp. Lesion 2: a fracture commences on the palmar aspect of the right third metacarpal on the medial aspect of the articular tubercle of the metaphysis. The fracture wraps around the tubercle in a supero-lateral direction, and then continues superiorly for 0.9 cm on the palmar aspect of the diaphysis. The fracture margins are all sharp.

3.3.6 KNM-WT 71257 (Extended Data Figure 6a)**:** Adult male, head N, face W/down. Skeleton on its right side, embedded in lake sediments, with the face tilted backwards and partly turned down into the sediments; the legs were slightly flexed upwards, with the lower extremities exposed and lost. Traumatic lesions are observed in the cranium (i).

i. Cranium: A depressed fracture is observed on the ectocranial surface of the left temporal region, measuring a maximum 9.9 cm in width and 5.0 cm in length. The fracture encompasses four bones of the left cranium: the parietal, temporal, frontal and sphenoid bones. The superior-most point of the lesion commences approximately 3.2 cm superior to the central superior aspect of the left temporal bone; the most anterior aspect of the lesion is located at the most anterior point of the left fronto-zygomatic suture. The temporal process of the left zygomatic bone has also been fractured at its eminence. The most posterior point of the lesion is located 10.4 cm posterior to this point on the horizontal plane, on the lateral aspect of the left parietal bone, approximately 7.4 cm superior to the superior aspect of the left digastric fossa. The fracture then travels inferiorly to bisect the temporal bone through the external auditory meatus. The zygomatic process of the temporal bone has also been fractured at its eminence. The lesion presents as a depressed fracture, the most superior margin of which has a superiorly-inclined arc. This margin is located on the left parietal and frontal bones. The bones inferior to this margin (the fractured parietal, frontal, temporal and sphenoid bones) have been medially displaced and have entered the cranial cavity, displacing the left basicranium in a medio-lateral direction, so that the left lateral margins of the foramen magnum are pushed against the right lateral aspect which retains its original shape. The surrounding bones of the fractured parietal bone, frontal, sphenoid, temporal and zygomatic bones sit superior to the depressed fracture in approximate anatomical position. The aetiology of these fractures appears to have been blunt force trauma to the left side of the head in a left medial direction, impacting just superior to the central superior aspect of the left temporal bone. The fracture margins are all sharp and bevelled, although in some areas they have eroded due to taphonomic processes. It is also possible that at least two radiating fractures appear on the frontal bone, the first originating at the point of the left supraorbital notch, then inclining in a supero-medial direction for approximately 13 cm to meet the coronal suture approximately 0.9 cm left lateral of bregma. The second possible radiating fracture originates from the first radiating fracture, at approximately 3.3 cm superior to the left supraorbital notch. It then continues in a medial, approximately horizontal direction for 6.7 cm. The individual lay on his right side with the lesion on the left side of the head in a superior position. Soil overburden would have contributed to compress the cranial vault medially and laterally due to its instability following the suite of fractures, which has subsequently been vertically elongated. The parietal and temporal bones within the fracture zone have been further fractured into approximately 20 small pieces of ≤ 3.0 cm², although this may be the result of taphonomic processes. The left aspect of the maxilla and basicranium, as well as the mandible are unaffected by the suite of fractures to the left cranium.

3.3.7 KNM-WT 71258: Adult male, head SE, face W. A poorly preserved fragmentary skeleton, lying on its left side, with the left leg flexed and the right arm crossing over the pelvis. The exposed margins of the bones are patinated, indicating that exposure and erosion occurred in antiquity. No lesions were observed in the preserved elements; however, an obsidian blade was found inside the pelvic area, and a microlith amidst the ribs within the thoracic cavity.

3.3.8. KNM-WT 71259 (Extended Data Figure 6b)**:** Adult female, head S, face down with chin on thorax. This individual was found embedded in lake sediments, in a semi-upright sitting/reclining position against a low sand bank, with the skull of a Nile Perch preserved *c.* 20 cm S of the left elbow. The head, being at a higher level than the rest of the body, was exposed and lost. The upper body was supported by the left arm bent at the elbow, with the left hand extended flat in front; the right arm is bent at the elbow in front of the pelvis, so that the right hand lies over the left wrist. The right leg is tightly flexed, lying horizontally in front of the body; the left leg is extended to the knee, which is bent unnaturally backwards so that the left foot lies beside the pelvis turned outwards underneath the left hand. Traumatic lesions are observed on three ribs, two of which appear to be consecutive and possibly result from the same insult (i), as well as possibly on the right femur (ii), right tibia (iii). Similarly to the case of KNM-WT 71251, the lesions affecting the right femur and tibia are thought to be trauma as opposed to post-mortem damage as the individual was lying on its left side; if soil overburden was to have caused damage to the element, it would be observed on the lateral, not the anterior aspect of the element. It is thought that the distal femoral and proximal tibial fractures communicate across the knee articulation as a result of the same insult. However, post-mortem damage to these elements, particularly the knee articulation, preclude certainty of the peri-mortem nature of the injuries observed. It should be noted, however, that although the distal left tibia/fibula and left carpal bones are too eroded to ascertain osteological lesions, the position of the left foot indicates that either the left knee or the left ankle was broken at the time of death, further suggesting ante-mortem trauma to the lower extremities.

i. **Ribs:** Fractures are observed on two mid-to-upper level ribs, which appear consecutive, and one lower-level rib. The ribs are all fragmented and highly degraded due to post-mortem damage. The fracture on the highest-placed rib of all the affected elements, determined by the shape and size of the extant head and neck, as well as the straightness of the shaft's relative declination in relation to the head, appears to be a penetration of the cortical bone on the posterior (dorsal) inferior aspect of the rib shaft, at the angle, commencing approximately 4.5 cm lateral to the lateral edge of the tubercle. The cortical surface appears to have been depressed into the underlying trabecular bone due to the application of sharp force in an anterior-inferiorly inclined direction. A fracture emanates from the edge of this depression, running 0.5 cm horizontally towards the medial aspect of the element. The margins appear straight and smooth, despite substantial post-mortem degradation to the surrounding bone. The second of these ribs appears to sit inferiorly in sequence to the first, and the fracture position is directly inferior to the fracture location described for the previous rib. In this case, the cortical bone on the superior ventral/pleural aspect of the rib has been fractured and displaced. The fracture commences approximately 4.4 cm lateral to the tubercle, in the area of the angle. A fragment of bone measuring 2.2 cm has been fractured and displaced anteriorly, folding into the pleural space while still hinged on the inferior margin of the fracture. This fragment of bone appears to be responding to the same application of sharp force in an anterior-inferiorly inclined direction, as described above. The two lesions communicate supero-inferiorly and may have resulted from the same insult. A similar fracture is observed on a more-inferiorly positioned rib. In this case, the fracture is on the superior aspect of the rib shaft, just lateral to the angle. A fragment of bone measuring 1.3 cm had been fractured and displaced posteriorly, folding outwards towards the dorsal aspect of the body while still hinged onto the inferior margin of the fracture. This fragment of bone also appears to be responding to an anterior-inferiorly inclined sharp force; however, in this case the bone fragment appears to have folded outwards rather than inwards, perhaps as the intruding implement was being withdrawn from the injury. A fracture emanates from the edge of this depression, running 0.7 cm horizontally towards the medial aspect of the element.

ii. **Right femur:** A series of fractures are observed on the anterior aspect of the distal end of the right femur, with the apex of the lesion located 9.2 cm superior to the extant distal edge of the element. A diagonal fracture, *c*. 3.1 cm in maximum length, inclined superiorly towards the medial aspect of the element, is observed on the distal aspect of the anterior diaphysis. The margins are straight and smooth. A vertical fracture, *c*. 7.2 cm in maximum length, is observed extending distally from the diagonal fracture towards the metaphysis, on the central, anterior aspect of the element. The full extent of this fracture is not known as the metaphysis has been lost due to post-mortem damage. There are a series of other smaller fractures extending from this central, vertical fracture. The cortical surface appears to have been depressed into the underlying trabecular bone due to the placement of severe blunt force in an antero-posterior direction. The point of impact appears to be approximately 1.5 cm superior to the extant distal, central edge of the element. Radiating/displacement fractures are also observed on the medial edge of the extant distal aspect of the element, where the anterior cortical bone has been displaced and folded posteriorly over the posterior cortical bone. The first fracture extends vertically 2.9 cm from the extant distal edge of the medial aspect of the element; the margins are straight and smooth. A flake of bone, measuring *c*. 2.0 cm in length and 0.5 cm in width, appears to have been evulsed from this fracture site and is no longer extant. A second fracture is observed on the posterior surface of the distal aspect of the element, *c*. 2.2 cm lateral to the previous fracture. It extends vertically approximately 4.9 cm in length from the extant distal edge of the element. The margins are straight and smooth. The extant lesion has a maximum length of 8.0 cm, and maximum width of 3.0 cm.

iii. Right tibia: A fracture is observed on the anterior aspect of the proximal metaphysis of the right tibia. The tibial tuberosity has been displaced posteriorly, creating a roughly trapezoidal fracture of the cortical bone; the full extent of this fracture is not known as the metaphysis has been lost due to taphonomic processes. The cortical surface appears to have been depressed into the underlying trabecular bone due to the placement of severe blunt force in an antero-posterior direction. The extant lesion has a maximum length of 3.4 cm, and a maximum width of 1.7 cm.

3.3.9 KNM-WT 71260: Adult male, head S, face W, preserved lying un-levelled on its left side. The body was bent, with the head and feet higher than the thorax; most of the skull, as well as both legs below the knee were exposed and lost. The upper left arm lies under the body; the left wrists and hands lie over the pelvis and along the upper part of the thigh; the right arm is crossed towards the front of the body over the pelvis, so that the right wrist lies over the distal part of the left arm; the right hand is unnaturally hyperextended over the pelvis. No lesions were observed on the extant elements of this individual, but the position of the hands suggests he may have been bound.

3.3.10 KNM-WT 71263 (Extended Data Figure 7a)**:** Adult male, head NE, face W/down, found in a tightly flexed position within lake sediments, with the face partly turned to the ground. Two traumatic lesions are observed on the cranium (i, ii).

i. Cranium, face/frontal bone: A suite of fractures are observed on the medial superior aspect of the face, involving the glabellar portion of the frontal bone, extending laterally to encompass most of the left supraorbital margin, and inferiorly the frontal processes of the maxilla, the nasal bones, and the medial margins of both orbits. All the above elements are depressed, with the facial and left supraorbital aspects crushed into small adhering pieces of ≤ 0.5-0.1 cm^2, due to the placement of severe blunt force in a posterior-inferiorly inclined direction. The point of impact appears to be the medio-lateral aspect of the face. The supero-lateral margin of the lesion is demarcated by a fracture that traverses the ectocranial layer of the bone for *c*. 2.3 cm, running diagonally inferior-superiorly from the medial aspect of the right supraorbital margin, *c*. 0.7 cm medially to the supraorbital notch, towards the left supraorbital area. Radiating/displacement fractures are also observed. The endocranial aspect of the medial portion of the frontal sinus has been fractured and displaced inwards, folding into the right orbital cavity, while still hinged on the inferior margin of the fracture across glabella. A linear perforating fracture emanates from the primary lesion on the anterior squama of the frontal bone, running sagitally and slightly obliquely, from glabella towards the middle of the frontal bone for *c*. 5 cm. The superior aspect of fracture is located *c*. 3 cm anterior to bregma; where it features a bevelled channel which extends for *c*. 0.2 cm, forming a 'V-shaped' incision that penetrates the ectocranium anteriorly for *c*. 0.1 cm. The margins of the fracture are smooth and straight, although in some areas they have eroded due to taphonomic processes. Two secondary radiating fractures emanate from this point. An ectocranial fracture travels horizontally towards the left aspect of the frontal bone for *c*. 6 cm. This fracture perforates the frontal bone at its point of origin, becoming ectocranial laterally, and ending in a 'V-shaped' channel. An endocranial fracture is also observed travelling for *c*. 2.5 cm towards the right aspect of the frontal bone, narrowing into a 'V-shaped' channel. The margins of the endocranial fracture are bevelled and sharp. The individual lay on his right side with the lesion on the anterior portion of the face. Soil overburden appears to have laterally compressed the anterior aspect of the cranial vault due to its instability following the suite of facial and frontal bone fractures. The right and posterior elements of the cranium are unaffected by the suite of fractures to the face and exhibit no distortion.

ii. Cranium, temporal bone: A perforation is observed on the superior aspect of the squama of the right temporal bone, just inferior to the temporal suture, *c*. 2.8 cm superior to the superior aspect of the eminence of the zygomatic process. When observed from the ectocranial surface, the central aspect of the perforation is semi-circular at its most inferior, posterior point and tapers to a triangular apex at its supero-anterior aspect. The maximum dimensions of the central portion of the perforation are 0.4 cm width, 0.2 cm length. The lesion perforates the outer table, diploë and inner table of the temporal bone. On the ectocranial surface, the inferior aspect of the perforation is surrounded by a slightly bevelled margin, which slopes inwards towards the centre of the lesion. The bevelled margin measures 0.8 cm width and 0.5 cm length. All ectocranial margins are sharp and well-defined. The endocranial aspect of the lesion also presents a bevelled margin on the inferior aspect. The bevel platform extends *c*. 0.3 cm inferior to the inferior aspect of the lesion in an inferiorly-sloping orientation. The endocranial aspect of the lesion, including the bevel, has maximum dimensions of 1.1 cm width and 0.6 cm length. All endocranial margins are sharp and well-defined. This lesion may have been the result of sharp-force trauma, possible a projectile, entering the right side of the head in an approximate horizontal, medially-oriented direction.

3.3.11 KNM-WT 71264 (Extended Data Figure 7b, Supplementary Figure 1)**:** Adult male, head S, lying prone on a sloping surface; the lower legs and feet were exposed and lost. Multiple traumatic lesions to the cranium, involving blunt force trauma to the frontal (i) and left temporal (ii) bones, resulting in the fracturing of the left mandibular condyle and displacement of teeth (iii), a radiating depressed fracture on the right temporal bone (iv), and a radiating depressed fracture on the occipital bone (v). This individual also has what appears to be a healed lesion resulting from sharp force trauma to the frontal bone (vi). The cranium is in a highly unstable state and has been treated with consolidant. The depositional matrix remains *in situ* in the cranial cavity, preventing further descriptions of these fractures on the endocranial surface.

i. **Cranium, frontal bone:** A series of inter-connected, depressed fractures are observed on the ectocranial surface of the frontal bone, across the superior aspect of the frontal bone squama, extending approximately from the right to left frontal bone eminences. There are four fractures in this region which appear to be associated with the same traumatic incident. The most superior is a roughly horizontal fracture, the approximate central point of which is 5.0 cm superior to the right supraorbital notch. This fracture extends from a point 4.7 cm supero-lateral to the frontal-zygomatic suture, for 9.0 cm across the frontal bone squama to a point 2.9 cm superior to the left supraorbital notch. The intermediate fracture extends directly inferiorly from the approximate central point of the superior-most fracture (5.0 cm superior to the right supraorbital notch) for 2.9 cm to join the most inferior fracture 1.9 cm above the orbital rim. The most inferior fracture has the same point of origin as the superior-most fracture (4.7 cm supero-lateral to the frontal-zygomatic suture), and extends diagonally in an inferior direction for 6.4 cm to its terminal point 0.2 cm medial to the right supraorbital notch. The right lateral fragment of the fractured frontal bone squama, superior to the right frontal trigone, is depressed centrally by *c*. 1.1 cm and displaced laterally, protruding beyond the margins of the cranium, while still hinged to the intermediate fracture. The medial aspect of the face also appears depressed. The aetiology of these fractures appears to have been blunt force trauma to the right forehead in a right lateral, posterior-inferiorly inclined direction, impacting at the point of intersection of the superior-most and intermediate fractures, or just inferior to this point (*c*. 2.1 cm). The bone has been depressed in this region, breaking and folding inwards into the cranial cavity. The left most-lateral aspect of the superior-most fracture radiates across the frontal bone squama in an inferior, left lateral direction for approximately 2.2 cm from the edge of the superior-most fracture's break point. The glabella region has also been posteriorly displaced due to the impact, while the right most-lateral aspect of the orbital margin and frontal-zygomatic suture remains in their approximate anatomical position, anterior to the point of impact. The fracture margins are all sharp and bevelled, although in some areas they have eroded due to taphonomic processes. It is thought that this insult was the first of (at least) two blows to the head suffered by this individual.

ii. Skull, left temporo-sphenoid (also involving the left parietal bone, left frontal bone and mandible): A depressed fracture is observed on the ectocranial surface of the left temporal region, which encompasses four bones of the left cranium. The superior-most point of the lesion commences at the left parietal-temporal suture and extends inferiorly to the base of the temporal bone. The lesion extends from the most-anterior point of the left fronto-sphenoidal suture in a posterior direction to the left temporo-parietal suture, 3.0 cm anterior to asterion. The fracture descends in an inferior direction from this point for 5.8 cm, running directly anterior to the left mastoid process. A fragment of temporal bone squama measuring maximum 1.8 cm in width and 2.1 cm in height, remains in situ 3.3 cm superior to the base of the mastoid process. The left mandibular condyle has been fractured on the lateral aspect, approximately 0.7 cm lateral to the medial edge. The left zygomatic bone has been fractured at the eminence of the temporal process, 1.0 cm lateral to the zygomatico-maxillary suture. The aetiology of these fractures appears to have been blunt force trauma to the left side of the head in a left lateral, medial and slightly inferiorly-inclined direction, impacting at the approximate centre of the temporal bone.

The temporal and sphenoidal bones have been depressed in this region, breaking and folding inwards into the cranial cavity. The left zygomatic process of the temporal bone has fractured at its eminence as a result of the blunt force. The left orbital lateral wall and floor have been medially and slightly inferiorly displaced as a result of the blunt force. They remain *in situ*. The temporal process of the zygomatic bone has been fractured as a result of the blunt force, as has the lateral aspect of the left mandibular condyle. The fracture margins are all sharp and bevelled, although in some areas they have eroded due to taphonomic processes. It is thought that this insult was the second of (at least) two blows to the head suffered by this individual. The maximum dimensions of the depressed region are 6.8 cm in width, and *c*. 6.2 cm in length. A radiating fracture is observed on the ectocranial surface of the left parietal bone. The fracture extends from a point on the left parieto-temporal suture *c.* 5.3 cm antero-superior to asterion, travelling posteriorly and slightly superiorly for 7.5 cm across the parietal bone squama, running inferior to the left parietal bone eminence. Another radiating fracture is observed on the ectocranial surface of the occipital bone, emanating from a point *c.* 0.3 cm above asterion, and running horizontally across the entire width of the occipital bone for *c.* 9.0 cm, narrowing towards the right lambdoid suture.

iii. Skull, displaced teeth: Several of the teeth are displaced within the oral cavity. On the right side, the upper RP4 and RM1 have been displaced inferiorly and mesially. The lower RM1 appears to have been dislodged from its alveolus. The crown of this tooth was obliterated ante-mortem, separating the mesial and distal roots of the tooth and forcing them to continuously erupt into occlusion. These roots have been dislodged from the alveolus. The upper RP4 has descended into the space made vacant by the evulsion of lower RM1. The upper RM1 has dislodged from its alveolus, and has descended mesially and inferiorly and now overlies the lower RM2. Only the mesio-buccal root of the upper RM1 remains in connection with the alveolus. On the left side, the upper premolars have been displaced inferiorly, mesially and lingually. The apex of the LP3 has broken through the alveolar process and is positioned at an acute angle outside the maxilla. The mesial root of lower LM1 has been dislodged from its alveolus. The crown of this tooth was obliterated ante-mortem, separating the mesial and distal roots of the tooth and forcing them to continuously erupt into occlusion. The upper LP4 has descended into the space made vacant by the dislodging of the mesial root of the lower LM1. The upper LM2 was dislodged from its alveolus and was observed in situ in a horizontal position with the crown oriented mesially, lying superficial to the upper LM1. The mesiobuccal root of the upper LM2 was broken peri-mortem as depositional matrix was observed to adhere to all fracture surfaces. It is probable that these teeth were all dislodged as a result of the peri-mortem blunt force trauma applied to the cranium, and remained displaced *in situ*, including the tooth evulsed from its alveolus to lie parallel and laterally to the maxilla within the oral cavity. The movement of the teeth appears to follow the directional forces of the blows applied to the head.

iv. Skull, right temporo-sphenoid: A (radiating) depressed fracture is observed on the ectocranial surface of the right temporal region. The fracture encompasses at least four bones of the right cranium. The superior point of the fracture commences at the superior aspect of the right sphenoidal bone at the point of articulation between the frontal, parietal and sphenoidal sutures. The fracture extends inferiorly 5.2 cm to cross the superior, posterior tip of the greater wing of sphenoid, then continues to cross the anterior aspect of the right temporal squama, extending to the base of the bone. The inferior tip of the right lesser wing of sphenoid has also been fractured. A second fracture extends from a point 1.7 cm anterior to asterion and extends directly downwards for 3.1 cm in an inferior, anterior direction directly in front of the right mastoid process. The zygomatic process of the right temporal bone has fractured at its eminence, while the frontal process of the right zygomatic bone has fractured at a point 1.9 cm inferior to the fronto-zygomatic suture. A small fragment of the process (maximum dimensions: 1.5 cm width, 0.7 cm length) remains in articulation with the zygomatic bone at the zygomatico-temporal suture. The right mandibular condyle has fractured at the medial aspect of the condylar head, descending diagonally infero-laterally across the neck, to a point 1.8 cm inferior to the lateral-most aspect of the right condylar head. The right temporal and zygomatic bones have broken and folded inwards into the cranial cavity. The right zygomatic bone remains *in situ*. This series of fractures may be the result of transferred force from the blunt-force trauma described for the frontal bone and right sides of the head. It is possible that a series of radiating fractures occurred as a result of these two blows, with the osseous elements subsequently being displaced due to post-depositional movement/taphonomic processes. The fracture of the right mandibular condyle may have been as a direct result of the blow to the left side of the head, with the strong lateral force applied to the left side causing the element to shift laterally, breaking the condyle within the temporo-mandibular joint. The fracture margins are all sharp and bevelled, although in some areas they have eroded due to taphonomic processes. The maximum dimensions of the depressed region are 7.3 cm width, and *c*. 6.3 cm length.

v. Basicranium: Temporary removal of the articulated splanchnocranium/mandible/cervical vertebrae for stabilisation revealed a radiating depressed fracture on the inferior aspect of the cranium. The fracture appears to traverse the entire basioccipital suture. It appears that the basioccipital suture was destabilised as a result of one or both of the blows described for the frontal bone and left regions of the head, and that these blows, and perhaps subsequent post-depositional/taphonomic processes, caused the cranial base to have folded in on itself, creating a depressed fracture along the basiocciput. The occipital bone presents two additional fractures at the right hypoglossal canal, and between the left posterior aspect of the clivus and the anterior aspect of the left occipital condyle, displacing these fragments of bone in an anterior, superior direction. The first four cervical vertebrae remain articulated and are adhered to the remaining depositional matrix in the oral cavity. The atlanto-occipital articulation is no longer intact, with the vertebrae being displaced in an anterior-inferior direction, coming into direct contact with the body of the mandible. Further observations regarding the condition of the vertebrae are inhibited due to the adhering depositional matrix in the vertebral canal. It is pertinent to note in this case that the individual was recovered lying in a prone position, with the head tightly flexed against the neck. It is possible that some of these fractures and displacement may have occurred as a result of post-depositional/taphonomic processes.

vi. Cranium, left frontal bone: A small, roughly circular lesion is observed on the ectocranial surface of the central aspect of the squama of the frontal bone. The lesion is well-demarcated with rounded edges and a concave centre. The edges appear to be slightly bossed and rounded, appearing a little raised in comparison to the surrounding bone. The margins are smooth and non-porous. Small radiating fractures are observed in three directions (diagonally, supero-laterally to the lesion and in a left postero-lateral direction, extending *c*. 1.2 cm; diagonally in an infero-lateral direction towards the left supraorbital margin, extending for *c*. 0.3 cm; and diagonally, in an infero-lateral direction towards the right supraorbital margin, extending for *c*. 0.5 cm). This lesion appears to be a healed depressed fracture or perforation, possibly caused by sharp force trauma from a projectile. The bone in this region has suffered some taphonomic damage, potentially obscuring further observations of this lesion (for example, the presence/extent of porosity). The maximum dimensions of the lesion are 0.6 cm width, 0.5 cm height, and 0.2 cm depth, tapering towards a point.

3.3.12: KNM-WT 71265 (Extended Data Figure 7c)**:** Adult male, head N, face W, very poorly preserved skeleton lying on a slope, mostly exposed and largely eroded away, although fragments were lying on the surface, including large portions of the cranium. The somewhat splayed right side of the skull and most of the frontal bone were found *in situ*, as the face was partly turned down into the ground. The margins of the remaining exposed cranium, as well as the surface fragments, are strongly patinated, suggesting exposure in antiquity. A traumatic lesion is observed on the extant part of the cranium (i).

i. **Cranium:** A series of fractures are observed to originate from a depressed fracture of the right frontal bone. The first (horizontal) fracture is located on the ectocranial surface, in the area of the right frontal bone eminence, approximately 4.6 cm supero-lateral to the nasofrontal suture. Its extant maximum length is 5.4 cm; however, post-mortem damage prevents observations of its full extent. This fracture extends through the outer table, diploë and inner table, and is visible on the endocranial surface. The second (vertical) fracture is located on the right frontal bone and extends superiorly from a point 0.5 cm lateral of the right supra-orbital notch for 10.0 cm towards the coronal suture. This fracture extends through the outer table, diploë and inner table, and is visible on the endocranial surface. The vertical fracture features a depressed fracture flake approximately 3.7 cm superior to the right supraorbital notch. The maximum dimensions of the flake are 2.1 cm length and 1.5 cm width. The fracture at the base of the flake extends 1.2 cm in an infero-medial direction towards the glabella. The flake has been depressed inferiorly into the diploë. A radiating fracture is observed 7.4 cm supero-lateral to the nasofrontal suture, extending diagonally from the vertical fracture in a postero-lateral direction, meeting the coronal suture 3.6 cm left-lateral of bregma. This fracture extends through the outer table, diploë and inner table, and is visible on the endocranial surface. Another radiating fracture is observed originating at the same point as the previous radiating fracture, approximately 7.4 cm supero-lateral to the nasofrontal suture, extending 7.6 cm diagonally in an infero-lateral direction, terminating at the left orbital rim 1.0 cm lateral to the left supraorbital notch. This fracture extends through the outer table and diploë, but does not continue into the inner table. It is not visible on the endocranial surface, although it does continue into the orbit and is observed to continue 1.0 cm into the extant portion of the orbital roof in a postero-medial direction. Another radiating fracture is observed to originate from the previous fracture, commencing at its extant edge in the orbital roof and extending diagonally 2.7 cm in a supero-medial direction into glabella. This fracture extends through the outer table and diploë, but does not continue into the inner table, and it is not visible on the endocranial surface. The aetiology of these fractures appears to have been blunt force trauma to the right forehead in a right lateral, posterior inferior-inclined direction, impacting in the region of the depressed fracture flake, *c*. 4.0 cm supero-lateral to the nasofrontal suture. The bone has been depressed in this region, breaking and folding inwards into the cranial cavity, while the right zygomatico-frontal trigone retains its natural shape. The glabella region has been posterior-inferiorly displaced due to the impact, with the left side twisting outwards and upwards while the right side has been pressed downwards and inwards, causing the radiating fractures described for the orbital roof. The fracture margins are all sharp, although in some areas they have eroded due to taphonomic processes. It is thought that this series of fractures was the result of a blow to the head suffered by this individual. The incomplete, fragmented and degraded nature of the cranium inhibits any further observations of additional cranial trauma.

4 Fauna

A relatively small number of animal remains, other than fish, were found on the surface/sub-surface of Nataruk (Supplementary Table 3). All loose sediments from the areas immediately above and surrounding the human skeletons were sieved, and the animal remains identified to major taxonomic level and counted. The site is covered in thousands of fragments of fish, with marked variation in size. Reptilian and mammalian remains were found concentrated on the sandy ridge, also very fragmentary and eroded. Hardly any complete bone element was found, and taxonomic identification was only carried out on a minority of fragments. A small number of fragments and/or teeth of crocodile (*Crocodylus niloticus)* were found, as well as the fragmentary remains of a small turtle and one unidentified snake vertebra. The mammalian fauna was dominated by fragments of hippopotamus (*Hippopotamus amphibius)*, although a number of bovids were also found, including buffalo (*Syncerus caffer)*, hartebeest (*Alcelaphus sp.*) and possibly eland *(Taurotragus oryx*). Other mammals, mostly represented by teeth or tooth fragments were warthog (*Phacochoerus africanus)*, and zebra (*Equus sp.)*. Some of the animal remains show marks of gnawing by carnivores, not observed in the human bones.

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Supplementary Table 3 - Summary of archaeological and faunal remains found at Nataruk, either above or with the human skeletal remains.

Location	Skeleton association	Sex	Age	Surface/sub-surface			Buried in sediments with skeleton	
				Scatter area (m)	Lithics and other archaeology*	Fauna**	Lithics	Fauna
NE mound A	KNM-WT 71251	M	Adult	2.0 x 3.0	15 (0:12:2:0)	Fish, hippo, UID	1 embedded in skull	
	KNM-WT 71252 KNM-WT 71268	 F?	Juvenile Adult	1.0 x 1.5 1.5 x 2.0		Fish, bovid p-cr frag		
NE mound B	KNM-WT 71253 KNM-WT 71254 KNM-WT 71269 KNM-WT 71255 KNM-WT 71256 KNM-WT 71270	M F? F F 	Adult Adult Juvenile Adult + foetus Adult Juvenile	4.0 x 4.0	2 (0:2:0:0)	Fish, crocodile tooth and frags (10), turtle (2), hippo teeth frags (4), 14 bovid teeth frags, suid teeth frags (6), UID (~220)		
	KNM-WT 71266	F?	Adult (FF)	1.0 x 2.0	1 (0:0:0:1)	Fish, crocodile, UID		
NW end of sandy ridge edge	KNM-WT 71257	M	Adult	4.0 x 4.0	7 (0:5:2:0), 1 harpoon frag	Fish, crocodile, hippo, suid teeth (2), equid tooth (2), bovid teeth (3), UID		
	KNM-WT 71258	M	Adult	2.0 x 2.0	5 (0:3:2:0)	Fish, hippo, bovid (teeth, p-cr), snake vertebra	2 in thoracic cavity	Fish
	KNM-WT 71259	F	Adult	1.0 x 1.5		Fish, turtle (1), bovid tooth frags, UID		Nile Perch skull, other fish, crocodile frags, UID
SW corner of site	KNM-WT 71260	M	Adult	2.0 x 2.0	36 (2:19:1:14)			
	KNM-WT 71276	M?	Adult (FF)	3.0 x 3.0	5 (0:1:2:2)	Fish, crocodile vertebra, hippo frags and teeth, suid tooth, bovid frags, UID		
Top/N edge of sandy ridge	KNM-WT 71261		Adult (FF)	6.0 x 6.0	628 (7:475:12:134)	Fish, bovid teeth frags, UID frags		
	KNM-WT 71262 KNM-WT 71271 KNM-WT 71263	 M	Adult (FF) Juvenile Adult	6.0 x 4.0	7 (1:6:0:0)	Fish (221), crocodile, hippo (32, suid teeth (5), bovid teeth (5), bovid p-cr (11), equid teeth (3), UID		
S edge of sandy ridge	KNM-WT 71264	M	Adult	2.0 x 2.0	8 (0:4:1:3)	Fish, bovid p-cr frag (1), UID (15)		
	KNM-WT 71267	F ?	Adult (FF)	2.0 x 10.0, gully	17 (0:14:0:3), 1 harpoon frag	Fish, turtle, UID		Fish
	KNM-WT 71277		Adult (FF)	4.0 x 4.0	3 (0:1:2:0)	Fish, UID (1)		
SE end of sandy ridge	KNM-WT 71265 KNM-WT 71272	F 	Adult Juvenile	3.0 x 4.0	19 (1:13:5:0)	Fish, hippo phalanx, suid tooth, UID (~100)		
	KNM-WT 71274 KNM-WT 71275 KNM-WT 71273	 F? 	Adult (FF) Adult (FF) juvenile	20.0 x 20.0	6 (1:4:0:1)	Fish (918), crocodile (5), turtle (11), hippo (105), v partial hippo juvenile skeleton, bovid frags (19), equid tooth (1), suid tooth (1), carnivore frag (1), UID (1172)		

Abbreviations: Adult (FF) – fragmentary human remains; M – male; F - female

762 lithics were found at Nataruk – 628 within a 6 x 6 m area above one of the skeletal remains, 131 throughout the site (either in the sediments above or surrounding the skeletal remains), 2 within the body cavity of a skeleton, and 1 embedded in a cranium.

* lithics shown as (cores: flakes: tools: chips);

** UID: unidentified fragments

5 Archaeology

A number of archaeological artefacts were recovered from the surface/sub-surface sediments above the human skeletons at Nataruk (Supplementary Table 3). The assemblage consists of a total of 762 artefacts - 14 cores and 748 flakes. Most of these (82.4%, 628/762) were concentrated in a 6 x 6 m area at the highest point of the ridge where recent sands and sediments were thickest. Below the latter, the fragmentary and partial remains of a human skeleton (KNM-WT 71261) were found. 131 lithic artefacts were found throughout the rest of the site, either on the surface among the human and animal bone scatters, or in the sediments sieved during the excavation of the articulated skeletons. Three artefacts were found embedded in or within the thoracic cavity of two skeletons. Flakes and debitage comprised the majority of the lithic artefacts; among the flakes, less than 5% consisted of shaped stone tools. The assemblage is Later Stone Age (LSA) in nature and similar to other LSA assemblages within the local area. Similarly, the Nataruk industry exhibits both a microlithic and macrolithic component, with the microlithic element accounting for 89.5% of the total assemblage.

Raw materials. All macrolithic artefacts at Nataruk were manufactured from a range of green, grey and brown basalts that originate from the Napedet mountain range several kilometres to the west of the site (Supplementary Tables 4 and 5). Whilst 20.5% of the microlithic component of the industry is also manufactured using these basalts, the majority of microlithic artefacts are made from a range of other raw material types. Quartz dominates the microlithic assemblage in terms of overall volume (56.0%), although chert is also common (15.2%). Lithics made on other raw material are far less common, but include an unidentified fine black material that is easily weathered (6.6%), microcrystalline silicate (1.0%), cryptocrystalline silicate (0.1%), and fine black obsidian (0.3%).

The larger grained, common, raw material types, such as basalt and quartz, dominate the volume of the assemblage. However, debitage and un-utilised flakes make-up a large proportion of the artefacts made from these raw material types. When only shaped and utilised flakes are considered, a different picture emerges - there is a clear preference for finer grained raw material types that occur in much lower frequencies, the sources of which have not yet been identified. Chert appears to be the preferred raw material for shaped tools – making up only 13.6% of the assemblage but over 50% of the tools; this is followed by basalt, quartz, and obsidian.

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Supplementary Table 4 - Assemblage breakdown by raw material type

	Basalt		Quartz		Chert		Soft Black		MCS		Obsidian		TCS		Total
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	
Microlithic	140	18.4	382	50.1	104	13.6	45	5.9	7	0.9	3	0.4	1	0.1	682
Macrolithic	80	10.5	.	0.0	.	0.0	.	0.0	.	0.0	.	0.0	.	0.0	80
Total	220	28.9	382	50.1	104	13.6	45	5.9	7	0.9	3	0.4	1	0.1	762

*MCS: microcrystalline silicate; TCS: cryptocrystalline silicate

Supplementary Table 5 - Assemblage component by raw material type

	Basalt		Quartz		Chert		Soft Black		MCS		Obsidian		TCS		Row Totals	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Shaped Tool	10	28.5	3	8.6	18	51.4	1	2.9	-	-	2	5.7	1	2.9	35	100
Cores	1	7.1	5	35.7	8	57.1	-	0.0	-	0.0	-	0.0	-	0.0	14	100
Flakes	72	12.9	362	64.7	73	13.1	44	7.8	7	1.3	1	0.2	-	0.0	559	100
Debitage	137	89.0	12	8.8	5	3.2	-	0.0	-	0.0	-	-	0.0	0.0	154	100

*MCS: microcrystalline silicate; TCS: cryptocrystalline silicate

Mode of production. The macrolithic basaltic elements in the industry are taken from mining sources or large boulders within the area; no macrolithic cores were evident at the site. The microlithic element is dominated by split pebble technology for both quartz and chert pieces; evidence of primary and secondary level reduction of these raw material types abounds in the form of both flakes and cores. These two raw materials, although of high quality on occasion, appear to occur only in small nodules or pebbles, which limit their usage. The mean core size for chert was only 31.5 mm, and 25.3 mm for quartz. There is no evidence of on-site reduction for the less common raw material types, such as obsidian, microcrystalline silicate and cryptocrystalline silicate, which are represented almost exclusively in the form of shaped stone tools. Most platforms are not prepared and have either a plain or cortical surface (55.0%), with the remainder being dihedral or faceted.

General metrics. The mean overall flake length is 20.94 ± 9.95 mm, with a mean length:breadth ratio of 0.63. The flakes are highly microlithic (unmodified flakes have a mean length of 19.95 mm). However, shaped tools tend to be larger in size, with a mean length of 26.9 mm for the overall assemblage, and 25.57 mm for geometrics.

Retouch. The lithic assemblage from Nataruk shows few retouched artefacts. The presence/absence and type of retouch was examined in 592 artefacts, and was observed in only 5.6% of these. Of the retouched lithics, the majority were shaped tools (78.8%), rather than utilised or re-sharpened flakes (only 21.2%). Abrupt retouch for the backing of geometric microliths and backed blades was the most common type of retouch. Direct retouch dominated the assemblage, with bifacial retouch occurring in only 4 cases and inverse retouch only once. It is likely that 3 artefacts (two crescents and a scraper) had been notched for hafting; otherwise, notching was not observed. Specialised retouch, such as burins, were also rare when compared to other East African LSA assemblages[145], and there were only two instances of burin use, neither of which were of a dihedral nature.

It is also worth noting that the only two obsidian shaped tools – a crescent and a trapeze – were found within the skull of KNM-WT 71251 and the thoracic cavity of KNM-WT 71258 respectively, suggesting that, firstly, this material was used for weaponry, and secondly, that it may have been an exotic material to the individuals whose biological remains were preserved at the site. Both artefacts show evidence of impact fractures on the tip, and the crescent embedded on the left parietal of KNM-WT 71251 has impact chips down 50% of the length of the blade.

6. Dating

6.1 Chronological summary

Dating of the site of Nataruk and the human remains found therein was carried out using three methods: (1) Radiocarbon dates (^{14}C) on human bone, sediments and shells were obtained by Beta Analytic Inc. and the Radiocarbon Dating Laboratory of the Australian National University; (2) Optically Stimulated Luminescence (OSL) dating of quartz grains was carried out at the University of Oxford; and (3) Laser Ablation Uranium-series Analyses (U-series) of the human remains was carried out at The Australian National University. The material dated derives from shallow sediments and shells above the skeletons (^{14}C), shells in immediate association with the human remains (^{14}C), lake sediments in which a human skeleton was embedded (OSL), and the human remains themselves, from which minimum ages were estimated (U-series).

The soils above the skeletons date between 7,270 - 8,160 cal BP, towards the end of the Holocene climatic optimum when smaller lakes and lagoons were in the process of regression[26]. Most of the fragmentary fauna and archaeological material are associated with these soils. Two shells collected from sediments surrounding 2 of the skeletons date to between 9,030 – 9,530 cal BP. The 2 shells prised from the surface of the human bones range in age between 9,260 – 10,480 cal BP. A shell cemented into lake sediments in which a human skeleton was found was dated to 10,190 – 10,275 cal BP, but a small percentage of contaminating carbon in the sample increases the uncertainty to 9,540 – 11,750 cal BP. A block of the sediments onto which the latter shell was found adhering was dated to 9,680 ± 805 years by OSL. The minimum ages obtained from Uranium-series analyses of the human remains present a complex picture. In their totality, the results indicate that the human remains are at least early Holocene in age; however, a few of the samples returned older estimates, including two independent measures of the same individual with no Uranium leaching or contaminants to suggest a problem with the samples. Given the site's taphonomy and similarity in deposition, preservation and cultural context of the remains, the shells cemented on the human remains have been taken here as the closest approximation to the age of the human remains, between 9,500 – 10,500 cal BP, although an earlier, mid-Upper Pleistocene age cannot be fully excluded.

Further details of the dating methods used are found in the Methods section of the paper, and of the dates obtained in the sections below.

6.2 Radiocarbon Dating

Three fragments of human bone sent for radiocarbon dating were unsuccessful (BA-343477, BA-343478, BA-346828). This is consistent with results from previous attempts at directly dating human remains from the area[27]. As a direct date on the skeletons was not possible, dates on soils and shells were obtained.

Three soil samples were submitted for radiocarbon dating (BA-344850, BA-341441, BA-344845); only the latter two were successful. These two radiocarbon dates derive from sediments stratigraphically above two of the skeletons (KNM-WT 71751, KNM-WT 71260).

Five radiocarbon dates were obtained from shells with different degrees of association with the human remains (Supplementary Table 6). Two shells were found amongst the sediments surrounding the skeletons. One of these was from the sieve of the excavation of skeleton KNM-WT 71254 (BA-344846), and the other from the surface around the exposed fragments of skeleton KNM-WT 71274 (BA-344849). Another two shell samples (BA-344847, BA-

344848) were prised from the surface of the human bones into which they had become cemented (KNM-WT 71258 and KNM-WT 71264 respectively). A fifth shell was from within the cemented sediments in which one of the skeletons was embedded (S-ANU 37218), specifically from the lower layer of the NNE wall of the excavation of skeleton KNM-WT 71251, which was removed as a block (to which the shell adhered) for OSL dating.

Supplementary Table 6 - Radiocarbon ages of gastropod shells from Nataruk

Skeleton association	Context	Sample code	**14**C age	Calibrated date	δ13C (o/oo)
KNM-WT 71254	From the sieve of the excavation of skeleton	BA-344846	8,210 ± 40 yrs BP	9,290 - 9,030 cal BP	3.5
KNM-WT 71274	From the surface around the exposed fragments of skeleton	BA-344849	8,450 ± 40 yrs BP	9,530 - 9,430 cal BP	-6.9
KNM-WT 71258	Prised from the surface of skeleton	BA-344847	8,330 ± 40 yrs BP	9,460 - 9,260 cal BP	-5.3
KNM-WT 71264	Prised from the surface of skeleton	BA-344848	9,160 ± 40 yrs BP	10,480 - 10,470 cal BP/ 10,420 - 10,230 cal BP	-2.5
KNM-WT 71251	From the edge of the block of sediments excavated from the lower layer of the NNE wall of the excavation of skeleton	S-ANU 37218	9,080 ± 35 yrs BP	10,275 - 10,190 cal BP (9,540 – 11,750 cal BP)	-7±2

If it is assumed that the shells directly associated with the skeletons were deposited on the human remains soon after death, they provide a minimum age for the people who died at the site. The five shells from Nataruk have different ages, as expected from their different origins within the stratigraphy of the site. It is unclear whether this is due to repeated wetting of the area by the lagoon and multiple phases of shell deposition, to the diagenesis of the shells, or if a radiocarbon reservoir effect may affect some species. Garcin and colleagues[3] have shown that a reservoir effect does not exist in Lake Turkana, so it is unlikely that the shells are affected by a variable freshwater reservoir effect. The cleaned sample dated at the Australian National University contained 5.1 ± 0.53% diagenetic calcite, and some contamination is therefore expected to remain in the sample. If all carbon in this calcite was modern, the age of the shell would shift from 9,080 yrs BP (10,275 - 10,190 cal BP) to 10,040 yrs BP (11,750 – 11,355 cal BP). If the carbon was ^{14}C-free, the date would shift to 8,660 yrs BP (9,690 – 9,540 cal BP). These maximum and minimum ages for this shell do not significantly change the interpretation of a late Pleistocene/Early Holocene chronology for the site. However, the result does suggest that it is possible that the other shell dates may also deviate in either direction from their real age by up to 1,000 - 2,000 years.

6.3 Optically Stimulated Luminescence Dating

An OSL date of (1σ): 9,680 ± 805 years (Laboratory sample code: X6481) was obtained from a block sample of the semi-consolidated sediment that was exposed through the excavation of KNM-WT 71251, with a 1σ range between 8,875-10,485 years. The dose equivalent (De) estimate, dose response curves and the obtained De using a central age model (CAM)[75] based on twelve individual measurements are illustrated in Extended Data Fig. 3d-f. The primary data cover a narrow range of values and display a relatively low overdispersion (OD) of 10.2 ± 0.8 %, with the majority of data points falling within the 2σ dispersion range of the radial plot (left side of Extended Data Fig. 3f). The histogram and kernel density estimate curve (right side of Extended Data Fig. 3f) do not feature a leading edge of low De values nor an asymmetric tail of high values often associated with partially bleached samples[146,147]. The dataset is consistent with a single dose population from a well bleached sample which remained unaffected by post-depositional mixing. The majority of aliquots displayed high sensitivity and the decay curves typically show a fast decreasing OSL signal (see Extended Data Fig. 3d). Measurements also showed a well-defined 110°C TL peak which is characteristic of quartz. Few aliquots revealed a noticeable response to infrared light stimulation thereby confirming that good sample preparation had been achieved and/or relative sparseness of feldspathic components. Repeat measurements of the luminescence signal resulting from the first regeneration dose (recycling test) indicate that the adopted SAR procedure provides adequate correction for changes in sensitivity. The mean recycling value is consistent with unity (1.03) and is further characterized by a small standard deviation (0.06) and standard error of the mean (0.02). The level of recuperation as monitored by the OSL response after a regeneration dose of zero was negligible and generally found to be below 2%. The calculated OSL age estimate and the associated error (within 1 σ) are shown in Supplementary Table 7 alongside the radioactivity data.

Supplementary Table 7 - Radioactivity data, De determination and calculated OSL age estimate.

Sample code	Radioisotopes K %	Th ppm	U ppm	Gamma dose rate (Gy/kyr)	Beta dose rate (Gy/kyr)	Cosmic dose rate (Gy/kyr)	Total dose rate[a] (Gy/kyr)	De[b] (Gy)	OSL age[c] (years)
X6481	1.47±0.07	3.8±0.2	1.0±0.1	0.62±0.03	1.27±0.06	0.19±0.05	2.11±0.14	20.42±1.06	9,680 ± 805

[a] The total dose rate includes a small assumed internal dose rate of 0.03±0.01 Gy/kyr to account for alpha and beta dose rates originating from small concentrations of ^{238}U and ^{232}Th within the quartz grains. The mean total uncertainty (at one sigma) was calculated as the quadriatic sum of the random and systematic uncertainties.

[b] The mean De was obtained using a central age model (CAM).

[c] The date is reported in years before 2014 and the uncertainty is expressed within one sigma (68% confidence interval).

6.4 Uranium-Series dating

The details for laser ablation U-series analyses of skeletal materials were recently summarised by Grün and colleagues[84]. U-series analysis provides an insight into when uranium migrates into a bone. This may occur a short time after the burial of the bone, but there also may be later overprints which are difficult to recognise. As such, apparent U-series results of bone have to be generally regarded as minimum age estimates.

Seventeen uranium-series measurements were obtained from the human remains from Nataruk (and one from a fragment of hippopotamus). Laser ablation data were obtained from spot analyses on the cortical sections of the bone on lines perpendicular to the surface (either along a single line for thick cortical bones, or along several lines for thinner cortical bone sections (e.g. ribs with a spongy centre)).

Laser ablation U-series age calculations are compromised if the U-concentrations are below about 0.5 ppm. Many of the samples have significant amounts of detrital ^{232}Th, which may either be derived from sediment material in pores, or diffused from the outside (see example in[84]). When the elemental U/Th ratios drop below 100, the resulting U-series result may be influenced by detrital ^{230}Th. A higher ratio (300), as proposed by Hellstrom[148], was not used, but given the nature of the samples and distribution of within sample U/Th ratios, we expect that the 300 cut-off ratio would not have a significant effect on which samples returned age estimates. Therefore, diffusion-adsorption-decay (DAD) age estimates were calculated when ≥4 data points remained after taking into account the level of U-concentration (>0.5 ppm), and amount of detrital ^{232}Th (U/Th elemental ratios >100)[85]. Cases when these conditions were not met, and thus no DAD calculation was carried out, are marked in bold in Supplementary Table 8. However, DAD calculations can only be successful if the data more or less comply with the underlying DAD model, i.e. there is no conflict between the ^{230}Th/^{238}U and ^{234}U/^{238}U data across the bone. If the data scatter too much, or violate the basic model assumptions, the calculation does not return an age with appropriate error. The DAD results are listed in the Supplementary Table 9. Since there were a number of samples for which no DAD ages could be calculated, the average spot data were used to calculate average ages (Supplementary Table 8). The DAD age estimates (Supplementary Table 9) agree within error with the average age estimates (Supplementary Table 10), but the former have considerably smaller errors and, if available, are generally preferable because they utilise the underlying principle of U-diffusion. The characterisation of the U-series samples is described in Extended Data Table 3.

The majority of the bones return U-series results that are expected from the radiocarbon analyses of the surrounding sediments, i.e. similar to or somewhat younger than the age bracket of 8,000 to 10,500 cal BP. Four samples returned average ages in the range of 20,000 to 25,000 yrs (3507, 3509, 3512 and 3517) and three in the range of 30,000 to 50,000 yrs (3487, 3513 and 3514). It is interesting to note that only two of these older samples (3487 and 3517) yielded DAD results, the other violated the model conditions, i.e. their U-series isotopic inventory does not result from a single stage diffusion process. This can perhaps be taken as a basis for disregarding four of these older results.

We would expect that if uranium is leached from the bone following an initial uptake phase this will be more visible near the surface of the bone (which will have lower Uranium concentration), the relationship between U-concentration and age will be altered, and the age of a sample could be overestimated. It is interesting to note that there is a trend of increasing $^{234}U/^{238}U$ ratios with apparent age, and that the three oldest samples have the largest scatter in this ratio (Supplementary Table 8 and Supplementary Figure 3c). We interpret these results as indicating firstly that the source of the uranium that migrated into these bones is different from the other bones (thus the scatter), and secondly, that there were processes in place that may perhaps have caused U leaching (and thus the potential overestimation of the ages of the samples). Nevertheless, samples 3487 and 3513 come from the same individual and give consistent results. Therefore, they cannot be disregarded off-hand. While we do not wish to imply that the human population at Nataruk could be as old as 30,000-50,000 yrs, this cannot be excluded from the U-series results. The possibility exists that the skeletons are older than the surrounding sediments and shells, if, for example, the remains had been partially exposed during a period of erosion such as the Last Glacial Maximum, and later covered by the high water levels in the early Holocene, when they could have become embedded in lake sediments and associated with shells of a younger age. Nevertheless, the probability that the skeletons would have remained articulated in this case is small, and on the basis of the consistency in the ^{14}C and OSL dates, we believe that the remains from Nataruk are likely to be terminal Pleistocene/early Holocene in age.

Supplementary Table 8 - U-series results on individual bone samples. No age calculations were carried out for U concentrations of ≤ 0.5 ppm or elemental U/Th ≤ 100, but not negative (indicated in bold). Negative U/Th are due to the background being higher than the measurement. Different analytical sections are separated by lines. All errors are 2-σ.

3485	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age error (kyr)
1	68.3	5896	**11.6**	1.0808	0.0059	1.0894	0.0027	n/a	
2	53.7	5557	**9.7**	1.1004	0.0102	1.1316	0.0034	n/a	
3	54.6	5992	**9.1**	1.1884	0.0134	1.1395	0.0035	n/a	
4	52.5	5719	**9.2**	1.2863	0.0155	1.1912	0.0024	n/a	
5	61.3	5040	**12.2**	1.2225	0.0109	1.1314	0.0028	n/a	
6	49.9	9077	**5.5**	1.2415	0.0099	1.1220	0.0031	n/a	
7	43.9	8630	**5.1**	1.2017	0.0091	1.0946	0.0029	n/a	
8	17.8	5487	**3.2**	1.3898	0.0120	1.1150	0.0051	n/a	
9	20.1	17485	**1.1**	1.5286	0.0469	1.1862	0.0086	n/a	
10	57.8	11012	**5.2**	1.2055	0.0080	1.1103	0.0023	n/a	
11	**0.5**	1284	**0.4**	8.9275	0.1538	1.7129	0.0366	n/a	
12	24.1	12747	**1.9**	1.5485	0.0106	1.2243	0.0053	n/a	
13	9.0	8162	**1.1**	2.0299	0.0270	1.3077	0.0084	n/a	
14	2.8	1588	**1.8**	3.0611	0.0443	1.4534	0.0171	n/a	
15	11.1	9768	**1.1**	1.8753	0.0312	1.3312	0.0086	n/a	
16	1.3	452	**3.0**	4.4301	0.0546	1.4473	0.0199	n/a	
17	0.5	1284	**0.4**	3.3500	0.1155	1.3545	0.0431	n/a	
18	1.4	459	**3.1**	4.2941	0.0808	1.5191	0.0274	n/a	
19	3.1	2614	**1.2**	2.5589	0.0306	1.4080	0.0116	n/a	
20	0.9	2811	**0.3**	4.8168	0.1136	2.2843	0.0431	n/a	
21	1.9	696	**2.7**	4.6401	0.0558	1.7814	0.0187	n/a	
22	0.9	2065	**0.4**	6.7899	0.1263	2.2999	0.0381	n/a	
23	38.3	27942	**1.4**	1.5713	0.0111	1.2042	0.0039	n/a	
24	6.0	21302	**0.3**	2.8300	0.0520	1.5055	0.0156	n/a	
25	0.6	4768	**0.1**	8.5721	0.2061	1.8440	0.0416	n/a	
26	**0.4**	3223	**0.1**	4.5467	0.1224	1.7703	0.0521	n/a	

3486	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	**0.1**	511	**0.2**	1.3270	0.1505	1.8100	0.1588	n/a	
2	**0.2**	434	**0.4**	0.7187	0.0858	1.6133	0.0840	n/a	
3	2.3	198	**11.6**	0.2340	0.0129	1.3767	0.0149	n/a	
4	2.4	81	**29.0**	0.4612	0.0154	1.3504	0.0165	n/a	
5	2.0	55	**35.9**	0.3397	0.0139	1.3407	0.0188	n/a	
6	2.0	101	**19.4**	0.4269	0.0166	1.3499	0.0160	n/a	
7	2.1	31	**67.1**	0.3458	0.0171	1.3661	0.0181	n/a	
8	1.4	352	**4.0**	0.3238	0.0214	1.4079	0.0180	n/a	
9	2.0	114	**17.4**	0.2876	0.0131	1.3964	0.0186	n/a	
10	1.4	32	**45.8**	0.3245	0.0231	1.4246	0.0193	n/a	
11	1.9	147	**12.8**	0.3074	0.0160	1.3872	0.0153	n/a	
12	1.3	229	**5.6**	0.2982	0.0167	1.3305	0.0255	n/a	
13	1.0	212	**4.8**	0.2987	0.0264	1.4069	0.0271	n/a	
14	1.8	179	**10.0**	0.3125	0.0141	1.3749	0.0155	n/a	
15	0.6	445	**1.3**	0.4150	0.0342	1.3793	0.0492	n/a	
16	0.9	389	**2.3**	0.3032	0.0266	1.4396	0.0272	n/a	
17	2.1	249	**8.5**	0.2528	0.0144	1.3539	0.0160	n/a	
18	0.9	378	**2.4**	0.3153	0.0248	1.3787	0.0303	n/a	
19	1.3	487	**2.6**	0.3173	0.0206	1.3800	0.0245	n/a	
20	0.7	1130	**0.6**	0.5141	0.0268	1.3923	0.0341	n/a	
21	**0.2**	484	**0.4**	0.6834	0.0769	1.5374	0.0842	n/a	
22	**0.4**	732	**0.5**	0.8656	0.0607	1.4134	0.0704	n/a	
23	**0.3**	659	**0.5**	0.6208	0.0581	1.4717	0.0571	n/a	
24	**0.4**	568	**0.8**	0.4259	0.0380	1.4206	0.0446	n/a	
25	**0.1**	383	**0.3**	1.0024	0.1308	1.7462	0.1451	n/a	

3487	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	0.6	31	**20.6**	0.5246	0.0253	1.3758	0.0362	n/a	
2	1.0	3	376.1	0.5118	0.0229	1.4508	0.0215	46.4	2.7
3	1.0	2	560.4	0.5428	0.0327	1.4730	0.0258	48.9	3.8
4	0.6	3	202.0	0.5262	0.0360	1.4386	0.0352	48.5	4.4
5	0.7	1	559.2	0.4872	0.0312	1.4444	0.0332	43.9	3.6
6	0.6	1	649.6	0.4601	0.0366	1.3969	0.0420	42.8	4.4
7	0.9	1	879.1	0.4592	0.0243	1.4125	0.0236	42.1	2.8
8	0.6	1	566.2	0.6486	0.0359	1.3266	0.0369	70.9	6.1
9	0.7	2	365.9	0.5189	0.0285	1.3784	0.0363	50.4	3.9
10	0.7	2	440.6	0.5170	0.0310	1.5021	0.0276	44.9	3.4
11	0.6	2	341.2	0.5203	0.0364	1.4578	0.0367	47.0	4.3

12	0.6	2	362.3	0.5241	0.0316	1.5057	0.0372	45.5	3.6
13	0.7	1	549.5	0.5539	0.0338	1.5043	0.0294	48.8	3.9
14	0.7	1	945.4	0.5465	0.0229	1.5534	0.0307	46.0	2.6
15	**0.4**	6	**72.1**	0.5775	0.0397	1.5213	0.0744	n/a	

3503	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	3.1	591	**5.3**	0.2289	0.0133	1.3295	0.0173	n/a	
2	7.3	5	1458.4	0.1411	0.0075	1.3674	0.0105	11.8	0.7
3	6.7	0	-197272	0.1263	0.0075	1.3514	0.0140	10.7	0.7
4	4.7	-1	-7078.5	0.1313	0.0088	1.3422	0.0114	11.2	0.8
5	5.2	0	-95223	0.1376	0.0098	1.3530	0.0099	11.7	0.9
6	6.3	1	11863.3	0.1529	0.0071	1.3665	0.0121	12.9	0.6
7	6.1	0	33924.6	0.1730	0.0070	1.3634	0.0087	14.7	0.6
8	5.1	1	3852.8	0.1385	0.0070	1.3267	0.0130	12.0	0.6
9	2.6	9	279.5	0.1369	0.0170	1.3602	0.0176	11.5	1.5
10	3.1	5	662.1	0.1313	0.0135	1.3400	0.0185	11.2	1.2
11	2.9	56	**52.9**	0.1410	0.0140	1.3396	0.0168	n/a	
12	3.2	32	100.5	0.1380	0.0112	1.3432	0.0139	11.8	1.0
13	5.5	20	277.3	0.1057	0.0097	1.3284	0.0103	9.0	0.9
14	**0.7**	928	**0.8**	2.4945	0.1985	1.1638	0.2281	n/a	
15	**0.9**	1264	**0.7**	3.8805	0.1083	1.2216	0.0276	n/a	
16	**0.8**	1263	**0.6**	3.1581	0.3455	1.2440	0.0294	n/a	
17	**0.8**	389	**2.0**	2.7556	0.1177	1.1411	0.0249	n/a	
18	**0.7**	1576	**0.4**	1.9917	0.1202	1.1782	0.0276	n/a	
19	**0.6**	333	**1.7**	1.6207	0.0957	1.1349	0.0315	n/a	
20	**0.1**	470	**0.3**	2.2827	0.3673	1.3198	0.1030	n/a	
21	**0.2**	403	**0.4**	3.2004	0.2930	1.1934	0.0679	n/a	
22	**0.0**	**2**	**1.6**	-11.0302	94.9361	5.8942	54.5736	n/a	
23	**0.1**	506	**0.1**	2.5502	0.4894	1.9059	0.1543	n/a	
24	**0.1**	344	**0.2**	3.3423	0.7861	1.5604	0.1969	n/a	
25	**0.4**	17656	**0.0**	9.3580	0.2532	1.7217	0.0552	n/a	
26	**0.2**	3020	**0.1**	3.4838	0.2845	1.3455	0.0804	n/a	
27	**0.3**	2476	**0.1**	2.4609	0.2159	1.2577	0.0729	n/a	

3504	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	3.5	2	2187.9	0.0702	0.0077	1.3489	0.0114	5.8	0.7
2	3.5	1	4233.2	0.0610	0.0089	1.3230	0.0173	5.1	0.8
3	3.4	0	-19030.1	0.0662	0.0107	1.3686	0.0147	5.4	0.9
4	2.5	0	7058.7	0.0783	0.0102	1.3576	0.0179	6.5	0.9
5	2.7	1	2548.0	0.0707	0.0104	1.3554	0.0175	5.8	0.9
6	2.4	1	4141.4	0.0789	0.0101	1.3498	0.0165	6.6	0.9
7	1.9	0	151837.7	0.0846	0.0106	1.3502	0.0193	7.0	0.9
8	2.3	1	2386.5	0.0892	0.0141	1.3550	0.0171	7.4	1.2
9	2.0	2	1136.3	0.0823	0.0122	1.3574	0.0199	6.8	1.0
10	1.9	3	600.6	0.1005	0.0107	1.3583	0.0173	8.4	0.9
11	2.0	4	477.8	0.0754	0.0116	1.3851	0.0205	6.1	1.0
12	2.1	0	-9653.7	0.0818	0.0101	1.3748	0.0191	6.7	0.9
13	1.2	53	**22.5**	0.1315	0.0204	1.3614	0.0303	n/a	
14	1.0	7	147.4	0.1269	0.0245	1.3463	0.0277	10.8	2.2
15	2.0	5	377.3	0.0974	0.0150	1.3482	0.0191	8.2	1.3
16	1.7	4	381.1	0.0749	0.0123	1.3691	0.0182	6.1	1.0
17	1.7	5	346.2	0.1002	0.0136	1.3463	0.0212	8.4	1.2
18	1.3	7	176.6	0.1029	0.0200	1.3712	0.0225	8.5	1.7
19	1.4	6	226.9	0.1110	0.0186	1.3065	0.0244	9.7	1.7
20	1.3	2	746.6	0.0907	0.0188	1.3355	0.0241	7.7	1.6

3505	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	5.6	7	765.4	0.1429	0.0067	1.3303	0.0106	12.3	0.6
2	5.8	1	9275.6	0.1563	0.0117	1.3202	0.0111	13.7	1.1
3	5.8	0	-12881	0.1018	0.0083	1.3303	0.0095	8.7	0.7
4	5.7	0	-14595	0.1217	0.0092	1.3303	0.0117	10.4	0.8
5	5.9	-1	-7363.7	0.1456	0.0107	1.3344	0.0129	12.6	1.0
6	4.7	-1	-4832.3	0.1475	0.0141	1.3266	0.0142	12.8	1.3
7	3.9	1	5000.0	0.1332	0.0130	1.3370	0.0179	11.4	1.2
8	6.0	1	4570.8	0.1052	0.0083	1.3273	0.0111	9.0	0.7
9	5.1	-1	-6964.3	0.0893	0.0086	1.3578	0.0115	7.4	0.7
10	4.1	-1	-3508.2	0.1006	0.0082	1.3415	0.0179	8.5	0.7
11	4.1	1	4180.2	0.1190	0.0149	1.3144	0.0133	10.3	1.4
12	4.7	0	-160550	0.1210	0.0097	1.3495	0.0122	10.2	0.9
13	5.2	0	12799.4	0.1286	0.0107	1.3451	0.0127	10.9	1.0

14	4.3	1	6511.5	0.1071	0.0099	1.3357	0.0152	9.1	0.9
15	5.3	1	4579.9	0.1212	0.0092	1.3262	0.0100	10.4	0.8
16	4.5	0	30002.5	0.1054	0.0101	1.3176	0.0126	9.1	0.9
17	3.9	2	2325.1	0.1244	0.0107	1.3452	0.0105	10.6	1.0
18	0.9	1068	**0.8**	0.5121	0.0593	1.3358	0.0286		
19	0.2	1338	**0.2**	1.5532	0.2002	1.3316	0.1140		
20	4.8	1	3740.9	0.0891	0.0080	1.3297	0.0176	7.5	0.7
21	4.4	0	16501.5	0.0863	0.0106	1.3252	0.0147	7.3	0.9
22	5.6	0	-15423	0.0807	0.0088	1.3288	0.0113	6.8	0.8
23	4.2	7	609.6	0.0919	0.0124	1.3426	0.0124	7.7	1.1
24	1.3	623	**2.1**	0.2906	0.0260	1.2581	0.0235		

3506	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	0.7	940	**0.7**	0.4915	0.0411	1.3341	0.0326		
2	5.3	15	354.2	0.0956	0.0075	1.3444	0.0113	8.0	0.7
3	4.9	3	1734.4	0.0771	0.0082	1.3534	0.0118	6.4	0.7
4	3.5	11	334.4	0.0976	0.0138	1.3525	0.0150	8.2	1.2
5	3.7	2	1971.0	0.1142	0.0323	1.3333	0.0154	9.7	2.9
6	4.1	2	1887.9	0.0814	0.0109	1.3643	0.0145	6.7	0.9
7	4.0	5	830.5	0.0775	0.0078	1.3437	0.0128	6.5	0.7
8	4.1	0	25017.7	0.0799	0.0142	1.3272	0.0148	6.8	1.2
9	6.1	2	3891.2	0.0682	0.0050	1.3453	0.0102	5.7	0.4
10	4.4	0	11521.2	0.0766	0.0152	1.3556	0.0150	6.3	1.3
11	5.1	0	11047.4	0.0854	0.0087	1.3327	0.0134	7.2	0.8
12	5.1	1	5281.1	0.0957	0.0178	1.3370	0.0139	8.1	1.6
13	4.8	0	39733.8	0.0969	0.0750	1.3542	0.0144	8.1	6.5
14	4.5	1	5205.3	0.0599	0.0477	1.3545	0.0734	4.9	4.0
15	4.2	5	820.3	0.0702	0.0197	1.3577	0.0160	5.8	1.7
16	3.2	47	**68.6**	0.0737	0.0272	1.3653	0.0199		
17	5.0	4	1421.4	0.0666	0.0511	1.3550	0.0173	5.5	4.3
18	3.8	2	1939.2	0.0509	0.0783	1.3623	0.0138	4.2	6.5
19	4.3	6	720.1	0.0662	0.0521	1.3540	0.0617	5.5	4.4

3507	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	1.0	404	**2.4**	0.2163	0.0396	1.3693	0.0400	n/a	
2	2.9	19	152.8	0.1475	0.0120	1.3214	0.0205	12.9	1.1
3	1.7	11	156.4	0.1928	0.0207	1.3354	0.0252	16.9	2.0
4	1.6	15	104.4	0.1723	0.0197	1.3732	0.0213	14.6	1.8
5	**0.1**	348	**0.4**	0.6527	0.2010	1.3983	0.1142	n/a	
6	**0.0**	2	**7.7**	-3.6104	66.3359	2.9402	19.3715	n/a	
7	**0.0**	2	**1.6**	-21.1944	41.3807	5.6771	14.3982	n/a	
8	2.3	8	306.3	0.2319	0.0155	1.3742	0.0180	20.0	1.5
9	1.9	66	**29.3**	0.2239	0.0203	1.3527	0.0150	n/a	
10	2.4	4	671.4	0.2221	0.0208	1.3145	0.0171	20.1	2.1
11	2.5	11	226.3	0.2504	0.0171	1.3726	0.0178	21.8	1.7
12	2.5	16	152.1	0.3039	0.0167	1.3384	0.0198	27.8	1.8
13	2.8	5	561.3	0.2498	0.0188	1.3366	0.0186	22.4	1.9
14	2.8	1	2271.7	0.2151	0.0159	1.3280	0.0162	19.2	1.6
15	2.0	544	**3.6**	0.2969	0.0273	1.3005	0.0178	n/a	
16	0.9	49	**17.6**	0.1807	0.0314	1.3739	0.0340	n/a	
17	1.6	45	**35.4**	0.1603	0.0242	1.3369	0.0239	n/a	
18	1.0	313	**3.1**	0.2434	0.0305	1.3436	0.0283	n/a	
19	0.8	1213	**0.6**	0.6205	0.0599	1.3866	0.0393	n/a	

3508	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	5.5	154	**35.6**	0.0738	0.0075	1.3470	0.0132	6.1	0.6
2	7.0	5	1484.2	0.0875	0.0083	1.3750	0.0075	7.2	0.7
3	7.7	0	-62865	0.0813	0.0067	1.3535	0.0119	6.7	0.6
4	6.2	1	10666.1	0.0627	0.0085	1.3516	0.0145	5.2	0.7
5	7.3	0	-35573	0.0627	0.0066	1.3621	0.0096	5.1	0.6
6	4.9	6	879.9	0.0790	0.0068	1.3563	0.0136	6.5	0.6
7	0.9	922	**0.9**	0.4733	0.0450	1.2395	0.0366	n/a	
8	5.8	28	209.4	0.0862	0.0090	1.3487	0.0111	7.2	0.8
9	7.3	4	1642.7	0.0831	0.0051	1.3596	0.0106	6.9	0.4
10	6.7	0	-21768	0.0753	0.0073	1.3585	0.0093	6.2	0.6
11	5.9	1	6250.4	0.0705	0.0072	1.3619	0.0127	5.8	0.6
12	4.6	72	**63.7**	0.0827	0.0078	1.3528	0.0131	6.9	0.7
13	6.5	6	1063.4	0.0623	0.0065	1.3792	0.0107	5.0	0.5
14	1.7	127	**13.2**	0.0987	0.0146	1.3397	0.0205	8.3	1.3
15	**0.3**	596	**0.5**	0.5752	0.1240	1.3595	0.0606	n/a	
16	**0.4**	2048	**0.2**	1.6723	0.1311	1.2944	0.0419	n/a	

17	**0.3**	741	**0.4**	0.4229	0.0776	1.3764	0.0679	n/a	
18	2.7	108	**25.4**	0.0669	0.0139	1.3430	0.0189	n/a	
19	0.8	351	**2.2**	0.0482	0.0200	1.3488	0.0350	n/a	
20	5.2	25	211.0	0.0716	0.0083	1.3585	0.0120	5.9	0.7
21	3.8	26	142.9	0.0671	0.0106	1.3559	0.0127	5.5	0.9
22	6.7	2	4243.7	0.0587	0.0064	1.3591	0.0125	4.8	0.5
23	5.4	2	3040.9	0.0457	0.0062	1.3596	0.0163	3.7	0.5
24	4.6	17	272.2	0.0760	0.0072	1.3648	0.0129	6.2	0.6
25	0.4	1634	**0.2**	1.6686	0.1344	1.3128	0.0544	n/a	
26	6.1	3	1857.2	0.0911	0.0068	1.3543	0.0105	7.6	0.6
27	4.9	1	6977.3	0.0630	0.0088	1.3847	0.0117	5.1	0.7
28	5.7	2	2420.7	0.0789	0.0078	1.3451	0.0139	6.6	0.7
29	6.0	10	586.5	0.0830	0.0071	1.3373	0.0115	7.0	0.6

3509	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	1.9	43	**44.6**	0.2754	0.0202	1.3527	0.0222	n/a	
2	2.2	6	344.0	0.2302	0.0159	1.3872	0.0176	19.6	1.5
3	1.9	2	794.5	0.2468	0.0182	1.3968	0.0167	21.0	1.7
4	1.7	0	-10587	0.2801	0.0186	1.4094	0.0160	23.9	1.8
5	1.7	1	2160.1	0.3001	0.0207	1.3752	0.0256	26.6	2.1
6	1.7	2	1030.7	0.3212	0.0175	1.3820	0.0164	28.5	1.8
7	2.0	1	1393.9	0.2913	0.0189	1.3771	0.0151	25.7	1.9
8	2.5	0	5925.3	0.3288	0.0156	1.3596	0.0167	29.9	1.7
9	2.0	0	7975.7	0.3519	0.0224	1.3556	0.0172	32.4	2.4
10	2.0	1	2948.4	0.3258	0.0158	1.3700	0.0155	29.3	1.7
11	1.8	110	**16.8**	0.2474	0.0198	1.3502	0.0158	n/a	
12	2.9	10	282.7	0.2009	0.0120	1.3333	0.0143	17.7	1.2
13	2.3	47	**47.7**	0.1962	0.0151	1.4003	0.0164	n/a	
14	2.6	9	295.2	0.2586	0.0146	1.3311	0.0152	23.4	1.5
15	2.8	8	349.4	0.2593	0.0136	1.3489	0.0145	23.1	1.4

3510	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	5.8	10	596.5	0.0583	0.0059	1.3356	0.0105	4.9	0.5
2	5.0	3	1988.1	0.0902	0.0081	1.3457	0.0095	7.6	0.7
3	3.6	1	2988.5	0.0820	0.0086	1.3598	0.0152	6.8	0.7
4	4.2	1	2941.1	0.0868	0.0073	1.3541	0.0139	7.2	0.6
5	5.9	1	9791.4	0.0775	0.0076	1.3543	0.0086	6.4	0.6
6	2.9	10	295.1	0.1134	0.0114	1.3349	0.0133	9.7	1.0
7	1.8	16	112.4	0.0739	0.0135	1.3619	0.0207	6.1	1.1
8	**0.4**	952	**0.4**	1.2879	0.2312	1.1101	0.1139	n/a	
9	**0.1**	270	**0.3**	1.4919	0.2729	1.2880	0.1519	n/a	
10	**0.2**	1065	**0.2**	1.9774	0.1898	1.1953	0.0446	n/a	
11	**0.1**	546	**0.2**	9.3357	0.6064	1.3111	0.0880	n/a	
12	**0.2**	930	**0.2**	2.4083	0.1980	1.1456	0.0677	n/a	
13	5.6	2	2340.8	0.0462	0.0047	1.3529	0.0141	3.8	0.4
14	6.1	1	4402.6	0.0477	0.0042	1.3303	0.0079	4.0	0.4
15	4.9	0	11888.2	0.0608	0.0062	1.3420	0.0116	5.1	0.5
16	4.7	-1	-3830.9	0.0643	0.0070	1.3226	0.0100	5.4	0.6
17	4.3	0	-10679	0.0679	0.0060	1.3432	0.0103	5.7	0.5
18	4.0	1	2754.2	0.0653	0.0061	1.3606	0.0125	5.4	0.5
19	4.3	1	3103.2	0.0577	0.0070	1.3196	0.0129	4.9	0.6
20	4.4	3	1443.8	0.0678	0.0065	1.3238	0.0137	5.7	0.6
21	4.3	5	896.5	0.0676	0.0074	1.3374	0.0126	5.7	0.6
22	5.0	2	2082.9	0.0689	0.0069	1.3420	0.0103	5.7	0.6
23	5.2	4	1235.1	0.0609	0.0050	1.3577	0.0142	5.0	0.4
24	4.0	11	373.9	0.0535	0.0065	1.3488	0.0135	4.4	0.6

3511	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	1.4	2	641.4	0.0897	0.0185	1.3102	0.0328	7.7	1.7
2	2.0	0	6220.6	0.0753	0.0116	1.3027	0.0187	6.5	1.0
3	1.7	0	3847.2	0.0888	0.0165	1.3196	0.0233	7.6	1.5
4	1.6	4	446.4	0.0806	0.0156	1.3227	0.0234	6.9	1.4
5	3.0	1	2357.7	0.0720	0.0099	1.3169	0.0123	6.1	0.9
6	3.2	5	698.6	0.0708	0.0086	1.3027	0.0148	6.1	0.8
7	2.9	0	-7976.1	0.0578	0.0108	1.2714	0.0139	5.1	1.0
8	2.8	0	13111.1	0.0927	0.0125	1.3344	0.0163	7.8	1.1
9	2.6	2	1487.1	0.0743	0.0123	1.3426	0.0140	6.2	1.1
10	2.2	1	1968.9	0.0845	0.0120	1.3741	0.0185	6.9	1.0
11	2.0	1	3688.3	0.1207	0.0222	1.3308	0.0171	10.3	2.0
12	2.1	0	-15605.4	0.1030	0.0143	1.2758	0.0239	9.2	1.3
13	2.0	1	2389.3	0.0951	0.0137	1.2968	0.0169	8.3	1.2

14	2.1	2	961.3	0.1335	0.0235	1.3562	0.0405	11.3	2.1
15	2.5	1	2186.8	0.0881	0.0114	1.3162	0.0196	7.5	1.0
16	2.1	0	4365.4	0.0776	0.0131	1.3194	0.0216	6.6	1.2
17	2.1	1	1918.2	0.0584	0.0122	1.4265	0.0270	4.6	1.0
18	2.3	0	-6350.1	0.0599	0.0109	1.3612	0.0195	4.9	0.9
19	2.9	3	1092.4	0.0817	0.0116	1.2966	0.0151	7.1	1.0

3512	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age error
1	**0.4**	534	**0.8**	0.6355	0.0818	1.3791	0.0403	n/a	
2	3.2	83	**38.6**	0.1851	0.0179	1.3653	0.0165	n/a	
3	3.1	56	**54.5**	0.2364	0.0100	1.3515	0.0132	n/a	
4	3.2	50	**63.8**	0.2262	0.0116	1.3667	0.0161	n/a	
5	3.2	60	**53.1**	0.2352	0.0141	1.3661	0.0121	n/a	
6	3.7	25	146.0	0.2013	0.0131	1.3454	0.0161	17.6	1.3
7	3.9	32	123.3	0.2031	0.0119	1.3540	0.0136	17.6	1.1
8	3.8	60	**63.4**	0.2045	0.0110	1.3708	0.0168	n/a	
9	5.2	309	**16.9**	0.1801	0.0068	1.3543	0.0100	n/a	
10	**0.4**	342	**1.1**	0.4425	0.0599	1.3949	0.0491	n/a	
11	0.6	3089	**0.2**	1.9215	0.1333	1.0799	0.0313	n/a	
12	0.7	848	**0.8**	0.6899	0.0514	1.3388	0.0253	n/a	
13	4.8	433	**11.1**	0.1196	0.0078	1.3253	0.0116	n/a	
14	4.6	131	**35.1**	0.1293	0.0066	1.3442	0.0122	n/a	
15	6.5	100	**65.7**	0.0868	0.0065	1.3463	0.0102	n/a	
16	**0.1**	26	**2.2**	0.0417	230.9286	1.4094	14.9497	n/a	
17	**0.3**	487	**0.5**	0.9656	0.1178	1.1329	0.0464	n/a	
18	**0.1**	220	**0.5**	0.5728	0.1702	1.2211	0.0908	n/a	
19	**0.2**	216	**0.7**	0.6978	0.1693	1.2704	0.0606	n/a	
20	**0.2**	309	**0.6**	0.7041	0.1058	1.3464	0.0627	n/a	
21	**0.1**	84	**1.5**	0.5202	0.1743	1.3707	0.0775	n/a	
22	**0.1**	720	**0.1**	2.1577	0.3552	1.3040	0.0861	n/a	
23	**0.1**	133	**0.5**	1.9872	0.3853	1.0996	0.1082	n/a	
24	0.3	220	**1.1**	0.2707	0.0605	1.3488	0.0494	n/a	

3513	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	1.3	123	**10.5**	0.4592	0.0376	1.4081	0.0296	n/a	
2	1.2	2	528.6	0.4170	0.0374	1.3963	0.0284	38.1	4.1
3	2.0	1	2495.2	0.4956	0.0360	1.4323	0.0203	45.3	4.1
4	1.9	1	1374.1	0.5235	0.0283	1.4274	0.0158	48.7	3.3
5	2.1	1	3581.6	0.5263	0.0315	1.3978	0.0263	50.3	3.9
6	1.2	3	362.9	0.4412	0.0344	1.3904	0.0328	40.9	4.0
7	1.9	1	2067.5	0.4175	0.6567	1.4166	0.9457	37.4	75.4
8	1.8	2	762.6	0.3595	0.0340	1.3713	0.0227	32.7	3.6
9	1.8	2	703.6	0.3443	0.0335	1.4123	0.0250	30.1	3.4
10	1.8	2	749.4	0.3183	0.0239	1.3948	0.0243	27.9	2.4
11	1.7	2	976.3	0.3662	0.0262	1.4237	0.0228	32.0	2.7
12	1.7	1	1952.6	0.2637	0.0228	1.3845	0.0230	22.8	2.2
13	1.5	96	**16.0**	0.4490	0.0359	1.4239	0.0245	n/a	
14	1.7	21	**81.3**	0.5306	0.0307	1.3772	0.0293	n/a	
15	1.8	3	592.0	0.3940	0.0282	1.3975	0.0255	35.6	3.1
16	0.8	9	**87.6**	0.4417	0.0479	1.3604	0.0356	n/a	
17	1.5	1	1114.7	0.4108	0.0260	1.3872	0.0224	37.7	2.9
18	1.2	10	121.5	0.4675	0.0426	1.3383	0.0252	46.0	5.2
19	2.5	7	360.2	0.5305	0.0268	1.4005	0.0206	50.7	3.3
20	1.4	939	**1.5**	0.5761	0.0423	1.4187	0.0219	n/a	
21	1.4	4	368.7	0.3631	0.0358	1.4277	0.0244	31.6	3.6
22	1.0	5	180.0	0.5307	0.0547	1.3586	0.0344	52.8	7.1
23	1.4	3	545.3	0.4708	0.0284	1.4526	0.0238	41.9	3.1
24	1.6	5	305.8	0.4361	0.0316	1.4494	0.0237	38.3	3.4
25	1.5	45	**33.0**	0.4351	0.0334	1.3350	0.0323	n/a	
26	0.6	1195	**0.5**	1.2636	0.0919	1.3944	0.0517	n/a	

3514	U (ppm)	Th (ppb)	U/Th	$^{230}Th/^{238}U$	$^{230}Th/^{238}U$ error	$^{234}U/^{238}U$	$^{234}U/^{238}U$ Error	Age (kyr)	Age Error (kyr)
1	**0.4**	5	83.9	0.4012	0.0741	1.4993	0.0485	n/a	
2	0.6	0	-3800.2	0.2624	0.0488	1.3718	0.0464	23.0	4.8
3	**0.5**	0	1007.3	0.2889	3.6662	1.4787	3.1864	23.5	333.2
4	0.8	1	666.1	0.2959	0.0394	1.3849	0.0296	25.9	3.9
5	0.6	1	545.3	0.3511	0.0543	1.3471	0.0335	32.5	5.9
6	0.7	0	4054.7	0.3690	0.0549	1.4157	0.0421	32.5	5.7
7	0.8	0	-4005.3	0.3101	0.0353	1.4327	0.0271	26.3	3.4
8	0.7	1	509.8	0.3688	0.0699	1.4022	0.0403	32.8	7.2
9	**0.5**	0	1959.4	0.4378	0.0544	1.4130	1.9672	na/	
10	0.6	1	1250.7	0.2890	0.3734	1.4600	0.0535	23.8	34.0

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11	0.8	0	-2465.1	0.3924	0.5168	1.3460	0.1133	37.1	57.4
12	0.7	1	1015.9	0.4203	0.0541	1.4109	0.0509	37.9	6.0
13	**0.5**	4	146.5	0.3502	0.0733	1.3697	0.0483	n/a	
14	0.8	2	504.8	0.4469	0.0563	1.3952	0.0277	41.4	6.3
15	0.8	4	206.6	0.2891	0.0566	1.5155	0.0304	22.8	4.9

3515	U (ppm)	Th (ppb)	U/Th	^{230}Th/^{238}U	^{230}Th/^{238}U error	^{234}U/^{238}U	^{234}U/^{238}U Error	Age (kyr)	Age Error (kyr)
1	4.1	0	19257.3	0.0566	0.0087	1.3221	0.0151	4.8	0.7
2	6.4	0	-33319.4	0.0747	0.0056	1.3533	0.0097	6.2	0.5
3	4.3	0	13338.0	0.0972	0.0087	1.3503	0.0103	8.1	0.8
4	3.7	-1	-4130.5	0.0755	0.0081	1.3520	0.0113	6.3	0.7
5	4.9	-1	-8958.0	0.0870	0.0101	1.3169	0.0101	7.4	0.9
6	3.5	-1	-4608.0	0.1022	0.0116	1.3424	0.0191	8.6	1.0
7	5.5	0	-36927.2	0.0819	0.0073	1.3318	0.0133	6.9	0.6
8	4.8	-1	-4336.2	0.0812	0.0060	1.3288	0.0113	6.9	0.5
9	3.5	0	14010.1	0.0740	0.0087	1.3269	0.0159	6.3	0.8
10	3.7	0	279475.7	0.0746	0.0090	1.3173	0.0146	6.4	0.8
11	5.1	-1	-6132.3	0.0919	0.0077	1.3452	0.0101	7.7	0.7
12	3.1	1	2347.8	0.0871	0.0119	1.3270	0.0168	7.4	1.0
13	4.7	0	-14622.9	0.0886	0.0083	1.3383	0.0136	7.5	0.7
14	4.5	-1	-7642.4	0.0735	0.0088	1.3192	0.0106	6.2	0.8
15	3.9	0	8087.3	0.1002	0.0105	1.3239	0.0150	8.6	0.9
16	3.3	9	353.2	0.0881	0.0087	1.3106	0.0185	7.6	0.8
17	4.8	1	3532.5	0.0894	0.0072	1.3944	0.0133	7.2	0.6
18	2.9	5	556.6	0.0822	0.0103	1.3158	0.0153	7.0	0.9

3516	U (ppm)	Th (ppb)	U/Th	^{230}Th/^{238}U	^{230}Th/^{238}U error	^{234}U/^{238}U	^{234}U/^{238}U Error	Age (kyr)	Age Error (kyr)
1	2.7	1	3033.5	0.0786	0.0097	1.3261	0.0125	6.7	0.8
2	2.2	0	5356.0	0.1092	0.0135	1.3397	0.0170	9.3	1.2
3	1.9	1	3004.3	0.1204	0.0148	1.3592	0.0132	10.1	1.3
4	2.0	-1	-2522.3	0.0756	0.0122	1.3260	0.0161	6.4	1.1
5	1.8	1	1852.2	0.1103	0.0136	1.3967	0.0230	8.9	1.2
6	1.0	5	186.7	0.1467	0.0209	1.3861	0.0259	12.2	1.8
7	1.6	2	915.4	0.1029	0.0155	1.3764	0.0166	8.5	1.3
8	0.0	16	**2.2**	0.0694	0.5157	1.3147	0.1795	n/a	
9	1.2	3	367.4	0.0996	0.0169	1.3771	0.0203	8.2	1.4
10	1.1	1	774.1	0.1067	0.0191	1.3243	0.0216	9.1	1.7
11	0.6	7	83.3	0.0921	0.0291	1.3572	0.0289	7.7	2.5
12	1.3	3	424.7	0.1387	0.0180	1.3683	0.0201	11.6	1.6
13	1.3	1	970.3	0.0965	0.0189	1.3569	0.0230	8.0	1.6
14	1.7	1	1969.4	0.0873	0.0138	1.3372	0.0197	7.4	1.2
15	1.3	2	546.9	0.0730	0.0156	1.3284	0.0189	6.2	1.4
16	1.5	8	201.6	0.0541	0.0133	1.3197	0.0214	4.6	1.1

3517	U (ppm)	Th (ppb)	U/Th	^{230}Th/^{238}U	^{230}Th/^{238}U error	^{234}U/^{238}U	^{234}U/^{238}U Error	Age (kyr)	Age Error (kyr)
1	2.4	125	**19.3**	0.2194	0.0159	1.3366	0.0211		
2	3.7	7	561.1	0.2080	0.0141	1.3587	0.0159	18.0	1.3
3	4.3	1	4782.9	0.2614	0.0139	1.3543	0.0126	23.2	1.4
4	3.4	0	7873.0	0.2506	0.0151	1.3376	0.0168	22.5	1.5
5	3.4	0	-10611	0.2301	0.0160	1.3180	0.0155	20.8	1.6
6	3.7	1	5769.4	0.2093	0.0127	1.3626	0.0166	18.1	1.2
7	3.6	0	8464.8	0.2261	0.0186	1.3552	0.0187	19.8	1.8
8	2.4	2	1326.4	0.2396	0.0225	1.3711	0.0182	20.8	2.2
9	3.3	-1	-3244.4	0.2592	0.0157	1.3601	0.0188	22.9	1.6
10	2.7	202	**13.4**	0.2835	0.0216	1.3860	0.0157		
11	3.9	52	**76.3**	0.2202	0.0136	1.3658	0.0171		
12	3.1	229	**13.6**	0.2690	0.0160	1.3569	0.0186		
13	2.3	24	**98.7**	0.2267	0.0146	1.3654	0.0203		
14	3.0	0	19543.3	0.2217	0.0150	1.3505	0.0163		
15	2.9	0	47865.8	0.2120	0.0164	1.3327	0.0195	18.8	1.6
16	2.9	0	36470.7	0.2501	0.0175	1.3463	0.0165	22.2	1.7
17	2.3	-2	-1470.5	0.2570	0.0209	1.3435	0.0176	23.0	2.1
18	1.8	-1	-1816.8	0.2355	0.0257	1.3729	0.0222	20.4	2.5
19	2.4	0	-16943	0.2851	0.0198	1.3526	0.0195	25.6	2.0
20	2.4	0	-7992.9	0.2863	0.0255	1.3442	0.0246	25.9	2.6
21	1.3	0	15323.7	0.2647	0.0326	1.4037	0.0421	22.6	3.2
22	1.7	0	-63089	0.2454	0.0265	1.4096	0.0277	20.7	2.5

Supplementary Table 9: Results of DAD calculations. Age errors are 2-σ.

Sample	Age (kyr)	Age Error (kyr)	iR48
3487	48.3	2.9	1.4540
3503 #2-10	12.2	0.7	1.3535
3504	6.68	0.45	1.3544
3505 #1-7	12.2	0.73	1.3291
3505 #8-13	9.54	0.86	1.3395
3506	6.64	0.46	1.3474
3508 #1-6	5.96	0.55	1.3622
3508 #8-14	6.67	0.51	1.3593
3510 #1-7	6.59	0.74	1.3469
3510 #13-24	5.59	0.45	1.3386
3516	8.91	0.93	1.3490
3517 #2-9	20.8	1.2	1.3506
3517 #14-22	21.8	1.4	1.3526

iR48: initial $^{234}U/^{238}U$ ratios

Supplementary Table 10: Average $^{234}U/^{238}U$ and age estimates, uncertainties are standard deviations on the data set.

Sample	$^{234}U/^{238}U$	$^{234}U/^{238}U$ STD	Age (kyr)	Age STD (kyr)
3487	1.4496	0.0611	48.15	7.27
3503	1.3477	0.0149	11.68	1.39
3504	1.3530	0.0182	7.21	1.48
3505	1.3331	0.0108	9.85	1.98
3506	1.3478	0.0110	6.67	1.41
3507	1.3400	0.0218	19.45	4.76
3508	1.3519	0.0260	6.05	1.12
3509	1.3721	0.0224	25.76	3.96
3510	1.3435	0.0133	5.75	1.37
3511	1.3251	0.0363	7.19	1.73
3512	1.3591	0.0102	18.93	1.54
3513	1.4031	0.0293	38.99	8.41
3514	1.4102	0.0488	30.79	6.58
3515	1.3342	0.0201	7.06	0.95
3516	1.3519	0.0251	8.31	2.02
3517	1.3577	0.0237	21.57	2.35

Supplementary references

89. Garvin, H. M. *et al.* in *A companion to Forensic Anthropology* (Dirkmaat, D. C.) 202–223 (Blackwell Publishing Ltd., 2012).
90. Nawrocki, S. P. in *Age Estimation of the Human Skeleton* (Finnegan, M.) 79–101 (Charles C Thomas Publisher, 2010).
91. Liversidge, H. M. Interpreting group differences using Demirjian's dental maturity method. *Forensic Science International* **201,** 95–101 (2010).
92. Liversidge, H. M. Similarity in dental maturation in two ethnic groups of London children. *Annals of Human Biology* **38,** 702–715 (2011).
93. İşcan, M. Y. in *Age markers in the Human Skeleton* (İşcan, M. Y.) 325–339 (Charles C Thomas Publisher, 1989).
94. Smith, T. & Brownlees, L. Age assessment practices: a literature review & annotated bibliography. *UNICEF: Child Protection Section* (2011).
95. Campbell, T. D. Food, food values and food habits of the Australian Aborigines in relation to their dental conditions. *Australian Journal of Dentistry* **43,** 1–15, 45–55, 73–87, 121–125, 141–156, 177–198. (1939).
96. Mays, S. The relationship between molar wear and age in an early 19th century AD archaeological human skeletal series of documented age at death. *Journal of Archaeological Science* **29,** 861–871 (2002).
97. Oliveira, R. N., Silva, S. F. S. M., Kawano, A. & Antunes, J. L. F. Estimating age by tooth wear of prehistoric human remains in Brazilian archaeological sites. *International Journal of Osteoarchaeology* **16,** 407–414 (2006).
98. Garvin, H. M. & Passalacqua, N. V. Current practices by forensic anthropologists in adult skeletal age estimation. *Journal of Forensic Science* **57,** 427–433 (2012).
99. Jurmain, R. *Stories from the Skeleton*. (Gordon and Breach, 1999).
100. Listi, G. A. The use of entheseal changes in the Femur and Os Coxa for age assessment. *Journal of Forensic Science* (2015). doi:10.1111/1556-4029.12905
101. Listi, G. A. & Manhein, M. H. The use of vertebral osteoarthritis and osteophytosis in age estimation. *Journal of Forensic Science* **57,** 1537–1540 (2012).
102. Mendl, R. S., Russell, K. F. & Lovejoy, C. O. Reliability of age at death in the Hamann-Todd collection: validity of subselection procedures used in blind tests of the summary age technique. *American Journal of Physical Anthropology* **83,** 349–357 (1990).
103. Lovejoy, C. O., Meindl, R. S., Mensforth, R. P. & Barton, T. J. Multifactorial determination of skeletal age at death: a method and blind tests of its accuracy. *American Journal of Physical Anthropology* **68,** 1–14 (1985).
104. Mendl, R. S. & Lovejoy, C. O. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the lateral-anterior sutures. *American Journal of Physical Anthropology* **68,** 57–66 (1985).
105. Erdal, Ö. D. A possible massacre at Early Bronze Age Titriş Höyük, anatolia. *International Journal of Osteoarchaeology* **22,** 1–21 (2012).
106. Hamperl, H. in *Diseases in antiquity* (Brothwell, D. R. & Sandison, A. T.) 630–634 (Charles C Thomas Publisher, 1967).
107. Hill, A. P. On carnivores and weathering damage to bone. *Current Anthropology* **17,** 335–336 (1976).
108. Jurmain, R. D. in *Human paleopathology: current synthesis and future options* (Ortner, D. J. & Aufderheide, A. C.) 241–248 (Smithsonian Institution Press, 1991).
109. Kilgore, L., Jurmain, R. D. & Gerven, D. V. Palaeopathological patterns of trauma in

a Medieval Nubian skeletal population. *International Journal of Osteoarchaeology* **7,** 103–114 (1997).
110. Miller, G. J. in *Lithic technology: making and using tools* (Swanton, E.) 211–226 (Mouton, 1975).
111. Raemsch, C. A. Mechanical procedures involved in bone dismemberment and defleshing in prehistoric Michigan. *Midcontinental Journal of Archaeology* **18,** 217–244 (1993).
112. Smith, M. O. A probable case of decapitation in the Late Archaic Robinson site (40SM4), Smith County, Tennessee. *Tennessee Anthropologist* **18,** 131–142 (1993).
113. Smith, M. O. Scalping in the Archaic period: evidence from the western Tennessee valley. *Southeast Archaeology* **14,** 60–68 (1995).
114. Standen, V. G. & Arriaza, B. T. Trauma in the pre-ceramic coastal populations of Northern Chile: Violence or occupational hazards? *American Journal of Physical Anthropology* **112,** 239–249 (2000).
115. Galloway, A., Symes, S. A., Haglund, W. & France, D. in *Broken bones: anthropological analysis of blunt force trauma* (Galloway, A.) 5–31 (Charles C Thomas Publisher, 1999).
116. Santure, S. K. in *Archaeological investigations at the Morton Village and Norris Farms 36 cemetery* (Santure, S. K., Ham, A. D. & Esarey, D.) **45,** 154–159 (Illinois State Museum, Reports of Investigations, 1990).
117. Smith, M. O. 'Parry fractures' and female directed interpersonal violence: implications from the Late Archaic period of west Tennessee. *International Journal of Osteoarchaeology* **6,** 84–91 (1996).
118. Walker, P. L. A bioarchaeological perspective on the history of violence. *Annual Review of Anthropology* 573–596 (2001).
119. Galloway, A. *Broken Bones: Anthropological Analysis of Blunt Force Trauma*. (Charles C Thomas Publisher, 1999).
120. Schultz, R. J. *The Language of Fractures*. (The Williams and Wilkins Company, 1972).
121. Whiteside, J. A., Fleagle, S. & Kalenak, A. Fractures and refractures in intercollegiate athletes, an eleven-year experience. *American Journal of Sports Medicine* **9,** 369–377 (1981).
122. Meyer, C., Lohr, C., Gronenborn, D. & Alt, K. W. The massacre mass grave of Schöneck-Kilianstädten reveals new insights into collective violence in Early Neolithic Central Europe. *PNAS* **112,** 11217–11222 (2015).
123. Hussain, K., Wijetunge, D. B., Grubnic, S. & Jackson, I. T. A comprehensive analysis of craniofacial trauma. *Journal of Trauma and Acute Care Surgery* **36,** 34–47 (1994).
124. Larsen, C. S. *Bioarchaeology: Interpreting Behavior From The Skeleton.* (Cambridge University Press, 1997).
125. Milner, G. R., Anderson, E. & Smith, V. G. Warfare in late prehistoric west-central Illinois. *Am. Antiq.* **56,** 581–603 (1991).
126. Bennike, P. in *Bog bodies, sacred sites and wetland archaeology* (Coles, B. J., Coles, J. M. & Jorgensen, S. M.) 27–32 (WARP, 1999).
127. Bennike, P. & Alexandersen, V. in *Ancient health* (Cohen, M. N. & Crane-Kramer, G. M. M.) 130–148 (University of Florida Press, 2007).
128. Brødholt, E. T. & Holck, P. Skeletal trauma in the burials from the royal church of St. Mary in medieval Oslo. *International Journal of Osteoarchaeology* **22,** 201–218 (2010).
129. Byers, S. N. *Introduction to forensic anthropology*. (Allyn and Bacon, 2005).

130. Facchini, F., Rastelli, E. & Belcastro, M. Perimortem cranial injuries from a Medieval Grave in Saint Peter's Cathedral, Bologna, Italy. *International Journal of Osteoarchaeology* **18,** 421–430 (2007).
131. Geber, J. Comparative study of perimortem weapon trauma in two early medieval skeletal populations (AD 400–1200) from Ireland. *International Journal of Osteoarchaeology* (2012). doi:10.1002/oa/2281
132. Judd, M. A. Continuity of interpersonal violence between Nubian communities. *American Journal of Physical Anthropology* **131,** 324–333 (2006).
133. Lewis, J. E. Identifying sword marks on bone: criteria for distinguishing between cut marks made by different classes of bladed weapons. *Journal of Archaeological Science* **68,** 15–28 (2008).
134. McDonald, J. J., Donlon, D., Field, J. H. & Fullagar, R. The first archaeological evidence for death by spearing in Australia. *Antiquity* **81,** 877–885 (2007).
135. Novak, S. A. in *Blood Red Roses: the archaeology of a mass grave from the Battle of Towton AD 1461* (Fiorato, V., Boylston, A. & Knüsel, C.) 90–102 (Oxbow Books, 2000).
136. Parsons, I. & Badenhorst, S. Analysis of lesions generated by replicated Middle Stone Age lithic points on selected skeletal elements. *S. Afr. J. Sci.* **100,** 384–387 (2004).
137. Peloponissios, N., Halkic, N., Moeschler, O., Schnyder, P. & Vuilleumier, H. Penetrating thoracic trauma in arrow injuries. *Ann. Thorac. Surg.* **71,** 1019–1021 (2001).
138. Oh, S. Clinical and experimental morphological study of depressed skull fracture. *Acta Neurochir (Wien)* **68,** 111–121 (1983).
139. Scott, R. M. & Buckley, H. R. Biocultural interpretations of trauma in two prehistoric Pacific Island populations from Papua New Guinea and the Solomon Islands. *American Journal of Physical Anthropology* **142,** 509–518 (2010).
140. Smith, M. J., Brickley, M. B. & Leach, S. L. Experimental evidence for lithic projectile injuries: improving identification of an under-recognised phenomenon. *Journal of Archaeological Science* (2007).
141. Wakeley, J. in *Material harm: archaeological studies of war and violence* (Carman, J.) 24–46 (Cruithne Press, 1997).
142. Weber, J. & Czarnetzki, A. Neurotraumatological aspect of head injuries resulting from sharp and blunt force in the Early Medieval Period of southwestern Germany. *American Journal of Physical Anthropology* **114,** 352–256 (2001).
143. Wenham, S. J. in *Weapons and warfare in Anglo-Saxon England* (Hawkes, S. C.) 123–139 (Oxford University Press, 1989).
144. Redfern, R. C. A re-appraisal of the evidence for violence in the Late Iron Age human remains from Maiden Castle hillfort, Dorset, England. *Proceedings of the Prehistoric Society* **77,** 111–138 (2011).
145. Wilshaw, A. The current status of the Kenya Capsian. *African Archaeological Review* (2016).
146. Arnold, L. J. & Roberts, R. G. Stochastic modeling of multi-grain equivalent dose (De) distributions: implications for OSL dating of sediment mixtures. *Quaternary Geochronology* **4,** 204–230 (2009).
147. Olley, J. M., Caitcheon, G. G. & Roberts, R. G. The origin of dose distributions in fluvial sediments, and the presence of dating single grains from fluvial deposits using optically stimulated luminescence. *Radiation Measurements* **23,** 497–500 (1999).
148. Hellstrom, J. U–Th dating of speleothems with high initial 230Th using stratigraphical constraint. *Quaternary Geochronology* **1,** 289–295 (2006).